DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT / SUPPLEMENTAL OVERSEAS ENVIRONMENTAL IMPACT STATEMENT FOR SURVEILLANCE TOWED ARRAY SENSOR SYSTEM LOW FREQUENCY ACTIVE (SURTASS LFA) SONAR

DEPARTMENT OF THE NAVY
CHIEF OF NAVAL OPERATIONS

AUGUST 2016

DRAFT
SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT/SUPPLEMENTAL OVERSEAS ENVIRONMENTAL IMPACT STATEMENT
For
SURVEILLANCE TOWED ARRAY SENSOR SYSTEM LOW FREQUENCY (SURTASS LFA) SONAR

AUGUST 2016

Abstract

Designation:	Draft Supplemental Environmental Impact Statement/Supplemental Overseas Environmental Impact Statement
Title of Proposed Action:	SURTASS LFA Sonar Routine Training, Testing, and Military Operations
Lead Agency:	Department of the Navy
Cooperating Agency:	National Marine Fisheries Service, Office of Protected Resources
Affected Region:	Pacific, Atlantic, and Indian oceans and Mediterranean Sea
Action Proponent:	Chief of Naval Operations
Point of Contact:	LCDR M. Murnane SURTASS LFA Sonar SEIS/SOEIS Program Manager 4350 Fairfax Drive, Suite 600 Arlington, Virginia 22203 eisteam@surtass-lfaeis.com
Date:	August 2016

The Department of the Navy along with the National Marine Fisheries Service as a cooperating agency has prepared this Supplemental Environmental Impact Statement/Supplemental Overseas Environmental Impact Statement (SEIS/SOEIS) in accordance with the National Environmental Policy Act (NEPA), as implemented by the Council on Environmental Quality Regulations and Navy regulations for implementing NEPA. The proposed action is the continued employment of up to four SURTASS LFA sonar systems onboard up to four U.S. Navy surveillance ships for routine training, testing, and military operations in the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea, with certain geographic operational constraints and mitigation and monitoring protocols applied. This SEIS/SOEIS evaluates the potential environmental impacts associated with the two action alternatives, Alternatives 1 and 2, and the No-Action Alternative to the following resource areas: marine water resources, biological resources, and economic resources.

This page intentionally left blank

Executive Summary

Proposed Action

The United States (U.S.) Department of the Navy (Navy) proposes to continue employing up to four Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) and compact LFA (CLFA) sonar systems onboard up to four U.S. Navy surveillance ships for routine training, testing, and military operations in the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea. In this SEIS/SOEIS, the terms “SURTASS LFA sonar” or “SURTASS LFA sonar systems” are inclusive of both the LFA and CLFA systems, each having similar acoustic operating characteristics.

The Navy has prepared this SEIS/SOEIS as a comprehensive assessment of the environmental effects associated with employment of SURTASS LFA sonar systems. On July 15, 2016, the Ninth Circuit issued a decision in Natural Resources Defense Council (NRDC), et al. v. Pritzker, et al., which challenged NMFS's analysis under the Marine Mammal Protection Act (MMPA) for the current MMPA Final Rule for SURTASS LFA sonar. The United States was still reviewing this decision at the time this Draft Supplemental EIS was published.

Purpose of and Need for the Proposed Action

The purpose of the proposed action is the continued employment of SURTASS LFA sonar globally in support of the Navy’s anti-submarine warfare (ASW) and national security mission. Due to the advancements and use of quieting technologies in diesel-electric and nuclear submarines, undersea submarine threats have become increasingly difficult to locate solely using passive acoustic technologies. At the same time as the distance at which submarine threats can be detected decreases due to quieting technologies, improvements in torpedo and missile design have extended the effective range of these weapons. To meet the requirement for improved capability to detect quieter and harder-to-find foreign submarines at greater distances, the Navy developed and employs SURTASS LFA sonar to meet the need for long-range submarine detection. The need for the proposed action is to provide capabilities for training and equipping combat-capable U.S. naval forces in readiness for global deployment.

Alternatives Considered

Alternatives were developed for analysis based upon the following reasonable alternative screening factors: allow the Navy to meet all routine training requirements for SURTASS LFA sonar systems, vessels, and crews; allow the Navy to meet all routine testing requirements for SURTASS LFA sonar systems, vessels, and crews; allow the Navy to meet all routine military operational requirements for SURTASS LFA sonar systems, vessels, and crews; allow the Navy to meet all requirements for maintenance and repair schedules, as well as vessel crew schedules for SURTASS LFA sonar vessels; allow the Navy to meet the requirement to use the best available data and information for the analysis and delineation of offshore biologically important areas (OBIAs) for marine mammals; and allow the Navy to meet all national security requirements that may involve the employment of SURTASS LFA sonar vessels.

The Navy is considering two action alternatives that meet the purpose and need for the proposed action. The No Action Alternative would not meet the purpose and need for the proposed action, but was carried forward to provide a baseline for environmental consequences. Both action alternatives include the employment of up to four SURTASS LFA sonar systems, with geographical restrictions to include maintaining SURTASS LFA sonar received levels (RLs) below 180 decibels (dB) re 1 microPascal (µPa) (root-mean-square [rms]) (sound pressure level [SPL]) within 12 nautical miles (nmi) (22 kilometers [km]) of any land and within the boundary of a designated OBIA during their respective effective periods when significant biological activity occurs. Additionally, the SURTASS LFA sonar RLs will not exceed 145 dB re 1 µPa (rms) within known recreational and commercial dive sites. Under Alternative 1, the maximum number of LFA sonar transmission hours will not exceed 432 hours per vessel per year, while under Alternative 2 (Preferred Alternative), the maximum number of LFA sonar transmission hours will not exceed 255 hours per vessel per year. Under the No Action Alternative, the proposed action would not occur and no operation of any SURTASS LFA sonar systems would occur.

Summary of Environmental Resources Evaluated in the SEIS/SOEIS

Council on Environmental Quality (CEQ) regulations, National Environmental Policy Act (NEPA), and Navy instructions for implementing NEPA (Executive Order 12114) specify that a SEIS/SOEIS should address those resource areas potentially subject to impacts. In addition, the level of analysis should be commensurate with the anticipated level of environmental impact.

The following resource areas have been addressed in this SEIS/SOEIS: marine water resources (ambient noise environment), biological resources, and economic resources. Since potential impacts were considered to be negligible or nonexistent for the following resources, they were not evaluated in this SEIS/SOEIS: air quality and airspace, geological resources, cultural resources, land use, infrastructure, transportation, public health and safety, hazardous materials and wastes, sociologic, and environmental justice.

The only potential impact on marine water resources associated with the operation of SURTASS LFA sonar is the addition of underwater sound during operation of both the SURTASS LFA sonar and the associated high frequency/marine mammal monitoring (HF/M3) sonar system. The parameters at which the HF/M3 sonar operates and the high transmission loss of its HF signals reduce the possibility for HF/M3 sonar to contribute to the ambient noise environment or affect marine animals.

Biological resources that may be impacted by the proposed action are marine animals, including marine invertebrates, fishes, sea turtles, and marine mammals, and marine habitats. The marine species that were evaluated must: 1) occur within the same ocean region and during the same time of year as the SURTASS LFA sonar operation, and 2) possess some sensory mechanism that allows them to perceive low-frequency (LF) sound, and/or 3) possess tissue with sufficient acoustic impedance mismatch to be affected by LF sounds. Among marine invertebrates, only cephalopods (octopus and squid) and decapods (lobsters, shrimps, and crabs) are known to sense LF sound. Fishes are able to detect sound, although there is remarkable variation in hearing capabilities in different species. While it is not easy to generalize about hearing capabilities due to this diversity, most fishes known to detect sound can at least hear frequencies from below 50 Hertz (Hz) up to 800 Hz, while a large subset of fishes can detect sounds to approximately 1,000 Hz and another subset can detect sounds up to about 2,000 Hz. Thus, many species of fishes can potentially hear SURTASS LFA sonar transmissions and were considered for potential impacts. It is also likely that all seven species of sea turtles hear LF sound, at least as adults, and so were considered for potential impacts. Marine mammals are highly adapted marine animals, able to detect underwater sound. Species that may occur in areas in which SURTASS LFA sonar might operate were included in the impact analysis. Four types of marine habitats, critical habitat, essential fish habitat, marine protected areas (MPAs), and national marine sanctuaries, which are protected under U.S. legislation, and OBIAs were considered in the impact analysis.

Summary of Potential Environmental Consequences of the Action Alternatives and Major Mitigating Actions

Marine Water Resources: When deployed and transmitting, sound generated by SURTASS LFA sonar will temporarily add to the ambient noise level in the frequency band (100 to 500 Hz) in which SURTASS LFA sonar operates, but the impact on the overall noise level in the ocean will be minimal. SURTASS LFA sonar produces a coherent LF signal with a duty cycle of less than 20 percent and an average pulse length of 60 seconds (sec). In most of the ocean, the LF (10 to 500 Hz) portion of the ambient noise level is dominated by anthropogenic noise sources, particularly shipping and seismic airguns. The total energy output of individual sources was considered in calculating an annual noise energy budget (Hildebrand, 2005). The percentage of the total anthropogenic acoustic energy budget added by each LFA source transmitting for 432 hour per year was estimated to be 0.25 percent of the total noise budget when commercial supertankers, seismic airguns, mid-frequency military sonar, and SURTASS LFA sonar were considered. Under Alternative 1, the maximum number of SURTASS LFA sonar transmission hours would not exceed 432 hours per vessel per year. Under Alternative 2, the maximum number of SURTASS LFA sonar transmission hours would not exceed 255 hours per vessel per year. Implementation of either action alternative would not result in significant impacts to marine water resources.

Biological Resources: The potential for impacts to marine animals is assessed from the perspective of an individual animal as well as the populations that comprise those individuals. Under the ESA, the potential for an effect on the fitness level of an individual, defined as changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success, is considered (NMFS, 2012). Similarly under the Marine Mammal Protection Act (MMPA), "any act that injures or has the significant potential to injure" or "disturbs or is likely to disturb…causing disruption of natural behavioral patterns…to a point where they are abandoned or significantly alerted" is considered. Potential impacts on marine animals from transmission of SURTASS LFA sonar include:

- non-auditory impacts: 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;
- auditory impacts: permanent threshold shift (PTS), which is a permanent loss of hearing sensitivity over the frequency band of the exposure, or temporary threshold shift (TTS), in which an animal's hearing sensitivity over the frequency band of exposure is impaired for a period of time (minutes to days);
- behavioral change: for military readiness activities such as the employment of SURTASS LFA sonar, Level B incidental "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;
- masking: when sounds in the environment interfere with an animal's ability to hear sounds of interest; and
- physiological stress: a response in a physiological mediator (e.g., glucocorticoids, cytokines, or thyroid hormones).

There is a paucity of data on marine invertebrates and their responses to underwater sound sources. The lack of any investigation using sonar signals makes a definitive analysis of the potential impacts from SURTASS LFA sonar impossible. However, the relatively high hearing threshold of invertebrates (e.g., approximately 110 dB re 1 µPa (rms) (SPL); Mooney et al. 2010), combined with the low probability of invertebrates being near the SURTASS LFA sound source, make it unlikely that biologically meaningful responses by individual invertebrates will occur and there is no potential for fitness level consequences. Therefore, considering the fraction of the cephalopod and decapod stocks that could possibly be found in the water column near a SURTASS LFA sonar ship while it is transmitting, the potential for impacts to marine invertebrates at the population level would be negligible.

Given the studies of sound exposure to fishes, the potential for impacts is restricted to within close proximity of SURTASS LFA sonar while it is transmitting. Popper et al. (2014) developed sound exposure guidelines for fishes, which were modified by NMFS (2015) to account for the signal duration of exposure. Based on the best available data on the potential for LF military sonar to affect fishes, the probability of any impact is low to moderate and would require fishes to be within close proximity (<0.54 nmi [<1 km]) of the SURTASS LFA sonar while it was transmitting. There is a minimal to negligible potential for an individual fish to experience non-auditory impacts, auditory impacts, or a stress response. There is a low potential for minor, temporary behavioral responses by or masking to an individual fish to occur when SURTASS LFA sonar is transmitting and there is no potential for fitness level consequences. Since a minimal to negligible portion of any fish stock would be in sufficient proximity during SURTASS LFA sonar transmissions to experience such impacts, there is minimal potential for SURTASS LFA sonar to affect fish stocks.

The paucity of data on underwater hearing sensitivities of sea turtles, whether sea turtles use underwater sound, or the responses of sea turtles to sound exposures make a quantitative analysis of the potential impacts from SURTASS LFA sonar transmissions impossible (NMFS, 2012). Popper et al. (2014) reviewed the available information and subjectively assessed that there is a low to moderate potential for any impacts to occur. In addition, given the lack of data on the distribution and abundance of sea turtles in the open ocean, it is not feasible to estimate the percentage of a stock that could be located in a SURTASS LFA sonar mission area. Given that the majority of sea turtles encountered in the oceanic areas in which SURTASS LFA sonar is proposed to operate would in high likelihood be transiting and not lingering, the possibility of significant behavior changes, especially from displacement, are unlikely and there is no potential for fitness level consequences. The geographical restrictions imposed on SURTASS LFA sonar operations would greatly limit the potential for exposure to occur in areas such as nesting beaches where sea turtles would be aggregated, potentially in large numbers. While it is possible that a sea turtle could hear the transmissions if it were in close proximity to SURTASS LFA sonar, when this is combined with the low probability of sea turtles potentially being near the LFA sound source while it is transmitting, the potential for impacts from exposure to SURTASS LFA sonar is considered negligible.

When exposed to SURTASS LFA sonar, marine mammals may experience auditory impacts (i.e., PTS and TTS), behavioral change, acoustic masking, or physiological stress (Atkinson et al., 2015; Clark et al., 2009; Nowacek et al., 2007; Southall et al., 2007). SURTASS LFA sonar transmissions are not expected to cause non-auditory impacts, such as gas bubble formation or strandings, particularly in beaked whales.

The most well understood potential impact from exposure to high-intensity sound is auditory impacts, specifically TTS; no studies have provided direct data on PTS. Several studies by a number of investigators have been conducted, focusing on the relationships among the amount of TTS and the level, duration, and frequency of the stimulus (Finneran, 2015; NOAA, 2016). None of these studies have resulted in direct data on the potential for PTS, empirical measurements of hearing, or the impacts of noise on hearing for baleen whales (mysticetes), which are believed to be most sensitive to SURTASS LFA sonar. In preceding SURTASS LFA sonar documentation (DoN, 2001, 2007, 2012, 2015), the potential for PTS and TTS was evaluated as MMPA Level A harassment for all marine mammals at RLs greater than or equal to 180 dB re 1 µPa (rms) (SPL) even though NMFS stated that TTS is not a physical injury in MMPA rulemaking for SURTASS LFA sonar (NOAA, 2002, 2007, 2012). Since the 2012 SEIS/SOEIS was released, NOAA published acoustic guidance that incorporates new data and summarizes the best available information. The NOAA acoustic guidance defines functional hearing groups, develops auditory weighting functions, and identifies acoustic threshold levels at which PTS and TTS occur (NOAA, 2016). The Navy used this methodology for estimating the potential for PTS and TTS for SURTASS LFA sonar.

The primary potential impact on marine mammals from exposure to SURTASS LFA sonar is change in a biologically significant behavior. The Low Frequency Sound Scientific Research Program (LFS SRP) in 1997 to 1998 provided important results on, and insights into, the types of responses by baleen whales (mysticetes) to SURTASS LFA sonar signals and how those responses scaled relative to RL and context. These experiments still represent the most relevant predictions of the potential for behavioral changes from exposure to SURTASS LFA sonar. The results of the LFS SRP confirmed that some portion of the total number of baleen whales exposed to SURTASS LFA sonar responded behaviorally by changing their vocal activity, moving away from the source vessel, or both; but the responses were short-lived and animals returned to their normal activities within tens of minutes after initial exposure (Clark et al., 2001). These LFS SRP results were used to derive the SURTASS LFA sonar risk continuum function, from which the potential for biologically significant behavioral response was calculated.

The potential for masking and physiological stress to marine mammals was assessed with the best available data. The potential for masking from SURTASS LFA sonar signals is limited because no single frequency is transmitted for longer than 10 sec and signals that consist of many frequencies do not span more than 30 Hz (i.e., they have limited bandwidths). Furthermore, when SURTASS LFA sonar is in operation, the source is active only 7.5 to 10 percent of the time, with a maximum 20 percent duty cycle, which means that for 90 to 92.5 percent of the time, there is no potential for masking. More research is needed to begin to understand the potential for physiological stress in marine mammals during noise exposure scenarios. The existing data suggest a variable response that depends on the characteristics of the received signal and prior experience with the received signal.

A quantitative impact analysis was conducted for marine mammals to assess their potential for PTS, TTS, and behavioral change. Twenty-six representative mission areas in the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea were analyzed to represent the acoustic regimes and marine mammal species that may be encountered during SURTASS LFA sonar operations. To predict acoustic exposure, the SURTASS LFA sonar ship was simulated traveling in a triangular pattern at a speed of 4 knots (kt) (7.4 km per hour [kph]) for a 24-hr period, with a signal duration of 60 sec and a duty cycle of 10 percent (i.e., the source transmitted for 60 sec every 10 min for 24 hr). The acoustic field around the SURTASS LFA sonar vessel was predicted with the operating parameters of SURTASS LFA sonar by the Navy standard parabolic equation propagation model. Each marine mammal species potentially occurring in a modeling area was simulated by creating animats (i.e., modeled animals) programmed with behavioral values describing their dive behavior, including dive depth, surfacing time, dive duration, swimming speed, and direction change. The Acoustic Integration Model© (AIM) integrated the acoustic field created from the underwater transmissions of SURTASS LFA sonar with the four-dimensional movement of marine mammals to estimate their potential sonar exposure at each 30-sec timestep within the 24-hr modeling period. The sound energy received by each individual animat over the 24-hr modeled period was calculated as sound exposure level (SEL) and the potential for PTS and then TTS was considered using the NOAA (2016) guidance. The sound energy received by each individual animat over the 24-hr modeled period was also calculated as dB single ping equivalent (SPE)[1] and used as input to the risk continuum function to assess the potential risk of biologically significant behavioral reaction. The percentage of marine mammal stocks that may experience TTS or behavioral changes from SURTASS LFA sonar exposures was calculated for one season in each of the 26 mission areas.

The potential for impacts to marine habitats, including critical habitat, essential fish habitat, marine protected areas, and national marine sanctuaries was considered within the context of the addition of sound energy to the marine environment while SURTASS LFA sonar is transmitting. SURTASS LFA sonar represents a vanishingly small percentage of the overall annual underwater acoustic energy budget and would not affect the ambient noise environment of marine habitats.

The objective of mitigation for the employment of SURTASS LFA sonar is to reduce or avoid potential exposures of marine mammals, sea turtles, and human divers to SURTASS LFA sonar transmissions. These objectives will be met by:

- Ensuring that coastal waters within 12 nmi (22 km) of shore (including islands) will not be exposed to SURTASS LFA sonar signal RLs ≥180 dB re 1 µPa (rms)(SPL);
- Ensuring that no OBIAs will be exposed to SURTASS LFA sonar signal RLs ≥180 dB re 1 µPa (rms)(SPL) during biologically important seasons;
- Minimizing exposure of marine mammals and sea turtles to SURTASS LFA sonar signal RLs below 180 dB re 1 µPa (rms)(SPL) by monitoring for their presence and delaying/suspending SURTASS LFA sonar transmissions when one of these animals enters the LFA mitigation zone; and
- Ensuring that no known recreational or commercial dive sites will be subjected to SURTASS LFA sonar signal RLs >145 dB re 1 µPa (rms)(SPL).

Twenty-two marine mammal OBIAs are currently designated for SURTASS LFA sonar. Since the 2012 SEIS/SOEIS and MMPA Final Rule for SURTASS LFA sonar, consideration and assessment of global marine areas as candidate OBIAs has continued as part of the Navy and NMFS' ongoing effort to assess areas of the world's oceans for candidate OBIAs for SURTASS LFA sonar. The Navy and NMFS conducted a comprehensive assessment of candidate marine areas as part of the analysis and development of this SEIS/SOEIS. Six new potential OBIAs and the expansion of five existing OBIAs were determined to meet the geographic, biological, and hearing criteria and were evaluated by the Navy for operational practicability. These eleven potential OBIAs were approved during the practicability review and will be implemented as part of the proposed action. When coupled with the existing OBIAs, a comprehensive list of 28 OBIAs is part of the proposed action.

The Navy is required to cooperate with NMFS and other Federal agencies to monitor impacts on marine mammals, to designate qualified on-site personnel to conduct mitigation monitoring and reporting activities. The Navy will continue to conduct the following monitoring to prevent injury to marine animals when SURTASS LFA sonar is employed:

1 The term "Single Ping Equivalent" (SPE) used herein is an intermediate calculation for input to the behavioral risk continuum used in the acoustic impact analysis for SURTASS LFA sonar. SPE accounts for the energy of all SURTASS LFA sonar transmissions that a modeled animal ("animat") receives during a 24-hr period of a SURTASS LFA sonar mission as well as an approximation of the manner in which the effect of repeated exposures accumulate. As such, the SPE metric incorporates both physics and biology. Calculating the potential behavioral risk from exposure to SURTASS LFA sonar is a complex process and the reader is referred to Appendix B for details. As discussed in Appendix B, SPE is a function of SPL, not SEL. SPE levels will be expressed as "dB SPE" in this document, as they have been presented in preceding environmental compliance documentation for SURTASS LFA sonar: FOEIS/FEIS (DoN, 2001); FSEIS (DoN, 2007); FSEIS/SOEIS (DoN, 2012); and FSEIS/SOEIS (DoN, 2015).

- Visual monitoring for marine mammals and sea turtles from the SURTASS LFA sonar vessels during daylight hours by personnel trained to detect and identify marine mammals and sea turtles;
- Passive acoustic monitoring using the passive SURTASS towed array to listen for sounds generated by marine mammals as an indicator of their presence; and
- Active acoustic monitoring using the 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.

Economic Resources: Analysis of impacts to economic resources is focused on potential impacts to commercial fisheries, subsistence harvesting of marine mammals, and recreational marine activities. If SURTASS LFA sonar operations were to occur in proximity to fish stocks, members of some fish species could potentially be affected by the LF sounds, but there is no potential for fitness level consequences or impacts to fish stocks. Due to the negligible impacts on fishes from the operation of SURTASS LFA sonar within the required guidelines and restrictions, there will be negligible impacts on commercial fisheries. With the geographic restrictions associated with SURTASS LFA sonar operations near coastal waters (within 12 nmi [22 km] of any coastline) and OBIAs, there would be no predicted overlap in time or space with subsistence hunts of marine mammals. In addition, the current and potential future employment of SURTASS LFA sonar would not lead to unmitigable adverse impacts on the availability of marine mammal species or stocks for subsistence use, particularly in the Gulf of Alaska and off the coasts of Washington or Oregon. There will be no significant impacts on recreational swimming, snorkeling, diving, or whale watching activities as a result of the employment of SURTASS LFA sonar due to the application of geographic restrictions for SURTASS LFA sonar use.

Table ES-1 provides a tabular summary of the potential impacts to the resources associated with each of the action alternatives.

Public Involvement

In the Notice of Intent (NOI), published in the *Federal Register* on June 5, 2015 (DoN, 2015), the Navy, with NMFS as a cooperating agency, announced its intention to prepare a SEIS/SOEIS for the worldwide employment of SURTASS LFA sonar. When the U.S. Environmental Protection Agency (EPA) publishes its Notice of Availability for the Draft SEIS/SOEIS for SURTASS LFA sonar employment in the *Federal Register*, per CEQ regulation (40 CFR §1506.10), a 45-day comment and review period will commence. In conjunction with filing this Draft SEIS/SOEIS with the EPA and announcing its public availability, correspondence will be sent notifying appropriate Federal and state government agencies and officials, Native Alaskan and Native tribal governments and organizations, as well as other interested parties that the Draft SEIS/SOEIS is available on the SURTASS LFA sonar website in accordance with NEPA requirements and EPA guidelines.

Table ES-1. Summary of Potential Impacts to Resource Areas[2]

Resource Area	*No Action Alternative*	*Alternative 1*	*Alternative 2*
Water Resources			
	No impact	Intermittent increase in ambient noise level during SURTASS LFA sonar transmissions for a maximum of 432 hr per vessel per year	Intermittent increase in ambient noise level during SURTASS LFA sonar transmissions for a maximum of 255 hr per vessel per year
Biological Resources			
Marine Invertebrates	No impact	Using the best available science, the Navy concludes that it is unlikely that biologically meaningful responses will occur due to high hearing thresholds and low potential of being exposed to SURTASS LFA transmissions make it unlikely that biologically meaningful responses will occur	
Marine Fishes	No impact	The Navy concludes after evaluating potential impacts using the best available science that a low to moderate probability of non-auditory, auditory, behavioral, masking, or physiological stress impacts may result when fish are in close proximity (<0.54 nmi [<1 km]) of the SURTASS LFA sonar	
Sea turtles	No impact	Low to moderate potential of non-auditory, auditory, behavioral, masking, or physiological stress impacts when turtles are in close proximity (<0.54 nmi [<1 km]) of the transmitting SURTASS LFA sonar based on use of the best available science	
Marine mammals	No impact	Potential for auditory or behavioral impacts evaluated quantitatively with the best available science; low to moderate probability of non-auditory, masking, or physiological stress assessed with best available scientific information and data	
Marine Habitats	No impact	Small, intermittent, and transitory increase in overall acoustic environment of marine habitats resulting in a negligible impact	Vanishingly small, intermittent, and transitory increase in overall acoustic environment of marine habitats resulting in an negligible impact
Economic Resources			
Commercial fisheries	No impact	Minimal potential for impacts to fish species and no potential for fitness level consequences resulting in negligible impacts on commercial fisheries	
Subsistence harvest of marine mammals	No impact	Geographic restrictions would result in no overlap in time or space with subsistence hunts of marine mammals, therefore no adverse impacts on the availability of marine mammal species or stocks for subsistence use	

2 If the conclusions for Alternative 1 and 2 were the same, one conclusion was presented for both alternatives.

Table ES-1. Summary of Potential Impacts to Resource Areas[2]

Resource Area	*No Action Alternative*	*Alternative 1*	*Alternative 2*
Recreational marine activities	No impact	Geographic restrictions limit the received level at known recreational and commercial dive sites to no greater than 145 dB re 1 µPa (rms)(SPL), resulting in no impact; the geographic restrictions were developed to limit the sonar levels in coastal waters in which higher concentrations of marine mammals may occur, which correlates to areas of prime whale watching and thus, would result in no impact to whale watching activities; additionally the same geographic restrictions would protect human swimmers in nearshore waters	

Table of Contents

List of Tables

List of Figures

Appendices

Abbreviations and Acronyms

Acronym	Definition
°C	Degrees Centigrade/Celsius
°F	Degrees Fahrenheit
µPa	microPascal(s)
%	percent or percentage
ABR	Auditory brainstem response
AEP	Auditory Evoked Potential
AIM	Acoustic Integration Model©
AM	amplitude modulated
AIP	Air-independent propulsion
ANSI	American National Standards Institute
APPS	Act to Prevent Pollution from Ships
ASCM	Anti-ship cruise missile
ASN(I&E)	Assistant Secretary of the Navy (Installations and Environment)
ASuW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
BIA	Biologically Important Area
BO	Biological Opinion
BRF	Behavioral Risk Function
BRS	Behavioral Response Study
CBLUG	consolidated bottom loss upgrade
CEE	controlled exposure experiment
CEQ	Council on Environmental Quality
CetMap	Cetacean Density and Distribution Mapping
CFR	Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species
CLFA	Compact Low Frequency Active
cm	centimeter(s)
CNO	Chief of Naval Operations (U.S.)
CSM	cross spectral matrix
CW	continuous wave
CWA	Clean Water Act

Acronym	Definition
CV	coefficient of variance
CZ	convergence zone
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Plan
DASN€	Deputy Assistant Secretary of the Navy for Environment
dB	decibel(s)
dB re 1 µPa	decibels referenced to one microPascal
dB re 1 µPa @ 1 m	decibels referenced to one microPascal measured at one meter from center of acoustic source
dB re 1 μPa^2-sec	decibels of the time integral (summation) of the squared pressure of a sound event
DoD	United States Department of Defense
DoI	Department of the Interior
DoN	United States Department of the Navy
DoS	Department of State
DPS	distinct population segment
DSEIS	Draft Environmental Impact Statement
Dtag	digital (animal) tag
EEZ	exclusive economic zone
EFH	essential fish habitat
EIS	Environmental Impact Statement
EO	Executive Order (Presidential)
EOG	Executive Oversight Group
EP	evoked potential
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESU	evolutionarily significant unit(s)
ETP	Eastern Tropical Pacific
FAO	Food and Agriculture

Acronym	Definition
	Organization
FEIS	Final Environmental Impact Statement
FM	frequency modulated
FOEIS/EIS	Final Overseas Environmental Impact Statement/EIS
FR	Federal Register
FSEIS	Final Supplemental Environmental Impact Statement
ft	feet/foot
FY	fiscal year
GIS	geographic information system
GOM	Gulf of Maine
GOMEX	Gulf of Mexico
HAPC	habitat areas of particular concern
HF	high frequency
HF/M3	high frequency/marine mammal monitoring
HLA	horizontal line array
hr	hour(s)
Hz	Hertz
ICES	International Council for the Exploration of the Sea
ICP	Integrated Common Processor
in	inch(es)
ISR	Intelligence, Surveillance, Reconnaissance
ITS	Incidental Take Statement
IUCN	International Union for Conservation of Nature
IUSS	Integrated Undersea Surveillance System
IWC	International Whaling Commission
kg	kilogram(s)
kHz	kiloHertz
km	kilometer(s)
kph	kilometers per hour
kt	knot(s)

Acronym	Definition
lb	pound(s)
LF	low frequency
LFA	Low Frequency Active
LFS SRP	Low Frequency Sound Scientific Research Program
LOA	Letter of Authorization
m	meter(s)
M3	marine mammal monitoring
MF	mid-frequency
MFA	mid-frequency active
MHI	Main Hawaiian Islands
mi	mile(s)
MILCREW	military crew
min	minute(s)
MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MPA	marine protected area
msec	millisecond(s)
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
NARW	North Atlantic right whale
NATO	North Atlantic Treaty Organization
Navy	U.S. Department of the Navy
NDAA	National Defense Authorization Act
NEPA	National Environmental Policy Act
NM	National Monument
NMFS	National Marine Fisheries Service
nmi	nautical mile(s)
NMPAC	National Marine Protected Area Center
NMS	National Marine Sanctuary
NMSA	National Marine Sanctuary Act
NOA	Notice of Availability
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent

Acronym	Definition
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
NRFCC	National Recreational Fisheries Coordination Council
NWHI	Northwest Hawaiian Islands
OAML	Oceanographic and Atmospheric Master Library
OBIA	offshore biologically important area
OEIS	Overseas Environmental Impact Statement
OIC	Officer in Charge
ONI	Office of Naval Intelligence
ONMS	Office of National Marine Sanctuaries
OPAREA	operating area
OPNAV	Office of the Chief of Naval Operations
OPNAVINST	Office of the Chief of Naval Operations Instruction
OPR	Office of Protected Resources
OW	Otariids underwater
Pa	Pascal
PADI	Professional Association of Diving Instructors
PE	parabolic equation
PEO	Program Executive Office
P.L.	public law
PLAN	People's Liberation Army Navy
PRN	pseudo-random noise
psu	practical salinity unit(s)
PTS	permanent threshold shift
PW	Phocids underwater
SEL	sound exposure level
PTS	Permanent threshold shift
RDT&E	research, development, test and evaluation
RL	received level
rms	root mean squared
ROD	Record of Decision

Acronym	Definition
SAG	Science Advisory Group
SAG	surface active group
SAR	Stock Assessment Report
SCUBA	Self-Contained Underwater Breathing Apparatus
SD	standard deviation
sec	second(s)
SEIS	Supplemental Environmental Impact Statement
SEL	sound exposure level
SL	source level
SLBM	Submarine-launched ballistic missile
SME	subject matter expert
SOCAL	Southern California
SOEIS	Supplemental Overseas Environmental Impact Statement
SONAR	sound navigation and ranging
SONG	Swatch-of-no-Ground
SPE	single ping equivalent
SPL	sound pressure level
spp.	species
SSP	sound speed profile
SURTASS	Surveillance Towed Array Sensor System
SVP	sound velocity profile
T-AGOS	Tactical-Auxiliary General Ocean Surveillance
TL	transmission loss
TTS	temporary threshold shift
TZCS	Transition Zone Chlorophyll Front
UNEP	United Nations Environmental Program
U.S.	United States
USDC-NDC	U.S. District Court, Northern District of California
U.S.C.	United States Code
USEPA	U.S. Environmental Protection Agency
USFWS	United States Fish and Wildlife

Acronym	Definition
	Service
USNS	U.S. Naval Ship
VLA	vertical line array
WDCS	Whale and Dolphin Conservation Society
WDPA	World Database on Protected Areas
yd	yard(s)

This page intentionally left blank

1 Purpose of and Need for the Proposed Action

1.1 Introduction

The United States (U.S.) Department of the Navy (Navy) proposes to continue employing up to four Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) and compact LFA sonar (CLFA) systems onboard up to four U.S. Navy surveillance ships for routine training, testing, and military operations[1] in the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea. In this SEIS/SOEIS, the terms "SURTASS LFA sonar" or "SURTASS LFA sonar systems" are inclusive of both the LFA and CLFA systems, each having similar acoustic operating characteristics.

Employment of SURTASS LFA sonar includes certain geographical restrictions and other preventive measures designed to mitigate potential adverse effects on the marine environment. This Proposed Action asserts the same number (four) of surveillance vessels and SURTASS LFA sonar systems will be employed, SURTASS LFA sonar will be operated in the same manner, and the same geographic areas will be encompassed as were described in the Final Supplemental Environmental Impact Statement/Supplemental Overseas Environmental Impact Statement (FSEIS/SOEIS) for SURTASS LFA Sonar (Department of the Navy [DoN], 2012) and the Final Supplemental Environmental Impact Statement/Supplemental Overseas Environmental Impact Statement (FSEIS/SOEIS) for SURTASS LFA Sonar (DoN, 2015a), which are both incorporated by reference herein. The current SEIS/SOEIS also builds upon the FOEIS/EIS for SURTASS LFA Sonar (DoN, 2001) and the FSEIS for SURTASS LFA Sonar (DoN, 2007). The 2012 FSEIS/SOEIS includes a detailed description of the history and background regarding the regulatory compliance for SURTASS LFA sonar.

The potential areas of SURTASS LFA sonar operations have remained the same since the 2001 FOEIS/EIS: the Pacific, Atlantic, and Indian oceans, less the polar regions, and the Mediterranean Sea, as depicted in Figure 1-1. Up to four SURTASS LFA sonar systems were proposed for employment in 2001, but until 2004 only one LFA system and vessel were available. From 2004 to 2008, two SURTASS LFA sonar systems were operational and in 2008, three SURTASS LFA sonar systems and vessels were at sea. Finally, by 2011, four SURTASS LFA sonar systems and vessels were operational. The 2001 FOEIS/EIS (DoN, 2001) provided a nominal annual summary of SURTASS LFA sonar vessel operations that estimated a total annual underway period for each vessel of 270 days. This period included up to 108 days of vessel transit or repositioning, 108 days of LFA operations (432 hr/vessel based on 20 percent duty cycle), 54 days of SURTASS passive operations, and 95 days not underway (in-port upkeep or regular overhaul). The 2007 FSEIS (DoN, 2007) updated these projections as follows: 54 days in vessel transit or repositioning, 240 days of LFA operations (432 hr/vessel based on a 7.5 percent duty cycle), and 71 days not underway, and the 2012 FSEIS/SOEIS reiterated these values (DoN, 2012). The operating features of LFA sonar have remained the same since the 2001 FOEIS/EIS, except for the updating of the LFA sonar duty cycle from 20 percent to 7.5-10 percent based on historical data (DoN, 2007), and in early 2009, the first CLFA sonar vessel became operational; CLFA acoustic operating characteristics are similar to LFA sonar.

---

1 The phrase "military operations" does not include use of SURTASS LFA sonar in armed conflict, or direct combat support operations, or use of SURTASS LFA sonar during periods of heightened threat conditions, as determined by the National Command Authorities.

The Navy has prepared this SEIS/SOEIS as a comprehensive assessment of the environmental effects associated with employment of SURTASS LFA sonar systems. The SEIS/SOEIS and associated analysis will be used to support consultations associated with expiring regulatory permits and authorizations in 2017. On July 15, 2016, the Ninth Circuit issued a decision in Natural Resources Defense Council (NRDC), et al. versus Pritzker, et al., which challenged NMFS's analysis under the Marine Mammal Protection Act (MMPA) for the current MMPA Final Rule for SURTASS LFA sonar. The United States was still reviewing this decision at the time this Draft Supplemental EIS was published. The Navy determined that the purposes of the National Environmental Policy Act (NEPA) and Executive Order 12114 (Environmental Effects Abroad of Major Federal Actions) would be furthered by the preparation of this additional supplemental analysis related to the employment of SURTASS LFA sonar systems. Further, this SEIS/SOEIS incorporates updated acoustic criteria and thresholds for assessing the potential for impacts to marine mammals.

This SEIS/SOEIS is prepared in compliance with the NEPA of 1969 (42 U.S. Code [U.S.C.] section 4321 et seq.); Executive Order (EO) 12114; the Council on Environmental Quality (CEQ) regulations for implementing the procedural provisions of NEPA (Title 40 Code of Federal Regulations [40 CFR] sections 1500 to 1508; Navy procedures for implementing NEPA (32 CFR section 775); and Navy environmental readiness guidelines. The National Marine Fisheries Service (NMFS) is a cooperating agency in accordance with 40 CFR section 1501.6 for the development of this SEIS/SOEIS for SURTASS LFA sonar.

1.2 Location

The Navy proposes employing SURTASS LFA sonar in the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea (Figure 1-1).

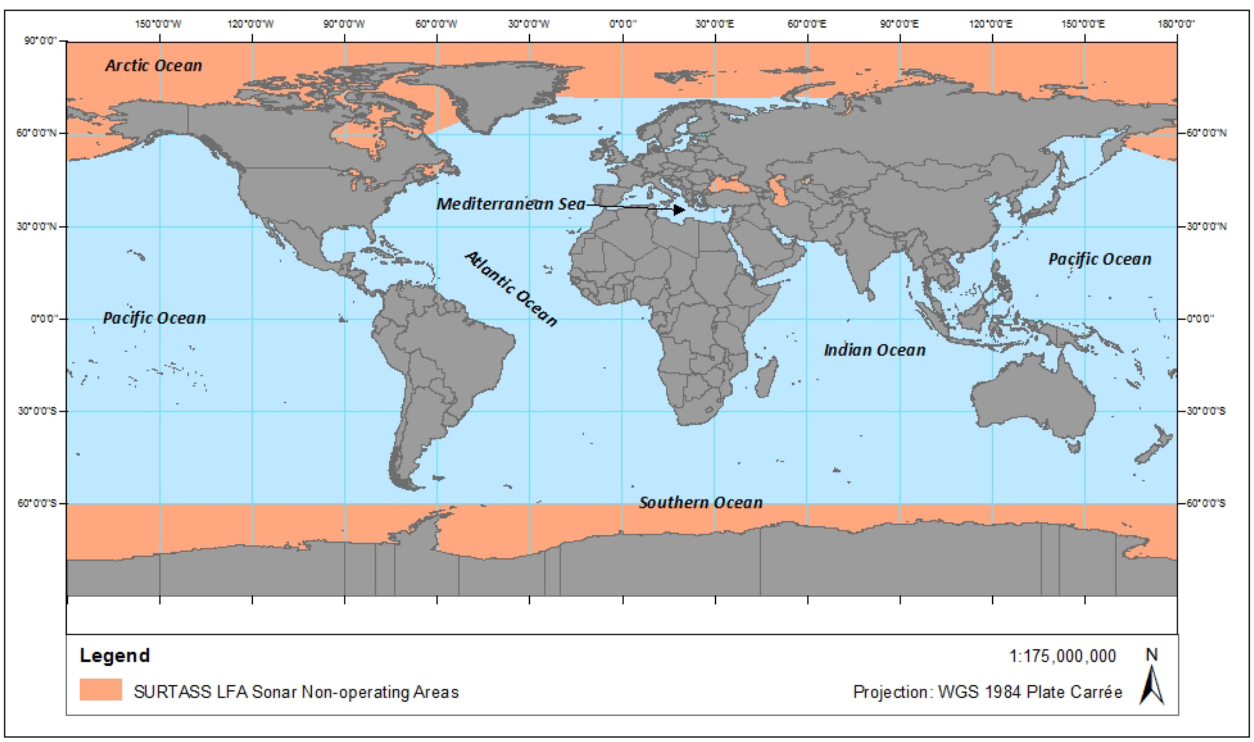


Figure 1-1. Potential operation areas for SURTASS LFA sonar.

1.3 Purpose of and Need for the Proposed Action: Employment of SURTASS LFA Sonar

The Navy's primary mission is to maintain, train, equip, and operate combat-ready naval forces capable of accomplishing America's strategic objectives, deterring maritime aggression, and assuring freedom of navigation in ocean areas. Anti-submarine warfare (ASW) is a critical part of that mission. Due to the advancements and use of quieting technologies in diesel-electric and nuclear submarines, undersea submarine threats have become increasingly difficult to locate solely using passive acoustic technologies. At the same time as the distance at which submarine threats can be detected decreases due to quieting technologies, improvements in torpedo and missile design have extended the effective range of these weapons. To meet the requirement for improved capability to detect quieter and harder-to-find foreign submarines at greater distances, the Navy developed and employs SURTASS LFA sonar to meet the need for long-range submarine detection. The purpose of the Navy's Proposed Action detailed in this SEIS/SOEIS is the continued employment of SURTASS LFA sonar globally in support of the Navy's ASW and national security mission.

The need for the Proposed Action is to train and equip combat-capable U.S. Naval forces to maintain readiness for global deployment to meet current maritime threats. In this regard, the Proposed Action furthers the Navy's execution of its congressionally-mandated roles and responsibilities under 10 U.S.C. Section 5062.

1.3.1 Current Maritime Threats and Maintenance of U.S. Maritime Superiority

The Chief of U.S. Naval Operations (CNO) recently presented *A Design for Maintaining Maritime Superiority* (DoN, 2016), which unveiled an updated Navy strategy that was developed in part to address the Navy's concern regarding Russian and Chinese military expansion. The CNO states, "For the first time in 25 years, the U.S. is facing a return to great power competition. Russia and China have advanced their military capabilities to act as global powers. Their goals are backed by a growing arsenal of high-end warfighting capabilities, many of which are focused specifically on our vulnerabilities…" (DoN, 2016). The rapid growth of the Chinese Navy's fleet is projected to result in China surpassing the U.S. Navy in number of ships by the mid-2020s (DoN, 2016). Additionally, the Navy's updated strategy also cites North Korea and Iran as potential threats to national security and regional stability. North Korea's furtherance of its nuclear weapons and missile programs and provocative actions, particularly towards South Korea, continue to threaten security in northeast Asia and beyond. Iran's advanced missile weaponry, proxy forces, and other conventional capabilities continue to threaten regional Middle Eastern stability, to which the Navy must be prepared to respond. For example, in December 2015, Iran engaged in live-fire missile testing within 1,500 yards (yd) (1,372 meters [m]) of a Navy carrier strike group in the Strait of Hormuz.

1.3.1.1 China

Roughly two thirds of South Korea's energy supplies, nearly 60 percent of Japan's and Taiwan's energy supplies, and 80 percent of China's crude oil imports are transported through the South China Sea (Kaplan, 2014). Since 2009, China claims sovereignty over nearly the entire South China Sea including islands, which conflicts with the maritime claims of other bordering nations, including the Philippines, Brunei, Vietnam, Malaysia, and Taiwan (U.S. Department of State [DoS], 2014).

China has invested heavily in its military forces; 2015 estimates from the Chinese government indicated an increase in military spending of 10.1 percent to an estimated $141.45 billion, which is second only to the U.S. in military spending (Rajagopalan and Wee, 2015). The U.S. Department of Defense (DoD) has noted that the People's Liberation Army Navy (PLAN) has placed a high priority on the modernization of its submarine force (DoD, 2015). China's attack submarines are armed with one or more of the following: land-attack cruise missiles, anti-ship cruise missiles (ASCMs), wire-guided and wake-homing torpedoes, and mines (O'Rourke, 2015). The DoD states that "by 2020, [China's submarine] force will likely grow to between 69 and 78 submarines (DoD, 2015). The U.S. Office of Naval Intelligence (ONI) projects 74 Chinese submarines by 2020, including 11 nuclear-powered and 63 non-nuclear-powered submarines (ONI, 2015a).

The *Yuan* class SSP (diesel-electric submarine, air-independent propulsion [AIP]) is China's most modern conventionally-powered submarine. Twelve are currently in service, with as many as eight more slated for production. Its combat capability is comparable to the *Song* class diesel-electric submarine, as both are capable of launching Chinese-built ASCMs, but the *Yuan* class SSP has the added benefit of an AIP system, which can lead to as much as a 10 to 20 dB sound pressure level (SPL) reduction in noise signature, and may have incorporated quieting technology from the Russian-designed *Kilo* class SS. (ONI, 2015a).

China continues to modernize its nuclear-powered attack submarine force. The *Shang*-class SSN's initial production run stopped after only two hulls that were launched in 2002 and 2003. After nearly 10 years, China is continuing production with four additional hulls of an improved variant, the first of which was launched in 2012. Following the completion of the improved *Shang*-class SSNs, PLA(N) will progress to the Type 095 SSN, which may provide a generational improvement in many areas, such as quieting and weapon capacity. (ONI, 2015a).

The PLAN's new nuclear-powered ballistic missile submarine (SSBN) is the Type 094 or *Jin* class. Each *Jin*-class SSBN is expected to be armed with 12 JL-2 nuclear-armed submarine-launched ballistic missiles. Each JL-2 missile has a range of 3,996 nautical miles (nmi) (7,041 kilometers [km]), which gives China its first credible sea-based nuclear deterrent (Starosciak and Davenport, 2014). Four *Jin*-class SSBNs are currently operational and up to five may enter service before China begins developing and testing its next-generation of SSBN, the Type 096, over the coming decade (DoD, 2015; ONI, 2015a). China began patrols with nuclear (ballistic) missile submarines for the first time (December 2015), giving Beijing a new strategic strike capability, according to the U.S. Strategic Command and Defense Intelligence Agency (Gertz, 2015).

A range of 3,996 nmi (7,041 km) could permit *Jin*-class SSBNs to attack:

- targets in Alaska (except the Alaskan panhandle) from locations close to China;
- targets in Hawaii from locations south of Japan;
- targets in the western half of the 48 contiguous U.S., as well as Hawaii and Alaska, from mid-ocean locations west of Hawaii; and
- targets in all 50 states from mid-ocean locations east of Hawaii.

China's increasing naval presence in the Pacific Ocean and their enhanced submarine capabilities, particularly quieting technology, underscore the need for the U.S. Navy to maintain operational readiness through routine training, testing and military operations using SURTASS LFA sonar.

1.3.1.2 Russia

According to Vice Admiral Clive Johnstone, Commander of NATO's Maritime Command, Western sub commanders are reporting "more activity from Russian submarines than we've seen since the days of the Cold War." Simultaneously, the technical capabilities displayed by Russian submarines have increased; it is "a level of Russian capability that we haven't seen before" the Admiral says (Gady, 2016). The Russian Navy accomplished this "through an extraordinary investment path not mirrored by the West" and has made "technology leaps that [are] remarkable, and credit to them." Russian submarines currently patrolling the oceans "have longer ranges, they have better systems, they're freer to operate" (Gady, 2016). In reference to Russia, NATO has "seen a rise in professionalism and ability to operate their boats that we haven't seen before," explained the Admiral (Gady, 2016).

Admiral Mark Ferguson, the U.S. Navy's top commander in Europe, stated that "The [submarine] patrols are the most visible sign of a renewed interest in submarine warfare by President Vladimir V. Putin, whose government has spent billions of dollars for new classes of diesel and nuclear-powered attack submarines that are quieter, better armed and operated by more proficient crews than in the past" (Schmitt, 2016).

In a February 2016 testimony before the U.S. Senate Armed Services Committee, the head of U.S. Pacific Command, Admiral Harry B. Harris, emphasized that Russia has also stepped up its activities in the Asia-Pacific region: "Russian ballistic missile and attack submarines remain especially active in the region," Harris said (ONI, 2015b). The admiral also noted that, "The arrival in late 2015 of Russia's newest class of nuclear ballistic missile submarine (*Dolgorukiy* SSBN) [on station] in the Far East is part of a modernization program for the Russian Pacific Fleet and signals the seriousness with which Moscow views this region" (ONI, 2015b). This class is equipped with 16 launchers for SS-N-32 Bulava submarine-launched ballistic missiles (SLBMs), and will form the core of Russia's naval strategic nuclear forces for most of the 21st century. The SS-N-32 has a reported range of 8,500 km (4,590 nmi) and plans are for a total of eight *Dolgorukiy* Class SSBNs to be delivered to the Russian Navy by 2020 (ONI, 2015b).

The *Severodvinsk* SSGN is a 4th-generation submarine designed as a multi-purpose nuclear attack submarine. Specific missions of this class include ASW, anti-surface warfare (ASuW), and land-attack. Its armament includes a wide range of advanced cruise missiles to destroy enemy ships and targets ashore. Eight are planned to be built through 2020 (ONI, 2015b). Rear Admiral Dave Johnson, U.S. Naval Sea Systems Command's program executive officer (PEO) for submarines said in 2014 during the Naval Submarine League's symposium, "We'll be facing tough opponents. One only has to look at the Severodvinsk…I am so impressed with this ship that I had Carderock [U.S. Naval Surface Warfare Center, Maryland] build a model from unclassified data" (ONI, 2015b).

The new Russian submarine and ship classes will incorporate the latest advances in militarily-significant areas such as: weapons; sensors; command, control and communication capabilities; signature reduction [making them quieter]; electronic countermeasures; and automation and habitability (ONI, 2015b). In the next 10 to 15 years, the Russian Navy will continue its historic transition to a new 21st-century Navy which parallels China's increasing naval presence and capabilities. These developments underscore the imminent need for the U.S. Navy to maintain ASW operational readiness, particularly against quiet submarines, through routine training, testing, and military operations using SURTASS LFA sonar.

1.4 Scope of Environmental Analysis

This SEIS/SOEIS includes an analysis of potential environmental impacts associated with the Proposed Action and Alternatives in SURTASS LFA sonar's global operating area of the Atlantic, Pacific, and Indian oceans and the Mediterranean Sea. The environmental resource areas analyzed in this SEIS/SOEIS include: marine water resources; biological resources; and marine economic resources.

1.5 Documentation Incorporated by Reference

Several key documents that are sources of information are incorporated by reference in this SEIS/SOEIS, per CEQ guidance. These documents are considered key documents because of the similarity and applicability in the action, analyses, or impacts to this Proposed Action. Documents incorporated by reference herein, in part or in whole include:

- FOEIS/EIS for SURTASS LFA Sonar (DoN, 2001). This is the foundational environmental document upon which subsequent supplemental assessments are based. In this FOEIS/EIS, the Navy considered the employment of up to four SURTASS LFA sonar systems in the Atlantic, Pacific, and Indian oceans and Mediterranean Sea operating areas (Figure 1-1).
- FSEIS for SURTASS LFA Sonar (DoN, 2007). This environmental document focused on providing additional information on aspects of the environment that could potentially be affected by employment of up to four SURTASS LFA sonar systems; the FSEIS also was prepared to remedy the deficiencies identified by the Court order of the U.S. District Court for the Northern District of California, including the need for additional alternatives analysis and mitigation and monitoring as well as an analysis of the potential impacts of LF sound on fishes.
- FSEIS/SOEIS for SURTASS LFA Sonar (DoN, 2012). This document focused on updating the information available on the potential impacts of SURTASS LFA sonar on the environment and further analysis of additional offshore (greater than 12 nmi (22.2 km) from land) biologically important areas (OBIAs) in operational regions, of whether a greater than 12-nmi (22.2-km) coastal standoff distance was practicable, and potential cumulative impacts with other active sonar sources.
- FSEIS/SOEIS for SURTASS LFA Sonar (DoN, 2015a). Pursuant to the amended summary judgment order issued by the U.S. District Court for the Northern District of California on May 22, 2014, this document was prepared for the limited purpose of remedying the NEPA deficiency identified in the Court's order. The Court specified that the Navy failed to use the best available data in its 2012 FSEIS/SOEIS (DoN, 2012) when it determined potential impacts from employment of SURTASS LFA sonar systems on one stock of common bottlenose dolphins in Hawaiian waters rather than the more current information that identified five stocks of common bottlenose dolphins in Hawaiian waters.

1.6 Relevant Legislation and Executive Orders

The Navy has prepared this SEIS/SOEIS based upon Federal legislation, statutes, regulations, and policies that are pertinent to the implementation of the Proposed Action, including those listed below. A description of the Proposed Action's consistency with the applicable laws, statutes, regulations, and policies, as well as the names of regulatory agencies responsible for their implementation, is presented in Chapter 6.

1.6.1 National Environmental Policy Act

The NEPA (42 U.S.C. sections 4321-4370h) requires an environmental analysis of major federal actions that have the potential to significantly impact the quality of the human environment.

The first step in the NEPA process for an SEIS/SOEIS is to prepare a Notice of Intent to develop the document. The Notice of Intent was published in the *Federal Register* on 5 June 2015 (80 FR 32097) and provides an overview of the proposed action and the scope of the SEIS/SOEIS. This Draft SEIS/SOEIS

(DSEIS/SOEIS) was prepared to assess the potential impacts of the proposed action and alternatives on the environment. A Notice of Availability published in the *Federal Register* and notices placed in local or regional newspapers announcing the availability of the DSEIS/SOEIS were also prepared indicating that this DSEIS/SOEIS is being circulated for review and comment.

The Final SEIS/SOEIS (FSEIS/SOEIS) will address all public comments received on the DSEIS/SOEIS. Responses to public comments may include correction of data, clarifications of and modifications to analytical approaches, and inclusion of new or additional data or analyses. Supplements to either the Draft or Final SEIS/SOEIS may be prepared if the agency makes substantial changes in the proposed action or if there are significant new circumstances or information relevant to environmental concerns. Finally, the decision-maker will issue a Record of Decision (ROD), no earlier than 30 days after the FSEIS/SOEIS is made available to the public.

1.6.2 Executive Order 12114

EO 12114, Environmental Effects Abroad of Major Federal Actions, directs federal agencies to provide for informed environmental decision-making for major federal actions outside the United States and its territories. Presidential Proclamation 5928, issued December 27, 1988, extended the exercise of U.S. sovereignty and jurisdiction under international law to 12 nautical miles (nmi). However, the proclamation expressly provides that it does not extend or otherwise alter existing federal law or any associated jurisdiction, rights, legal interests, or obligations. Thus, as a matter of policy, the Navy analyzes environmental effects and actions that have the potential to significantly affect the environment within 12 nmi under NEPA (an EIS or SEIS) and those effects occurring beyond 12 nmi under the provisions of EO 12114 (an OEIS or SOEIS).

1.6.3 Council on Environmental Quality Regulations

The U.S.C. of Federal Regulations Title 40 (Protection of the Environment), Chapter V (CEQ), Parts 1500-1508, provide the CEQ regulations for the implementation of the procedural provisions of NEPA.

1.6.4 Navy Regulations

Navy regulations for implementing NEPA (32 CFR part 775), which provides Navy policy for implementing CEQ regulations and NEPA, were followed in the preparation of this SEIS/SOEIS.

1.6.5 Marine Mammal Protection Act

The MMPA of 1972 (16 U.S.C. sections 1361 et seq.) established a moratorium on “taking, with certain exceptions” of marine mammals in waters and lands under U.S. jurisdiction. Upon request, authorizations are permitted under the MMPA to unintentionally take marine mammals incidental to conducting an activity. MMPA amendments in 1994 defined two levels of marine mammal harassment: Level A harassment is any act of pursuit, torment, or annoyance that has the potential to injure a marine mammal or marine mammal stock, while Level B harassment is any act that has the potential to disturb a marine mammal or marine mammal stock by disrupting biologically important behavioral patterns.

Within the 2004 National Defense Authorization Act, the MMPA’s definition of Levels A and B harassment were altered in regards to military readiness activities. Level A harassment was redefined as any act that injures or has the significant potential to injure a marine mammal or marine mammal stock, and Level B harassment was redefined as any act that disturbs or is likely to disturb a marine mammal or marine mammal stock by causing disruption of natural, biologically important behavioral patterns such that the behavior is abandoned or significantly altered. In addition, it eliminated the "small numbers" and "specified geographic region" requirements from the incidental take permitting process for military readiness activities. Further, NMFS' determination of "least practicable adverse impact on a species or stock and its habitat" must include consideration of personnel safety, practicality of implementation, and impact on the effectiveness of the military readiness activity.

1.6.6 Endangered Species Act

The Endangered Species Act (ESA) of 1973 (16 U.S.C. sections 1531 et seq.) was established to protect and conserve threatened and endangered species and the ecosystems upon which they depend. Under the ESA, an endangered species is one in danger of extinction throughout all or a significant portion of its range while a threatened species is one likely to become endangered within the foreseeable future throughout all or a significant portion of its range. ESA-designated critical habitat is a geographic habitat area essential to the conservation of a threatened or endangered species.

Unintentional takes of endangered species incidental to the execution of an activity can be permitted upon request. Federal agencies must consult with NMFS under Section 7 of the ESA on measures to minimize the effects of their activities on species and critical habitat listed under the ESA for which NMFS has jurisdiction.

1.6.7 National Marine Sanctuaries Act

In 1992, Title III of the Marine Protection, Research and Sanctuaries Act was designated as the National Marine Sanctuaries Act (NMSA) (16 U.S.C. sections 1431 et seq.). The NMSA authorizes the designation and management of marine areas with special national significance as national marine sanctuaries (NMS). Federal agencies are required to consult under Section 304(d) of the NMSA with the Office of National Marine Sanctuaries (ONMS) on proposed actions that are "likely to destroy, cause the loss of, or injure a sanctuary resource". The NMSA defines "to injure" as "to change adversely, either in the short or long term, a chemical, biological or physical attribute of, or the viability of. This includes, but is not limited to, to cause the loss of or destroy."

1.6.8 Magnuson-Stevens Fishery Conservation and Management Act

Reauthorized and amended as the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (Public Law [P.L.] 104-297) in 1996, the MSFCMA mandates the conservation and management of fishery resources. One of the most significant mandates in the MSFCMA is the essential fish habitat (EFH) provision (16 U.S.C. sections 305, 104-297[b]) that provides the means by which to conserve fish habitat, which includes those waters and seafloor substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. The MSFCMA requires Federal agencies to consult with NMFS on activities that may adversely affect EFH (16 U.S.C. sections 104-297[b][2]).

1.6.9 Act to Prevent Pollution from Ships

The Act to Prevent Pollution from Ships (APPS, 33 USC 1901, et seq.) implements the provisions of MARPOL (International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978) and the annexes to which the U.S. is a party.

1.6.10 Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) (16 U.S.C. section 1451 et seq.) provides for coastal states to develop coastal zone management programs to achieve wise use of the land and water resources of the coastal zone. Under CZMA, Federal agency activities, inside or outside the coastal zone, which affect any land, water use, or natural resource of the coastal zone must be carried out in a manner that is consistent to the maximum extent practicable with the enforceable policies of approved State management programs.

1.6.11 Clean Water Act

The purpose of the Clean Water Act (CWA) (33 U.S.C. section 1251 et seq.) is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. One means by which this is accomplished is through the regulation, in the form of permits, of discharges of pollutants into territorial seas, the waters of the contiguous zone, or the oceans (33 U.S.C section 1431 [401 permits]).

1.6.12 Executive Order 12962, Recreational Fisheries

EO 12962 (60 C.F.R. 30769) requires the fulfillment of certain duties, including evaluating the effects of Federally funded, permitted, or authorized actions on aquatic systems and recreational fisheries and documenting those effects relative to the conservation, restoration, and enhancement of aquatic systems to provide for increased recreational fishing opportunities nationwide.

1.6.13 Executive Order 13089, Coral Reef Protection

EO 13089 established the interagency U.S. Coral Reef Task Force to develop and implement a comprehensive program of research and mapping to inventory, monitor, and identify the major causes and consequences of degradation of coral reef ecosystems.

1.6.14 Executive Order 13158, Marine Protected Areas

EO 13158 was established to (1) ensure that each Federal agency whose authorities provide for the establishment or management of marine protected areas (MPAs) shall take appropriate actions to enhance or expand protection of existing MPAs and establish or recommend, as appropriate, new MPAs; (2) develop a scientifically-based, comprehensive national system of MPAs; and (3) avoid causing harm to MPAs through Federally conducted, approved, or funded activities. MPAs include those areas of coastal and ocean waters, and submerged lands thereunder, over which the U.S. exercises jurisdiction, consistent with international law.

1.6.15 Executive Order 13175, Consultation and Coordination with Indian Tribal Governments

EO 13175 provides direction, to ensure that Federal agencies conduct regular, meaningful consultations and collaborations with tribal officials on the development of Federal policies that have tribal implications.

1.6.16 Executive Order 13547, Stewardship of the Ocean, Our Coasts and the Great Lakes

EO 13547 requires Federal agencies to collaborate to ensure that the ocean, our coasts and the Great Lakes, are healthy and resilient, safe, and productive through the development of coastal and marine spatial plans that build upon and improve existing Federal, State, tribal, local, and regional decision-making and planning processes.

1.7 Public and Agency Participation and Intergovernmental Coordination

Per CEQ regulations (40 CFR part 1506.6) as well as Navy regulations and guidance, the public is to be involved in preparing and implementing NEPA procedures. Additionally, per the requirements of Federal legislation and Executive Orders, the Navy is required to coordinate and consult with other Federal agencies, and Indian Tribal governments pursuant to the Proposed Action detailed in this SEIS/SOEIS.

1.7.1 Public Participation

On June 5, 2015, the Navy published a Notice of Intent (NOI) in the *Federal Register* to prepare a SEIS/SOEIS for the employment of SURTASS LFA sonar to support consultations associated with expiring MMPA and ESA 5-year regulatory permits in 2017 (DoN, 2015b). No comments were received in response to the NOI.

Public involvement in the review of the Draft SEIS/SOEIS is stipulated in 40 CFR Part 1503.1 of CEQ's NEPA implementing regulations as well as in Navy environmental compliance guidance. These regulations and guidance provide for active solicitation of public comment via public comment periods. This Draft SEIS/SOEIS will be made available to the public in August 2016, when a Notice of Availability (NOA) will be published by the U.S. Environmental Protection Agency (EPA) in the *Federal Register*. Comments on this Draft SEIS/SOEIS will be accepted for 45 days beginning with the publication of the official NOA. Additionally, in conjunction with filing this Draft SEIS/SOEIS with the EPA, correspondence notifying that the Draft SEIS/SOEIS is available on the SURTASS LFA sonar website will be sent to appropriate Federal, state, and tribal government agencies and organizations as well as other interested parties.

1.7.2 Cooperating Agency: National Marine Fisheries Service

The NMFS has the primary Federal responsibility for the conservation, management, and development of living marine resources and for the protection of certain marine mammals and endangered species under numerous Federal laws. These responsibilities are inherent in NMFS's mission to achieve a continued optimum utilization of living marine resources for the benefit of the U.S.

NMFS is a cooperating agency, as envisioned under 40 C.F.R. 1501.6, on the development of this SEIS/SOEIS for SURTASS LFA sonar. This document will serve as the required NEPA documentation for the issuance of regulations and letters of authorization (LOAs) pursuant to the rulemaking process under the MMPA.

1.7.3 National Marine Fisheries Service Consultation (ESA and MMPA)

In August 2016, pursuant to requirements of the MMPA and ESA, the Navy will initiate consultation for incidental taking of ESA-listed species and marine mammals that may be associated with the employment of SURTASS LFA sonar.

1.7.4 National Marine Sanctuaries Consultation

In accordance with Section 304(d) of the NMSA, the Navy will initiate consultation with the ONMS on the Proposed Action with the submission of a Sanctuary Resource Statement, prepared jointly with the NMFS Office of Protected Resources.

1.7.5 Consultation/Coordination with Indian Tribal Governments

Pursuant to EO 13175 Federal agencies are to consult and coordinate with Federally-recognized Indian or Alaskan tribal governments on actions or policies that may have tribal implications. The Navy will contact American Indian or Alaskan tribal governments for which the Proposed Action may have relevancy to provide them with the opportunity to review and comment upon the Draft SEIS/SOEIS.

1.7.6 Additional Consultation/Coordination

Additional consultation/coordination was conducted as part of the analyses for the Navy's 2001 FOEIS/EIS (DoN, 2001) and 2012 FSEIS/SOEIS (DoN, 2012) for SURTASS LFA sonar. Since the Proposed Action has not changed since 2001, the information in these documents regarding consultations and agency or tribal government coordination remains valid and is incorporated by reference herein.

Negative determinations pursuant to the CZMA were submitted in conjunction with the 2001 DOEIS/EIS to 23 U.S. states and five territories with coastlines that potentially could be affected by the proposed action. The Navy determined that under the preferred alternative (selected in the ROD), employment of SURTASS LFA sonar was consistent with the enforceable policies of each state or territory's coastal zone management plan.

Consultation on the NMSA occurred between November 2000 and July 2001 on the Navy's 2001 proposed action (FOEIS/EIS [DoN, 2001]) and issuance of NMFS' Final Rule for SURTASS LFA sonar employment. The Navy determined that the employment of SURTASS LFA sonar would not impact sanctuary resources.

On 28 February 2000, pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, the Navy submitted a determination of no adverse effects on essential fish habitat (EFH) for the operation of SURTASS LFA sonar to the Office of Habitat Conservation, NMFS. In accordance with EO 13175 (Consultation and Coordination with Indian Tribal Governments), on 30 May 2012, the Navy distributed notification letters to 25 Federally-recognized tribes and tribal groups in Alaska, Washington, and Oregon to make these groups aware of the Navy's intension to continue employing SURTASS LFA sonar; no responses were received.

1.8 Literature Cited

Department of Defense (DoD). (2015). Annual report to Congress [on] military and security developments involving the People's Republic of China, May 2015, pp. 8, 9, 32. Washington, D.C.: Office of the Department of Defense.

Department of the Navy (DoN). (2001). Final overseas environmental impact statement and environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/FEIS%20Vol%20I.pdf>.

DoN. (2007). Final supplemental environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS.pdf; <http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS_V2.pdf>.

DoN. (2012). Final supplemental environmental impact statement/supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS-SOEIS.pdf>.

DoN. (2015a). Final supplemental environmental impact statement/supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/Final_SEIS-SOEIS_SURTASS_LFA_sonar.pdf>.

DoN. (2015b). Notice of intent to prepare a supplemental environmental impact statement/supplemental overseas environmental impact statement for employment of Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Department of the Navy, Department of Defense. Federal Register 80(108):32097. <http://www.surtass-lfa-eis.com/docs/NOI_FR_2015.pdf>.

DoN. (2016). A design for maintaining maritime superiority, Version 1.0, 10 pp. Washington, D.C.: Office of the Chief of Naval Operations.

Department of State (DoS). (2014). Limits in the seas No. 143 China: Maritime claims in the South China Sea. Washington, D.C.: U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs, 26 pp. Retrieved 22 February 2016, from <http://www.state.gov/documents/organization/234936.pdf>.

Gady, F. (2016, February 5). Russian submarine activity at highest level since Cold War. *The Diplomat.* Retrieved April 14, 2016, from <http://thediplomat.com/2016/02/russian-submarine-activity-at-highest-level-since-cold-war>.

Gertz, W. (2015, December 9). Pentagon confirms patrols of Chinese nuclear missile submarines. *The Washington Times*. Retrieved February 2, 2016, from <http://www.washingtontimes.com/news/2015/dec/9/inside-the-ring-chinas-nuclear-missile-submarine-p/?page=all>.

Kaplan, R.D. (2014). Asia's cauldron: The South China Sea and the end of a stable Pacific. New York, NY: Random House.

Office of Naval Intelligence (ONI). (2015a). The PLA Navy, new capabilities and missions for the 21st century, April 2015, pp. 18, 19-20. Washington, D.C.: Office of Naval Intelligence.

ONI. (2015b). The Russian Navy, a historic transition, December 2015, pp. 17, 18, 43. Washington, D.C.: Office of Naval Intelligence.

O'Rourke, R. (2015). China naval modernization: Implications for U.S. Navy capabilities—Background and issues for Congress, December 21, 2015, pp. 16 to 19. Washington, D.C.: Congressional Research Service.

Rajagopalan, M. and S-L. Wee. (2015, March 5). UPDATE 2-China to raise defence budget 10.1 pct this year in high-tech drive. *Reuters.com*. Retrieved February 29, 2016 from <http://www.reuters.com/article/china-parliament-defence-idUSL4N0W704220150305>.

Schmitt, Eric. (2016, April 21). Russia expands submarine fleet as rivalry grows. *The New York Times*, p. A1. Retrieved April 22, 2016, from <http://www.nytimes.com/2016/04/21/world/europe/russia-bolsters-submarine-fleet-and-tensions-with-us-rise.html?_r=0>.

Starosciak, B., and K. Davenport. (2014, July 2). China seen nearing sea-based deterrent. *Arms Control Association*. Retrieved February 2, 2016 from <http://www.armscontrol.org/print/6352>.

Torode, G., and M. Rajagopalan. (2016, February 24). Paracels build-up a pointer to China's broader South China Sea ambitions. *Reuters.com.* Retrieved February 24, 2016, from <http://www.reuters.com/article/us-southchinasea-china-paracels-idUSKCN0VT0YA>.

2 Description of the Proposed Action and Alternatives

2.1 Proposed Action

The U.S. Navy proposes to employ up to four SURTASS LFA and compact LFA sonar systems (hereafter, collectively, LFA sonar) onboard up to four U.S. Navy surveillance ships for routine training, testing, and military operations in the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea. The polar regions as depicted in Figure 1-1 are non-operating areas for SURTASS LFA sonar for the purpose of this proposed action. Four U.S. Navy surveillance ships operate SURTASS LFA sonar systems: U.S. Naval Ship (USNS) VICTORIOUS (Tactical-Auxiliary General Ocean Surveillance [T-AGOS] 19); USNS ABLE (T-AGOS 20); USNS EFFECTIVE (T-AGOS 21); and USNS IMPECCABLE (T-AGOS 23). The proposed action would include the employment of up to four SURTASS LFA sonar systems with geographical restrictions that include maintaining LFA sonar received levels below 180 dB re 1 µPa (root-mean-square [rms]) within 12 nmi (22 km) of any land and at the boundary of designated Offshore Biologically Important Area (OBIA) during their effective periods of biological activity. Additionally, LFA sonar received levels will not exceed 145 dB re 1 µPa (rms) within known recreational dive sites. Monitoring mitigation includes visual, passive acoustic, and active acoustic (high frequency marine mammal monitoring [HF/M3] sonar) monitoring to prevent injury to marine animals when SURTASS LFA sonar is transmitting, by providing methods to detect these animals within the mitigation zone for SURTASS LFA sonar and delay/suspend transmissions accordingly. The Navy is currently authorized to transmit the maximum number of 432 hours of LFA sonar transmission hours per vessel per year. Under Alternative 1, the Navy would retain this maximum number of 432 hours of LFA sonar transmissions per year, while under Alternative 2, the

References to Underwater Sound Levels

- References to underwater sound pressure level (SPL) in this SEIS/SOEIS 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).
- In this SEIS/SOEIS, underwater sound exposure level (SEL) is a measure of energy, specifically the squared instantaneous pressure integrated over time; 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) used herein is an intermediate calculation for input to the risk continuum used in the acoustic impact analysis for SURTASS LFA sonar. SPE accounts for the energy of all LFA sonar transmissions that a modeled animal ("animat") receives during a 24-hr period of a SURTASS LFA sonar mission as well as an approximation of the manner in which the effect of repeated exposures accumulate. As such, the SPE metric incorporates both physics and biology. Calculating the potential risk from exposure to SURTASS LFA sonar is a complex process and the reader is referred to Appendix B for details. SPE levels will be expressed as "dB SPE" in this document, as they have been presented in preceding environmental compliance documentation for SURTASS LFA sonar: FOEIS/FEIS (DoN, 2001); FSEIS (DoN, 2007); FSEIS/SOEIS (DoN, 2012a); and FSEIS/SOEIS (DoN, 2015).

Navy would only transmit the maximum number of 255 hours of LFA sonar per vessel per year.

2.1.1 Description of SURTASS LFA Sonar System

SURTASS LFA sonar is a long-range system operating in the low-frequency (LF) band (below 1,000 hertz [Hz]). This system is composed of both active and passive components (Figure 2-1). The active component is the LFA sonar source array and the passive component is the SURTASS receive array.

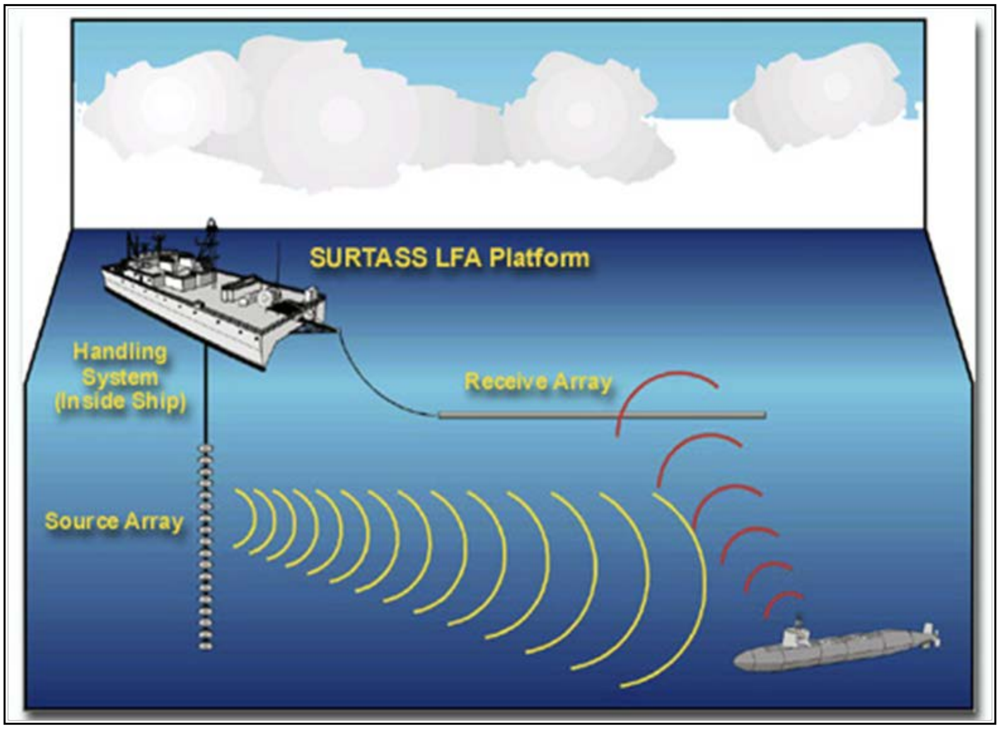


Figure 2-1. The SURTASS LFA Sonar System Includes the Active Sonar Vertical Line Array (Source Array) and the Passive Horizontal Line Array (Receive Array).

SONAR is an acronym for SOund NAvigation and Ranging, and its definition includes any system that uses underwater sound, or acoustics, for observations and communications. Sonar systems are used for many purposes, ranging from commercial “fish finders” to military anti-submarine warfare (ASW) systems used for detection and classification of submarines.

The SURTASS LFA sonar system uses two basic types of sonar:

- Passive sonar detects the sound created by an object (source) in water. This is a one-way transmission of sound waves through the water from the source to the receiver and is the same as people hearing sounds that are created by a source and transmitted through the air to the ear. Very simply, passive sonar “listens” without sending any sound signals.
- Active sonar detects objects by creating a sound pulse or “ping” that is transmitted through the water and reflects off a target, returning in the form of an echo to be detected by a receiver. Active sonar is a two-way transmission (source to reflector to receiver). Some marine mammals use a type of active biosonar called echolocation to locate underwater objects such as prey or the seafloor for navigation.

SURTASS LFA sonar systems were initially installed on two SURTASS vessels: R/V *Cory Chouest*, which was retired in 2008, and USNS IMPECCABLE (T-AGOS 23). As future undersea warfare requirements continued to transition to littoral[1] ocean regions, a compact version of the LFA sonar system deployable on SURTASS ships was needed. This sonar system upgrade is known as compact LFA, or CLFA, which consists of smaller, lighter-weight source elements than the SURTASS LFA sonar system and is compact enough to be installed on the VICTORIOUS Class platforms (such as T-AGOS 19, 20, and 21). CLFA sonar 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.
- Lighter-weight design with mission weight of 142,000 pounds (lb) (64,410 kilograms [kg]) for the CLFA sonar system versus 324,000 lb (155,129 kg) mission weight for the LFA sonar system.

The operational characteristics of the CLFA sonar system are comparable to the existing LFA sonar system as presented in Subchapter 2.1 of the FOEIS/EIS (DoN, 2001) and FSEIS/SOEISs (DoN, 2007, 2012a). Therefore, the potential impacts from CLFA sonar are expected to be similar to, and not greater than, the effects from the LFA sonar system. For this reason, in this SEIS/SOEIS the term low frequency active sonar, or LFA sonar, will be used to refer to both the LFA and/or the CLFA sonar systems, unless otherwise specified.

2.1.1.1 Active Sonar System Components

The active component of the SURTASS LFA sonar system, LFA, is an adjunct to the SURTASS passive capability and is employed when active sound signals are needed to detect and track underwater targets. LFA sonar complements SURTASS passive operations by actively acquiring and tracking submarines when they are in quiet operating modes, measuring accurate target range, and re-acquiring lost contacts.

LFA sonar consists of a vertical source array of transmitting elements suspended by cable under one of the T-AGOS vessels (Figure 2-1). These elements, called projectors, are devices that produce the active sonar sound pulses or pings. To produce a ping, the projectors transform electrical energy to mechanical energy (i.e., vibrations), which travel as pressure disturbances in water. The LFA sonar source is a vertical line array (VLA) consisting of as many as 18 source projectors. Each LFA source projector transmits sonar beams that are omnidirectional (360 degrees) in the horizontal, with a narrow vertical beamwidth that can be steered above or below the horizontal. The source frequency ranges between 100 and 500 Hz.

1 The term littoral is one of the most misunderstood terms used in naval warfare. 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 seafloor to the top of the atmosphere and from the land surface to the top of the atmosphere (Naval Oceanographic Office, 1999). The common definition of littoral is pertaining to the shore or a shore or coastal region, while the marine science definition refers to the shallow-water zone between low- and high-tide. The Navy’s meaning differs because it is based on a tactical, not geographical or environmental, perspective relating to overall coastal operations, including all assets supporting a particular operation regardless of how close, or far, from the shore they may be operating.

2.1.1.2 Passive Sonar System Components

SURTASS is the passive, or listening, component of the system that detects returning echoes from submerged objects, such as threat submarines, through the use of hydrophones. Hydrophones transform mechanical energy (received acoustic sound waves) to an electrical signal that can be analyzed by the processing system of the sonar. SURTASS consists of a twin-line (TL-29A) horizontal line array (HLA), which is a "Y" shaped array with two apertures that is approximately 1,000 ft (305 m) long. The TL-29A can be towed in shallow, littoral environments; provides significant directional noise rejection; and resolves bearing ambiguities without having to change the vessel's course.

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

2.1.1.3 Operating Profile

The operating features of the active component, LFA sonar, are:

- The SL of an individual source projector on the LFA sonar array is approximately 215 dB re 1 µPa at 1 m (rms) or less. Since the projectors work together as an array to create the sound field, the array's measured sound field will never be higher than the SL of an individual source projector.
- The typical LFA sonar signal is not a constant tone but consists of various waveforms that vary in frequency and duration. A complete sequence of sound transmissions (waveforms) 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, a variety of signal types can be used, including continuous wave (CW) and frequency-modulated (FM) signals. The duration of each continuous-frequency sound transmission within the wavetrain is no longer than 10 seconds.
- Average duty cycle (ratio of sound "on" time to total time) is less than 20 percent. The typical duty cycle, based on historical SURTASS LFA sonar operational parameters (2003 to 2016), is nominally 7.5 to 10 percent.
- The time between wavetrain transmissions is typically from 6 to 15 minutes.

The SURTASS LFA sonar vessels usually 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.

Due to the uncertainties in the world's political climate, a detailed account of future operating locations and conditions cannot be predicted. However, for analytical purposes, a nominal annual deployment schedule and operational concept were developed, based on actual LFA sonar operations since January 2003 and projected Fleet requirements. The information on the deployment schedule and operational concept previously provided in the Navy's 2007 and 2012 SEISs for SURTASS LFA Sonar (DoN, 2007 and 2012a), which as previously noted are incorporated by reference, remains valid. Annually, each SURTASS LFA sonar vessel is expected to spend approximately 54 days in transit and 240 days at sea conducting routine training, testing, and military operations. 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 as well as the morale of the crew. The actual number and length of individual missions within the 240 day annual period are difficult to predict.

2.2 Alternatives

NEPA's implementing regulations provide guidance on the consideration of alternatives to a Federal proposed action and require rigorous exploration and objective evaluation of reasonable alternatives. Only those alternatives determined to be reasonable and that meets the purpose and need of the proposed action require analysis.

2.2.1 Reasonable Alternative Screening Factors

Screening criteria were developed to aid in assessing the feasibility of proposed alternatives and define the range of reasonable alternatives. Potential alternatives that meet the Navy's purpose and need were evaluated against the following screening factors:

- The alternative must allow the Navy to meet all routine training requirements for SURTASS LFA sonar systems, vessels, and crews.
- The alternative must allow the Navy to meet all routine testing requirements for SURTASS LFA sonar systems, vessels, and crews.
- The alternative must allow the Navy to meet all routine military operational requirements for SURTASS LFA sonar systems, vessels, and crews.
- The alternative must allow the Navy to meet all requirements for maintenance and repair schedules, and vessel crew schedules for SURTASS LFA sonar vessels.
- The alternative must allow the Navy to meet the requirement to use the best available data and information for the analysis and delineation of OBIAs for marine mammals.
- The alternative must allow the Navy to meet all national security requirements that may involve the employment of SURTASS LFA sonar vessels.

The evaluation process involved assessing whether each of the three potential alternatives (No Action, Action Alternative 1, and Action Alternative 2) would allow the Navy to meet the requirements of the six screening factors. The No Action Alternative would not allow the Navy to meet any of the screening factor requirements or the Navy's purpose and need. Action Alternatives 1 and 2 would allow the Navy to meet all the requirements of the screening factors and its purpose and need.

2.2.2 Alternatives Carried Forward for Analysis

After consideration of the screening factors, two action alternatives were identified that would meet the purpose and need for the proposed action. The No Action Alternative would not meet the purpose and need for the proposed action, but was carried forward to provide a baseline for environmental consequences.

2.2.2.1 No Action Alternative

Under the No Action Alternative, the proposed action would not occur, and no operation of any SURTASS LFA sonar systems would occur. The Navy's purpose and need would not be met since its ability to locate and defend against enemy submarines would be greatly impaired. Although the No Action Alternative would not meet the purpose and need for the proposed action, as required by NEPA, the No Action Alternative is carried forward for analysis in this SEIS/SOEIS, and provides a baseline for measuring the environmental consequences of the action alternatives

2.2.2.2 Alternative 1

Alternative 1 is the alternative chosen in the Navy's 2012 ROD (DoN, 2012b), plus any alterations to the 2012 ROD resulting from the ongoing comprehensive scientific data, information, and literature review being conducted as part of this SEIS/SOEIS development. The alternative chosen in the 2012 ROD includes the employment of up to four SURTASS LFA sonar systems, with geographical restrictions to include maintaining SURTASS LFA sonar received levels below 180 dB re 1 µPa (rms) within 12 nmi (22 km) of any coastline and within the designated OBIAs during their respective effective periods of significant biological activity. Additionally, the sound fields generated by SURTASS LFA sonar will not exceed RLs of 145 dB re 1 µPa (rms) within known recreational and commercial dive sites. This alternative represents a continuation of SURTASS LFA sonar routine training, testing, and military operations as they have been conducted since the execution of the 2012 ROD.

Annually, each SURTASS LFA sonar vessel is expected to spend approximately 54 days in transit and 240 days at sea conducting routine training, testing, and military operations. The actual number and length of the individual missions within the 240 days are difficult to predict, but the maximum number of LFA sonar transmission hours will not exceed 432 hours per vessel per year under Alternative 1.

Monitoring mitigation includes visual, passive acoustic, and active acoustic (HF/M3 sonar) monitoring to prevent potential adverse effects to marine animals to the extent practicable when LFA sonar is transmitting.

The OBIA screening criteria developed by NMFS and described in the 2012 FSEIS/SOEIS (DoN, 2012a) are being used in this SEIS/SOEIS, and include the following selection criteria:

- Biological criteria:
  - Areas with high densities of marine mammals; or
  - Areas of known/defined marine mammal breeding/calving grounds, foraging grounds, migration routes; or
  - Areas inhabited by small, distinct populations of marine mammals with limited distributions; or
  - Areas designated as marine mammal critical habitat.
- LF hearing sensitivity criteria: A marine area must be inhabited at least seasonally by marine mammal species whose best hearing sensitivity is in the LF range.
- Geographic criteria: Marine areas that are within potential operational areas for SURTASS LFA sonar—specifically, areas not in the polar regions (depicted in Figure 1-1) and outside of the coastal standoff range (i.e., greater than 12 nmi [22 km] from any land) for SURTASS LFA sonar.
- Navy practicability criteria: Once an area has been assessed to meet the geographical, LF hearing sensitivity, and biological criteria, and the area is considered eligible as a candidate OBIA for SURTASS LFA sonar by the Navy and NMFS, the Navy conducts a review of the potential OBIAs to assess personnel safety, practicality of implementation, and impacts on the effectiveness of military readiness activities, including routine training, testing and military operations. If no issues are found during the Navy's practicability review, the area meets all criteria for designation as a SURTASS LFA sonar OBIA for marine mammals.

More details on the delineation of additional OBIAs can be found in Chapter 4 and Appendix C of this SEIS/SOEIS.

2.2.2.3 Alternative 2 (Preferred Alternative)

Alternative 2 is the Navy's Preferred Alternative. This alternative is the same as Alternative 1 except for a substantial reduction in the annual hours of LFA sonar transmissions per SURTASS LFA sonar vessel. Specifically, under this alternative, the maximum number of LFA sonar transmission hours will not exceed 255 hours per vessel per year. This number of LFA sonar transmission hours is the minimum necessary for the Navy to meet the purpose and need outlined in this SEIS/SOEIS. Annually, each vessel is expected to spend approximately 54 days in transit and 240 days at sea conducting routine training, testing, and military operations. The actual number and length of the individual missions within the 240 days are difficult to predict, but the maximum number of LFA sonar transmission hours under this alternative would not exceed 255 hours per vessel per year, which is a 41 percent reduction in annual LFA sonar transmission hours per vessel.

Although NMFS has previously authorized a maximum of 432 hours of LFA sonar transmission time per vessel per year, actual annual LFA sonar transmission hours have been lower. Accordingly, the Navy has conducted additional analysis to determine the minimum number of LFA sonar transmission hours per vessel per year that would still meet its purpose and need. The following considerations were addressed during this analysis: 1) previous annual LFA sonar transmission hours; 2) the number of LFA sonar vessels available for employment during those periods; 3) recent world events, which have caused an increase in LFA sonar mission areas and system usage requirements for LFA sonar; and 4) a new requirement (by Navy direction) setting a minimum level of annual at-sea training for LFA sonar operators on the four LFA sonar vessels, which can only be met by using LFA sonar. This analysis concluded that in order to meet the purpose and need outlined in this SEIS/SOEIS, the minimum number of LFA sonar transmission hours per vessel per year required is 170 hours. Since actual usage of SURTASS LFA sonar could increase based on world events, it is prudent to apply a reasonable surge factor of 50 percent, which results in a maximum of 255 hours of LFA sonar transmissions per vessel per year.

2.2.3 Alternatives Considered But Not Carried Forward For Analysis

The initial FOEIS/EIS for SURTASS LFA sonar (DoN, 2001) considered alternatives to SURTASS LFA sonar, such as other passive and active acoustic, and non-acoustic technologies, as discussed in FOEIS/EIS Subchapters 1.1.2, 1.1.3, and 1.2.1; and Table 1-1 (DoN, 2001). These were also addressed in the 2002 NMFS Final Rule (NOAA, 2002) and the 2002 Navy ROD (DoN, 2002). These alternatives were eliminated from detailed study in the FOEIS/EIS in accordance with CEQ Regulation section 1502.14. These acoustic and non-acoustic detection methods included radar, laser, magnetic, infrared, electronic, electric, hydrodynamic, and biological technologies, and high- or mid-frequency active sonar. The FOEIS/EIS concluded that these technologies did not meet the purpose and need of the proposed action to provide Naval forces with reliable long-range detection and, thus, did not provide adequate reaction time to counter potential threats. Furthermore, they were not considered practicable and/or feasible for technical and economic reasons. These non-acoustic technologies were re-examined in Subchapter 1.1.4 of the 2012 FSEIS/SOEIS for SURTASS LFA sonar (DoN, 2012a), and this evaluation reached the same conclusion as the 2001 FOEIS/EIS. No new information on alternate technologies or their capabilities has arisen since the analyses in these documents; therefore, the relevant information from the 2001 and 2012 SURTASS LFA sonar documents are incorporated by reference herein.

2.3 Literature Cited

American National Standards Institute. (2006). *ANSI Reference Quantities for Acoustical Levels, ANSI-S1-8-1989*, revised 2006. New York, New York: Acoustical Society of America.

Council on Environmental Quality (CEQ). (1978). Title 40: Protection of the environment, Sections 1500 to 1508: Purpose, policy, and mandate. 40 Code of Federal Regulations (CFR) Sections 1500 to 1508. Retrieved February, 2015, from: <https://www.gpo.gov/fdsys/pkg/CFR-2012-title40-vol34/pdf/CFR-2012-title40-vol34-chapV.pdf>.

Department of the Navy (DoN). (2001). Final overseas environmental impact statement and environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/FEIS%20Vol%20I.pdf>.

DoN. (2002). Record of decision for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar; Notice of decision and availability. Washington, D.C.: Department of the Navy, Chief of Naval Operations. *Federal Register 67*(141): 48145-48154. <http://www.surtass-lfa-eis.com/docs/LFA%20EIS%20ROD.pdf>.

DoN. (2007). Final supplemental environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS.pdf>.

DoN. (2012a). Final supplemental environmental impact statement/ supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS-SOEIS.pdf>.

DoN. (2012b). Record of Decision for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar; Notice of decision and availability. Washington, D.C.: Department of the Navy, Chief of Naval Operations. *Federal Register* 77(168):52317. <http://www.surtass-lfa-eis.com/docs/ROD_Final_LFA_15Aug12.pdf>.

DoN. (2015). Final supplemental environmental impact statement/ supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/Final_SEIS-SOEIS_SURTASS_LFA_sonar.pdf>.

Naval Oceanographic Office. (1999). *Fleet oceanographic and acoustic reference manual (RP 33).* Prepared under the authority of Commander, Naval Meteorology and Oceanography Command. Stennis Space Center, MS: Department of the Navy, Department of Defense.

National Oceanic and Atmospheric Administration (NOAA). (2002). Taking and importing marine mammals: taking marine mammals incidental to Navy operations of Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar; Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register 67*(136), 46712-46789. <http://www.surtass-lfa-eis.com/docs/LFA%20Final%20Rule7-16-2002.pdf>.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene Jr., C. R., Kastak, D., Ketten, D. R., Miller, J. H., Nachtigall, P. E., Richardson, W. J., Thomas, J. A., & Tyack, P. L. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals*, *33*(4), 411-522.

Urick, R. J. (1983). *Principles of underwater sound, 3rd ed*, pp. 14. New York, New York: McGraw-Hill.

3 AFFECTED ENVIRONMENT

This chapter presents a description of the environmental resources and baseline conditions that could potentially be affected by implementing the proposed action or its alternatives. All potentially relevant environmental resource areas were initially considered for analysis in this SEIS/SOEIS. However, in compliance with NEPA, CEQ, and 32 CFR part 775 guidelines, the discussion of the affected environment (i.e., existing conditions) focuses only on those resource areas potentially subject to impacts relevant to the proposed action. Additionally, the level of detail used in describing a resource is commensurate with the anticipated level of potential environmental impacts. Accordingly, the resource areas detailed in this chapter include marine water resources (ambient noise environment); biological resources; and economic resources.

Since the proposed action, the continued employment of SURTASS LFA sonar, will occur entirely within the marine environment and principally entails the introduction of acoustic energy into that environment, the following resource areas are non-existent or non-relevant to the proposed action and consequently were not analyzed further in this SEIS/SOEIS:

- Water Resources—Only two components of water resources, marine waters and marine sediments, are germane to a proposed action that takes place entirely in oceanic waters. However, the continued use of SURTASS LFA sonar will have no impact on marine sediments as all parts of the sonar system are deployed only in the marine water column. The only aspect of marine waters affected by the operation of SURTASS LFA sonar is the addition of sound to the ambient ocean environment. Water quality will in no other way be affected by the operation of SURTASS LFA sonar systems, and for this reason, the only aspect for which impacts pertain, the ambient noise environment, will be described herein.
- Air Quality and Airspace—Since SURTASS LFA sonar systems are deployed into the marine environment and entail the use of underwater sonar technology, no air emissions or airborne noise would result from the routine training, testing, or military operation of the SURTASS LFA sonar systems. No airspace is involved with the routine employment of LFA sonar systems.
- Geological Resources—The proposed action and its alternatives are at-sea deployments of in-water sonar systems and related equipment that entail no deployment to the seafloor of any equipment that may cause physical disturbances to marine geological resources, including seafloor sediments.
- Cultural Resources—Deployment and use of SURTASS LFA sonar systems would not impact any marine cultural resources such as shipwrecks since the generation of underwater sound would not affect any cultural artifacts nor is any equipment deployed to the seafloor where cultural artifacts might be impacted.
- Land Use—The proposed action and alternatives solely entail the at-sea use of underwater sonar systems for routine training, testing, and military operations. As such, no construction activities associated with any terrestrial resources would be conducted and the proposed action would not involve any activities inconsistent with current or foreseeable land-use approaches and patterns.
- Infrastructure—Maintenance, repair, and porting to access ship staff associated with the continued operation of SURTASS LFA sonar systems and vessels require no expansion or alteration to any shore facilities. No changes to support facilities are planned as part of the proposed action.

- Transportation—During the employment of SURTASS LFA sonar, the T-AGOS vessels make no unusual maneuvers and operate according to all maritime regulations and normal vessel operation. No impacts to ocean-going ship or boating traffic would result from the continued operation of SURTASS LFA sonar.
- Public Health and Safety—SURTASS LFA sonar is not employed above RLs of 145 dB re 1 µPa (rms) near recreational or commercial dive sites where human divers could potentially be affected by SURTASS LFA sonar transmissions. Employment of the SURTASS LFA sonar systems is accomplished by trained merchant mariners and Navy personnel following all prudent safety measures.
- Hazardous Materials and Wastes—No hazardous waste or materials would be handled during the proposed action and no release of hazardous waste or materials is foreseeably expected as a result of the proposed action. Although some incidental discharges from the SURTASS LFA sonar vessels are normal for ship operations, SURTASS LFA vessels are operated in compliance with all requirements of the Clean Water Act (CWA) and the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), which is implemented by the Act to Prevent Pollution from Ships (APPS) (33 United States Code [U.S.C.] 1901 to 1915). Therefore, no discharges of pollutants regulated under the APPS or CWA will result from the operation of the SURTASS LFA sonar vessels nor will unregulated environmental effects occur in association with the operation of the SURTASS LFA sonar vessels.
- Sociologic—The proposed action does not involve any activities that would contribute to changes in sociological resources such as demography, communities, or social institutions.
- Environmental Justice—Implementation of the proposed action would not result in adverse impacts to any environmental resource area that would be expected to disproportionately affect minority or low-income human populations in the areas adjacent to the test areas and no significant impacts are reasonably foreseeable.

3.1 Regulatory Setting

This section provides a brief overview of the relevant primary Federal statutes, executive orders, and guidance that form the regulatory framework for the resource evaluation of the affected environment. Additionally, Chapter 6 (Other Considerations Required by NEPA) provides a summary listing and status of compliance with applicable environmental laws, regulations, and executive orders that were considered in preparing this SEIS/SOEIS for SURTASS LFA sonar.

3.1.1 Clean Water Act

The CWA (33 U.S.C. § 1251 et seq.) regulates discharges of pollutants in surface waters of the U.S. Section 403 of the CWA provides for the protection of ocean waters (waters of the territorial seas, the contiguous zone, and the high seas beyond the contiguous zone) from point-source discharges. Under Section 403(a), an authorized agency may issue a permit for an ocean discharge only if the discharge complies with CWA guidelines for protection of marine waters. Discharges incidental to the normal operation of Navy ships are excluded under the CWA[1] and are not part of the proposed action.

3.1.2 National Environmental Policy Act

This SEIS/SOEIS has been prepared in accordance with the President's CEQ regulations implementing NEPA (40 CFR §§ 1500–1508). NEPA (42 U.S.C. §§ 4321–4347) requires federal agencies to prepare an EIS for a proposed action with the potential to significantly affect the quality of the human environment, disclose significant environmental impacts, inform decision makers and the public of the reasonable alternatives to the proposed action, and consider comments to the EIS. Based on Presidential Proclamation 5928, issued 27 December 1988, impacts on oceans areas that lie within 12 nmi of land (U.S. territory) are subject to analysis under NEPA.

3.1.3 Executive Order 12114, Environmental Effects Abroad of Major Federal Actions

The preparation of this SEIS/SOEIS has been conducted in accordance with EO 12114 and Navy implementing regulations in 32 CFR Part 187. An OEIS is required when a proposed action and alternatives have the potential to significantly harm the environment of the global commons. The global commons are defined as geographical areas outside the jurisdiction of any nation and include the oceans outside of the territorial limits (more than 12 nmi from emergent land) and Antarctica, not including the contiguous zones and fisheries zones of foreign nations (exclusive economic zones) (32 CFR § 187.3). Environment is defined in EO 12114 as the natural and physical environment and excludes social, economic, and other environments. As permitted under NEPA and EO 12114, the SEIS and SOEIS for SURTASS LFA sonar have been combined into one document to reduce duplication.

3.1.4 Executive Order 13547, Stewardship of the Ocean, Our Coasts, and the Great Lakes

EO 13547 (75 FR 43023) was issued in 2010. It is a comprehensive national policy for the stewardship of the ocean, our coasts, and the Great Lakes. This order adopts the recommendations of the Interagency Ocean Policy Task Force and directs executive agencies to implement the recommendations under the guidance of a National Ocean Council. This order establishes a national policy to ensure the protection, maintenance, and restoration of the health of ocean, coastal, and Great Lakes ecosystems and resources; enhance the sustainability of ocean and coastal economies, preserve our maritime heritage, support sustainable uses and access; provide for adaptive management to enhance our understanding of and capacity to respond to climate change and ocean acidification; and coordinate with our national security and foreign policy interests.

3.1.5 Endangered Species Act

The ESA of 1973 (16 U.S.C. § 1531 et seq.) establishes protection over and conservation of threatened and endangered species and the ecosystems upon which they depend. An "endangered" species is a species in danger of extinction throughout all or a significant portion of its range, while a "threatened" species is one that is likely to become endangered within the near future throughout all or in a significant portion of its range. The ESA allows the designation of geographic areas as critical habitat for threatened or endangered species. The U.S. Fish and Wildlife Service (USFWS) and NMFS jointly

1 In 1996 the Clean Water Act was amended to create section 312(n), "Uniform National Discharge Standards for Vessels of the Armed Forces." Section 312(n) directs U.S. EPA and DoD to establish national discharge standards for discharges incidental to the normal operation of a vessel of the armed forces. These national standards will preempt State discharge standards for these vessels.

administer the ESA and are also responsible for designating or listing of species as either threatened or endangered and designating critical habitat. NMFS manages the ESA-listed marine species and critical habitats that may occur in the waters in which SURTASS LFA sonar may be operated.

Section 7(a)(2) requires each Federal agency to ensure that any action it authorizes, funds, or carries out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species. When a Federal agency's action “may affect” a listed species, the agency is required to consult with NMFS or USFWS, depending on which Service has jurisdiction over the species (50 CFR § 402.14(a)).

3.1.6 Marine Mammal Protection Act

The MMPA of 1972 (16 U.S.C. § 1361 et seq.) establishes, with limited exceptions, a moratorium on the “taking” of marine mammals in waters or on lands under U.S. jurisdiction. The act further regulates “takes” of marine mammals in the global commons (e.g., the high seas or international waters) by vessels or persons under U.S. jurisdiction. As defined in Section 3 (16 U.S.C. § 1362(13)) of the MMPA, “take” means “to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal.” “Harassment” is further defined in the 1994 amendments to the MMPA as two levels of harassment: Level A (potential injury) and Level B (potential behavioral disturbance).

The MMPA allows, upon request, the incidental but not intentional taking of small numbers of marine mammals by U.S. citizens or agencies that engage in an activity other than commercial fishing within a specified geographical region if NMFS finds that the taking will have a negligible impact on the species or stock(s) and will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses (where relevant). The authorization must set forth the permissible methods of taking, and other means of affecting the least practicable adverse impact on the species or stock and its habitat (i.e., mitigation), and requirements pertaining to the monitoring and reporting of marine mammal takes. In the context of military readiness activities, a determination of least practicable adverse impact must include consideration of personnel safety, practicability of implementation, and impact on the effectiveness of the military readiness activity. When a Federal agency intends to conduct an action that may result in the incidental taking of marine mammals, the agency may request authorization from NMFS for those takes, either as a Letter of Authorization, which requires rulemaking and is effective for up to five years or an Incidental Take Authorization, which requires no rulemaking and is good for up to one year.

The National Defense Authorization Act (NDAA) of Fiscal Year 2004 (Public Law 108-136) amended the MMPA definition of harassment, removed the “specified geographic area” requirement, and removed the small numbers provision as applied to military readiness activities or scientific research activities conducted by or on behalf of the Federal government consistent with Section 104(c)(3) (16 U.S.C. § 1374(c)(3)). The Fiscal Year 2004 NDAA adopted the definition of “military readiness activity” as set forth in the Fiscal Year 2003 NDAA (Public Law 107-314). A “military readiness activity” is defined as “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.” For military readiness activities, harassment is further defined as any act that:

- injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild (“Level A harassment”) or

- disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behavioral patterns are abandoned or significantly altered ("Level B harassment") (16 U.S.C. § 1362(18)(B)(i) and (ii)).

3.1.7 Magnuson-Stevens Fishery Conservation and Management Act and Sustainable Fisheries Act

The Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. § 1801 et seq.) enacted in 1976 and amended by the Sustainable Fisheries Act in 1996, mandates identification and conservation of essential fish habitat (EFH). EFH is defined as the waters, including the water column, and benthic substrates necessary (required to support a sustainable fishery and the federally managed species) to fish for spawning, breeding, feeding, or growth to maturity (i.e., full life cycle). EFH waters include aquatic areas and their associated physical, chemical, and biological properties used by fish, and may include areas historically used by fish. Substrate types include sediment, hard bottom, structures underlying the waters, and associated biological communities. Fishery Management Councils identify EFH for specific geographic regions of the U.S. Federal agencies are required to consult with NMFS and to prepare an EFH assessment if potential adverse effects on EFH are anticipated from their activities.

3.1.8 Marine Protection, Research, and Sanctuaries Act

The Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972 (33 U.S.C. §§ 1401-1445) regulates dumping of toxic materials beyond U.S. territorial waters and provides guidelines for designation and regulation of marine sanctuaries. Titles I and II prohibit persons or vessels subject to U.S. jurisdiction from transporting any material out of the United States for the purpose of dumping it into ocean waters without a permit. The term "dumping" does not include intentional placement of devices in ocean waters or on the sea bottom when the placement occurs pursuant to an authorized federal or state program.

3.1.9 National Marine Sanctuaries Act

During the reauthorization of the MPRSA in 1992, Title III of the MPRSA was designated the National Marine Sanctuaries Act (NMSA) (16 U.S.C. §§ 1431-1445[c]). The NMSA provides for the designation and management of marine areas as national marine sanctuaries that have special national significance. A marine area may be designated as a national marine sanctuary (NMS) on the basis of its conservation, recreational, ecological, historical, cultural, archaeological, scientific, educational, or aesthetic qualities. Thirteen NMS have been designated in U.S. waters.

Each of the 13 NMSs has adopted a Management Plan and implementing regulations, which are found at 15 CFR 922. These regulations identify specific activities that are prohibited within a NMS. However, for most of the NMSs, the prohibitions include exemptions for certain military activities.

Section 304(d) of the NMSA requires Federal agencies to consult with the Office of National Marine Sanctuaries (ONMS) before taking actions "likely to destroy, cause the loss of, or injure a sanctuary resource." There is an exception for the Gerry E. Studds Stellwagen Bank NMS, wherein Federal agencies are required to consult on proposed actions that "may affect" the resources of a NMS.

3.1.10 Executive Order 13158—Marine Protected Areas

The purpose of EO 13158 on Marine Protected Areas (MPAs) (2000) is the protection of the significant natural and cultural resources within the marine environment by strengthening and expanding the

Nation's system of MPAs and creating the framework for a national system of MPAs. The national MPA system is to be a "scientifically based, comprehensive national system of marine protected areas (MPAs) representing diverse U.S. marine ecosystems." The EO further specifies that the national system should "preserve representative habitats in different geographic regions of the marine environment."

MPAs are defined in 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." EO 13158 strengthens governmental interagency cooperation in protecting the marine environment and calls for strengthening management of existing MPAs, creating new ones, and preventing harm to marine ecosystems by federally approved, conducted, or funded activities (Agardy, 2000). The National MPA Center was established in 2000 to lead the development of the national MPA system.

3.1.11 Executive Order 12962—Recreational Fisheries

EO 12962 on Recreational Fisheries (60 C.F.R. 30769) was issued in 1995 to ensure that Federal agencies strive to improve the "quantity, function, sustainable productivity, and distribution of U.S. aquatic resources" so that recreational fishing opportunities increase nationwide. The overarching goal of this order is to promote conservation, restoration, and enhancement of aquatic systems and fish populations by increasing fishing access, education and outreach, and multi-agency partnerships. The National Recreational Fisheries Coordination Council (NRFCC), co-chaired by the Secretaries of the Interior and Commerce, is charged with overseeing Federal actions and programs that this order mandates. The specific duties of the NRFCC include: (1) ensuring that the social and economic values of healthy aquatic systems, which support recreational fisheries, are fully considered by federal agencies; (2) reducing duplicative and cost-inefficient efforts among federal agencies; and (3) disseminating the latest information and technologies to assist in conservation and management of recreational fisheries. In June 1996, the NRFCC developed a comprehensive Recreational Fishery Resources Conservation Plan (RFRCP) specifying what member agencies would do to achieve the order's goals. In addition to defining Federal agency actions, the plan also ensures agency accountability and provides a comprehensive mechanism to evaluate achievements. A major outcome of the RFRCP has been increased utilization of artificial reefs to better manage recreational fishing stocks in U.S. waters.

3.1.12 Department of Defense and Navy Directives and Instructions

In addition to the U.S. federal legislation that governs Navy activities in the marine environment, the Navy is required to comply with environmental readiness guidelines and requirements promulgated by the Navy's Energy and Environmental Readiness Division.

3.2 Marine Water Resources

The only potential impact on the physical environment of the oceans associated with the operation of SURTASS LFA sonar is the addition of underwater noise during operation of both LFA sonar and the associated mitigation monitoring system, HF/M3 sonar. With the exception of the addition of sound to the oceanic environment, the operation of these sonar systems will not affect other marine water resources, including seafloor sediments or oceanic water quality. Accordingly, a general discussion of the ocean's ambient noise environment is included in this section while sediments and water quality are not included.

3.2.1 Ambient Noise

Marine animals use underwater sound to sense and obtain information about the ocean environment. Using both active (echolocation and vocalizations) and passive (listening) acoustics, marine animals employ sound for such functions as communication, navigation, obstacle and predator avoidance, and prey detection (Au and Hastings, 2008). The ability to use sound as an effective sensing medium in the ocean is dependent on the level of ambient or background noise in the ocean environment, since that noise could potentially interfere with an animal's ability to hear or produce sound.

Ambient noise is the typical or persistent background noise that is part of an environment. Ambient noise is produced by both natural and anthropogenic (man-made) sources, is typically characterized by a broad range of frequencies, and is directional both horizontally and vertically, so that the received sound levels are not equal from all directions. Noise generated by surface ocean waves and biologically-produced sounds are the two primary contributors of natural ambient sound over the frequency range of 300 Hz to 5 kHz. The sound produced by propulsion systems of ocean-going ships, with frequencies centered in the frequency range of 20 to 200 Hz, is the dominate source of anthropogenic sound in the ocean (Tyack, 2008).

A comprehensive overview of oceanic ambient noise can be found in Urick (1983), Richardson et al. (1995), and Au and Hastings (2008). Previous documentation for SURTASS LFA sonar presented information on the natural and anthropogenic components of ambient ocean noise: FOEIS/EIS subchapter 3.1.1 (DoN, 2001) and 2012 SEIS/SOEIS subchapter 3.1.1 (DoN, 2012). Since the information presented therein remains valid and pertinent, it is incorporated by reference in this SEIS/SOEIS. Recent research and information, particularly on LF oceanic noise, follows.

3.2.1.1 Ambient Oceanic Noise Trends

In the Indian Ocean, LF (5 to 115 Hz) sounds have increased 2 to 3 dB over the past decade, while acoustic measurements in the Northeast Pacific Ocean indicate that LF (10 to 100 Hz), deep water ambient sound levels have been rising for the last 60 years (Miksis-Olds and Nichols, 2016). Ambient noise data from the 1950s and 1960s show that noise levels increased at a rate of approximately 3 dB per decade or 0.55 dB per year. Beginning in the 1980s, the rate of increase in ambient noise levels slowed to 0.2 dB per year (Chapman and Price, 2011). Andrew et al. (2002) reported an increase of about 10 dB in the range of the 20 to 80 Hz band during a six-year observation period (1995 to 2001), which was less than expected based on a rate of 0.55 dB increase per year (Andrew et al., 2011).

3.2.1.2 Ambient Shipping Noise

The overall increasing ambient noise trends in both the Pacific and Indian Oceans have primarily been attributed to increasing shipping noises (Miksis-Olds and Nichols, 2016). Recent measurements in the Northeast Pacific region show a leveling or slight decrease in sound levels, even though shipping activity continued to rise, which confirms the prediction by Ross (1976) that the rate of increase in ambient ocean noise levels would be less at the end of the twentieth century compared to that observed in the 1950s and 1960s (Andrew et al., 2011). Better design of propulsion systems and economic conditions affecting the price of oil were some factors that may contribute to this reduced rate of increase in oceanic noise levels (Chapman and Price, 2011).

3.2.1.3 Other Ambient Noise Sources

Shipping alone does not fully account for the increases in noise levels in the 30 to 50 Hz LF band that was observed from 1965 to 2003. Other sources of anthropogenic ambient noise in the ocean including noise from oil and gas exploration, seismic airgun activity, and renewable energy sources (e.g., wind farms) are contributors to the overall ocean soundscape. These sources contribute to sound in the lower LF frequency band and have been increasing over time (Miksis-Olds et al., 2013). Many of these anthropogenic sources are located along well-traveled shipping routes and encompass coastal and continental shelf waters, areas that are important marine habitats (Hildebrand, 2009).

Sound produced by renewable-energy production developments, particularly that of offshore wind energy, differ from other types of anthropogenic sound sources in that the underwater noise levels generated from the operation of the wind farms is more persistent and of long duration. Anthropogenic noise generated by seismic exploration is transient in nature, but the expected lifetime of an offshore wind farm is twenty to thirty years. The associated noises from the operation of the wind farm would result in an almost constant and permanent source of noise in the vicinity of a wind farm (Tougaard et al., 2009).

As ocean ambient noise levels increase overall, remarkably, many marine animals such as marine mammals that produce sound to communicate underwater may also inadvertently, and probably to a small degree, contribute to rising oceanic ambient noise. Marine mammals, for example, that utilize the LF bands for communication have been observed to employ noise compensation mechanisms such as increasing the amplitude of their vocalizations to overcome increasing noise levels at specific frequencies; these compensation mechanisms for an increasingly noisy ocean environment in turn contribute to a slight increase in the naturally-derived component of rising ocean sound levels (Miksis-Olds et al., 2013).

3.2.1.4 Climate Change and Ocean Acidification

The effects that climate change will have on our ocean continue to be understood in relation to observed ocean ambient noise trends. It's important to consider components of the ocean soundscape such as noise from changing ice dynamics and other yet-to-be-identified changes in natural sound source producing mechanisms in relation to ocean sound levels. Global climate change is projected to impact the frequency, intensity, timing, and distribution of hurricanes and tropical storms, which will also affect the ocean soundscapes on many levels (Miksis-Olds and Nichols, 2016).

Ocean acidification and its potential impact on ocean noise via changes in the acoustic absorption coefficient at low frequencies has become a subject of worldwide concern. Ocean acidification, due to the decrease of pH in the ocean from an increase in dissolved CO_2, will affect sound absorption, which has a strong dependency on pH at frequencies less than 2 kHz (Joseph and Chiu, 2010). This decrease in sound absorption may impact ocean ambient noise levels within the auditory range critical for environmental, military, and economic interests (Hester et al., 2008).

In parts of the North Atlantic Ocean, for example, a conservative estimate is that LF sound absorption has decreased over 15 percent at 440 Hz from the pre-Industrial Revolution until the 1990s, with a greater than 10 percent decrease common above 1,312 ft (400 m) in the Pacific and Atlantic oceans (Hester et al., 2008). While these decreases in LF absorptivity represent truly immeasurably small changes, to try and resolve the uncertainty regarding the amount noise levels could increase due to these changes in sound absorption, some researchers have tried to calculate and quantify changes in ambient noise levels. Joseph and Chiu (2010) reported an expected increase of 0.2 dB for a scenario that has a surface pH change of 0.7 over the years from 1960 to 2250 in the frequency range of 50 to 2,000 Hz. Reeder and Chiu (2010) predicted changes of less than 0.5 dB for all frequencies in the deep ocean, with no statistically significant change in shallow water or surface duct environments when there was a decrease in pH from 8.1 to 7.4. Last, Ilyina et al. (2010) estimated that ocean pH could fall by 0.6 by 2100 and sound absorption in the 100 Hz to 100 kHz band could decrease by 60 percent in high latitudes and deep-ocean waters over the same period. These authors further predicted that over the 21st Century sound absorption in the 100 Hz to 100 kHz frequency band will decrease by almost half in regions of the world's oceans with significant anthropogenic noise, such as the North Atlantic Ocean. However, because sound absorption is a very small factor in acoustic propagation at low frequencies, the impact of these changes in absorption are likely to be so vanishingly small as to be insignificant (i.e., less than 1 dB).

3.3 Biological Resources

Biological resources include living, native, or naturalized plant and animal species and the habitats within which they occur. Habitat can be defined as the resources and conditions present in a specific area that support plants and animals. In the marine environment, only marine animals or wildlife and marine habitats may potentially be affected by the proposed action. Within this SEIS/SOEIS section, those marine animals as well as their habitats potentially affected by SURTASS LFA sonar operations are discussed in detail.

3.3.1 Marine Species Selection Criteria

Since SURTASS LFA sonar systems operate in ocean environments, the potential exists for it to interact with marine species and their environments. Marine species have been screened to determine whether or not they may potentially be affected by LF sounds produced by SURTASS LFA sonar. Accordingly, to be evaluated for potential impacts in this SEIS/SOEIS, the marine species must: 1) occur within the same ocean region and during the same time of year as the SURTASS LFA sonar operation, and 2) possess some sensory mechanism that allows it to perceive LF sound, and/or 3) possess tissue with sufficient acoustic impedance mismatch to be affected by LF sounds. Species that did not meet these criteria were excluded from further consideration.

Marine species must be able to hear LF sound and/or have some organ or tissue capable of changing sound energy into mechanical effects to be affected by LF sound. For there to be an effect by LF sound, the organ or tissue must have acoustic impedance different than water, where impedance is the product of density and sound speed. Since many organisms do not have an organ or tissue with acoustic impedance different than water, they would be unaffected, even if they were in areas ensonified by LF sound. These factors immediately limit the types of organisms that could be adversely affected by LF sound.

A marine species' potential to be affected by SURTASS LFA sonar has been discussed in detail in previous NEPA documentation (DoN, 2007, 2012). Except as noted below, there have been no significant changes to the knowledge or understanding relating to the factors that may affect an organism's ability to sense LF sound, and the previous contents are incorporated herein by reference. The screening information is summarized and updated, as necessary, in the remainder of this section.

3.3.1.1 Marine Invertebrates

Many invertebrates can be categorically eliminated from further consideration because: 1) they do not possess the requisite organs or tissues whose acoustic impedance is significantly different from water; and 2) they have high LF hearing thresholds in the frequency range used by SURTASS LFA sonar. For example, siphonophores and some other gelatinous zooplankton have air-filled bladders, but because of their size, they do not have a resonance frequency close to the low frequencies used by SURTASS LFA sonar.

Coral appear to lack the requisite auditory sensing organs/tissues to perceive sound at all. The only auditory sensing capabilities known for coral is the response of free-swimming coral larvae to the underwater sounds produced by reef fish and crustaceans that Vermeij et al. (2010) reported. Some species of coral larvae apparently detect reef sounds and then show an attraction response to the sounds generated on coral reefs, possibly using the detection of the reef sounds as a means of identifying favorable sites for settlement and development to adult life stages (Vermeij et al., 2010). Despite this promising insight, the lack of information on the ability of larval coral or other lifestages to sense sound, and thus, potentially be affected by it, leads to the conclusion that sound generated by SURTASS LFA sonar will not affect coral species.

Among invertebrates, only cephalopods (octopus and squid) and decapods (lobsters, shrimps, and crabs) are known to be capable of sensing LF sound (Budelmann, 1994; Lovell et al., 2005; Mooney et al., 2010; Packard et al., 1990). Budelmann and Williamson (1994) demonstrated that the hair cells in cephalopod statocysts[2] are directionally sensitive in a way that is similar to the responses of hair cells on vertebrate vestibular and lateral line systems. Packard et al. (1990) showed that three species of cephalopods were sensitive to particle motion, not pressure, with the lowest thresholds of 2 to 3 x 10^{-3} m/sec^2 at 1 to 2 Hz. This type of hearing mechanism was confirmed by Mooney et al. (2010) who demonstrated that the statocyst of squid enables the animal to detect particle motion of a sound field, for which they measured a pressure threshold of 110 dB re 1 µPa at 200 Hz.

Lovell et al. (2005) found a similar sensitivity for prawn, 106 dB re 1 µPa at 100 Hz, noting that this was the lowest frequency they tested and that animals might be more sensitive at even lower frequencies. Thresholds at higher frequencies have been reported, i.e., 134.4 dB re 1 µPa and 139.0 dB re 1 µPa at 1,000 Hz for the oval squid (*Sepioteuthis lessoniana*) and the octopus (*Octopus vulgaris*), respectively (Hu et al., 2009). However, Mooney et al. (2010) suggested that the measurement techniques of Hu et al. (2009) placed the animals close to the air-sea interface and introduced particle motion to which animals were responding rather than the pressure measurements reported. Popper et al. (2003) also reviewed behavioral, physiological, anatomical, and ecological aspects of sound and vibration detection by decapod crustaceans. Many decapods also have an array of hair-like receptors within and upon the body surface that potentially respond to water- or substrate-borne displacements as well as proprioceptive organs that could serve secondarily to perceive vibrations. However, the acoustic sensory system of decapod crustaceans remains under-studied (Popper, et al., 2003).

Popper and Schilt (2008) stated that, like fish, some invertebrate species produce sound, possibly using it for communications, territorial behavior, predator deterrence, and mating. Well known biological sound producers include lobster (*Panulirus* sp.) (Latha et al., 2005) and the snapping shrimp (*Alpheus*

2 A statocyst is a sac-like sensory organ found in many invertebrate animals that is filled with fluid and lined with sensory hairs (hair cells).

heterochaelis) (Herberholz and Schmitz, 2001). Snapping shrimp are found worldwide and make up a significant portion of the ambient noise budget between 500 Hz and to 20 kHz.

3.3.1.2 Marine and Anadromous Fish

Fish are able to detect sound, although there is remarkable variation in hearing capabilities in different species. While it is not easy to generalize about hearing capabilities due to this diversity, most all fish known to detect sound can at least hear frequencies from below 50 to 800 Hz, while a large subset of fish can detect sounds to approximately 1,000 Hz and another subset can detect sounds to about 2,000 Hz. Thus, many species of fish can potentially hear SURTASS LFA sonar transmissions. Of the estimated 33,200 living species of fish (Froese and Pauly, 2016), of which roughly half are marine species, audition or sound production has only been studied on a small percentage (Popper et al., 2003).

Of the 100 or more fish species on which hearing studies have been conducted, all are able to detect sound. While only a relatively small number of species have been studied, it is apparent that many bony fish (but apparently no sharks and rays) are able to produce vocalizations and use these sounds in various behaviors. Hearing and sound production is documented in well over 240 fish species comprising at least 58 families and 19 orders, although it is likely that with additional study it will be found that many more species produce sounds.

The ability of fish to hear SURTASS LFA sonar is considered by the taxonomic class for this analysis, although it must be recognized that even within a taxonomic order or family, different species may have different hearing capabilities or uses of sound. Two taxonomic classes of fish are considered in this SEIS/SOEIS: Chondrichthyes (cartilaginous fish including sharks and rays) and Osteichthyes (bony fish). With the exception of the species listed below, these are the fish groups that will be evaluated further in this SEIS/SOEIS for potential impacts associated with SURTASS LFA sonar transmissions.

Several species in the two fish taxa to be considered herein are listed under the ESA. However, a number of the ESA-listed fish species do not meet the criteria for co-occurrence with SURTASS LFA sonar operations. The ESA-listed marine and anadromous fish species excluded from further consideration on this basis are:

- Banggai Cardinalfish *(Pterapogon kauderni)*—threatened species generally found in shallow (1.6 to 2 ft [0.5 to 6 m]), sheltered bay or nearshore insular waters of Banggai Archipelago, Indonesia (Allen and Donaldson, 2007) in seagrass beds, coral reefs, or less commonly in open areas of low branching coral and rubble.
- Dwarf Sawfish *(Pristis clavata)*—endangered species restricted to shallow (< 33 ft [10 m]) tropical coastal, estuarine, and riverine waters of the western-central Pacific and Eastern Indian oceans; no records from offshore waters have been substantiated.
- Largetooth Sawfish (*Pristis perotteti*)—endangered species typically occurring in shallow, estuarine and lagoonal waters of the Gulf of Mexico that are considered euryhaline (i.e., <31 practical salinity units [psu]).

- Smalltooth Sawfish *(Pristis pectinata)*—endangered, non-U.S. distinct population segment (DPS)[3], with records only from shallow (< 32 ft [10 m]), coastal and estuarine brackish waters of the Bahamas and Sierra Leone, West Africa.
- European Sturgeon *(Acipenser sturio)*—endangered species that has a restricted distribution in French and Georgian rivers (Rioni basin).
- Adriatic Sturgeon (*Acipenser naccarii*)—endangered species that occurs in estuaries and freshwater rivers and never enters purely marine waters in the ocean outside of an estuary.
- Kaluga Sturgeon *(Huso dauricus)* endangered species that is only found in the lower reaches of the Amur River of Russia and China.
- Shortnose Sturgeon (*Acipenser brevirostrum*)—endangered species that inhabit nearshore marine, estuarine, and riverine habitat of large coastal river systems of U.S. northwestern Atlantic Ocean; does not make long distance offshore migrations.

3.3.1.3 Seabirds

The more than 270 species of seabirds that exist globally are classified in five taxonomic orders, with each order containing marine bird species that dive to water depths exceeding 82 ft (25 m). Few data on seabird hearing, especially underwater hearing, have been measured. Considerable research, however, has been conducted on seabird foraging ecology, particularly on foraging habitat, behavior, and strategy. Foraging habitat features include oceanographic and environmental features such as water masses, fronts, hydrographic gradients, topographical features, and sea ice.

Ballance et al. (2001) noted that seabirds spend 90 percent of their life at sea foraging over hundreds to thousands of miles (kilometers) and that prey on a global scale is patchier in oceanic waters than shelf and slope waters. Seabird foraging behavior mostly involves taking prey within a half meter of the sea surface (Ballance et al., 2001). However, some species take prey at water depths of 66 ft (20 m) or deeper, feed on dead prey at the surface, or take prey from other birds. Foraging behaviors involve such aspects as locating physical oceanic features, relying on subsurface predators (marine mammals and large fish) to drive prey to the surface, feeding in flocks, feeding at night, and maximizing surface area surveillance (Ballance et al., 2001). None of these foraging behaviors appear to require the use of underwater sound. Seabirds use a variety of foraging behaviors that could expose them to underwater sound. Most seabirds plunge-dive from the air into the water or perform aerial dipping (the act of taking food from the water surface in flight); others surface-dip (swimming and then dipping to pick up items below the surface) or jump-plunge (swimming, then jumping upward and diving under water); none of these foraging strategies would result in substantial exposure to SURTASS LFA sonar. Seabirds such as gannets, boobies, tropicbirds, and brown pelicans, plunge-dive to capture prey and are typically submerged for no more than a few seconds, so that any exposure to underwater sound would be very brief. Other birds that are pursuit divers, including penguins, auks, petrels, cormorants, grebes, and loons, dive beneath the surface of the ocean and pursue their prey, swimming deeper and staying underwater longer than plunge-divers. Some of these birds may stay underwater for up to several minutes and reach depths between 50 ft (15.2 m) and 550 ft (167.6 m) (Ronconi et al., 2010).

3 A DPS is a vertebrate population (or group of populations) of the same species that is discrete from other populations of the species but that is significant to the entire species. An ESU is a Pacific salmon population or group of populations that is substantially reproductively isolated from other conspecific populations and that represents an important component of the evolutionary legacy of the species.

The potential for seabirds to be exposed to SURTASS LFA sonar depends on several factors, including the spatial distribution of foraging habitat in relation to LFA sonar operations, species-specific foraging strategies, and the ability to hear SURTASS LFA sonar transmissions. Very little is known about seabird's hearing abilities in air, much less, under water. Audiograms for approximately fifty species of birds have been constructed, but only two of those species are aquatic. To fill in this data gap, the in-air hearing ability of ten diving seabird species was measured with auditory brainstem response (ABR) technologies, revealing that all species had greatest sensitivity between 1 and 3 kHz (Crowell et al., 2015). This research is continuing with underwater sensitivity measurements to create behavioral audiograms of in-air and underwater hearing (Crowell, 2016). Until more data are available on underwater hearing sensitivities of seabirds, it is not possible to determine the potential for effects from SURTASS LFA sonar exposure.

Not only are data on underwater hearing sensitivities limited on seabirds, but the mechanism(s) by which seabirds might sense underwater sound is not known. Seabirds possess fat columns that connect with the tympanic membrane, suggesting soft tissue analogs to pinnae for channeling sound to the inner ear (Ketten, 2013). To determine the potential for non-auditory impacts from exposure to LFA sonar, more information is needed on the structure and anatomy of hearing in seabirds. However, given the underwater behavior of diving seabirds, they are very unlikely to be in sufficient proximity to sense LFA sonar given its operational parameters. Lacking data on the hearing sensitivities of seabirds, the potential for auditory impacts, such as permanent threshold shift (PTS) and temporary threshold shift (TTS[4]), is difficult to estimate. However, given that in-air hearing has best sensitivities at 1 to 3 kHz (Crowell et al., 2015), which is considerably above the frequency range of SURTASS LFA sonar at 100 to 500 Hz, very little potential exists for diving seabirds to experience auditory impacts from exposure to LFA sonar transmissions.

No studies of the potential for behavioral responses in seabirds due to sound exposure from sonar have been conducted. It is highly unlikely that a seabird would experience a behavioral response given several factors. There are only up to four SURTASS LFA sonar vessels, and even if a diving seabird were to encounter a vessel at sea, the physical presence of the vessel and its slow speed would alert the bird to the unique situation. If a bird were to dive near the vessel, the LFA sonar would have to be transmitting, which it only does up to a maximum of 20 percent of the time (but more typically, 7.5 to 10 percent) and the bird would need to dive deep enough to encounter the LFA sound field (see Chapter 2 for more details of the operational profile of LFA sonar). Given these factors, the potential for a behavioral response is vanishingly small. There are no data that indicate whether seabirds use sound underwater and thus have the potential to experience masking. While studies of stress responses in seabirds related to foraging have been conducted (Paredes et al., 2015), no exposure studies have been conducted to determine the potential for a stress response from exposure to underwater sound. Without sufficient information, it is impossible to determine the potential for masking or physiological stress from exposure of seabirds to LFA sonar. However, as stated earlier, given the foraging strategies of seabirds and the operational profile of LFA sonar, seabirds are very unlikely to be in proximity to LFA sonar while it is transmitting, resulting in a very limited potential for masking or a stress response to occur.

4 Permanent threshold shift (PTS) is a severe condition and auditory injury that occurs when sound intensity is very high or of such long duration that the result is permanent hearing loss and irreparable damage (Southall et al., 2007). Temporary threshold shift (TTS) is a lesser impact to hearing caused by underwater sounds of sufficient loudness to cause a transient hearing impairment for a period of time. With TTS, hearing is not permanently or irrevocably damaged, so TTS is not considered an injury.

Although seabirds clearly possess the auditory organs to be capable of hearing LFA sonar transmissions, their known in-air hearing sensitivity in the 1 to 3 kHz range is above the transmission frequencies of SURTASS LFA sonar. Given the paucity of data on underwater hearing sensitivities in seabirds, the use of underwater sound by seabirds, and the responses of seabirds to sound exposures, it is impossible to determine if SURTASS LFA sonar transmissions have the potential to affect seabirds. The in-air hearing sensitivities of seabirds combined with the low likelihood of seabirds being underwater and near the SURTASS LFA sonar source while it is transmitting together are indicative of highly unlikely potential for biologically meaningful responses by seabirds to occur from exposure to LFA sonar of for the potential for fitness level consequences. Therefore, seabirds have been excluded from further evaluation in this SEIS/SOEIS.

3.3.1.4 Sea Snakes

Sea snakes are wholly aquatic reptiles that primarily inhabit coastal areas in tropical oceans, notably the Indian Ocean and western Pacific Ocean (Young, 2003). Sea snakes lack gills and must surface to breathe, typically diving to water depths no deeper than 328 ft (100 m) (Heatwole, 1999) and staying submerged for about 30 minutes, although some species can stay submerged for up to 1.5 to 2.5 hours (Heatwole and Seymour, 1975).

The one sea snake species listed under the ESA, the dusky sea snake (*Aipysurus fuscus)*, is an endangered species that occurs in water depths less than 33 ft (10 m) amongst the corals and sand substrate of isolated, inner coral reef lagoons off northwestern Australia in the Ashmore Reef area (Timor Sea) and off Papua New Guinea in the Celebes Islands (Celebes Sea) (McCosker, 1975; Australian Government, 2016). Little is known about the population status of the venomous, benthic dusky sea snake, as no current or historical population data exist, but local surveys of some Australian reefs indicate severe population declines. Sea snakes typically have patchy distributions and can be found in very dense aggregations in certain locations within their ranges (Heatwole, 1997).

Although sea snakes possess no external ear and lack many of the interior auditory components that facilitate hearing, sea snakes do possess sensory organs or tissues that allow them to perceive underwater sounds. Snakes possess an inner ear with a functional cochlea that is connected to their jawbones, through which they likely perceive vibrational information (Friedl et al., 2008). Researchers have speculated that sea snake's inner ear may receive sound signals in water via their lungs, which may function similarly to swim bladders in fish. Experimental work with terrestrial royal pythons suggests that all snakes have lost pressure sensitivity and respond only to particle motion (Christensen et al., 2012).

Research on hearing ability in snakes is limited, especially in sea snakes, with current scholarship suggesting that while snakes may perceive LF noises, their hearing threshold is very high at approximately 100 dB in water (this number is extrapolated based on data from terrestrial snakes and corrected for water) (Young, 2003). Westhoff et al. (2005) demonstrated that a sea snake could respond with electro-potentials to vibrating motions and pressure fluctuations in water, although the sensitivity was low (low-amplitude water displacement from 100 to 150 Hertz [Hz]), but may be sufficient to detect movements of fish. Although sea snakes may be able to detect at least some component of LFA sonar transmissions, there is no information available on how underwater anthropogenic sound affects sea snakes.

Based on the dearth of information on hearing ability and the effects of underwater sound on sea snakes, the Navy has concluded that sea snakes would not be subject to behavioral reactions because of their poor sensitivity to LF sound and that the risk of injury is negligible if exposed to SURTASS LFA sonar transmissions. Since sea snakes are predominately shallow diving, near shore inhabitants, it is unlikely that sea snakes would be exposed to LFA sonar signals at all, much less at levels high enough to affect them adversely. For these reasons, sea snakes are eliminated from further consideration herein.

3.3.1.5 Sea Turtles

There are seven species of marine turtles, six of which are listed as either threatened and/or endangered under the ESA. The flatback turtle (*Natator depressus*) is not listed under the ESA as its distribution is restricted largely to the tropical, continental shelf waters of Australia; Papua New Guinea; and Papua, Indonesia (Limpus, 2007). Since it is likely that all species of sea turtles hear LF sound, at least as adults (O'Hara and Wilcox, 1990; Ridgway et al., 1969), all species of sea turtles are considered for evaluation in this SEIS/SOEIS.

3.3.1.6 Marine Mammals

Marine mammals are highly adapted marine animals, found in a variety of aquatic habitats, ranging from freshwater rivers and estuaries to the deep ocean. Globally, a wide diversity of marine mammal species exists in the waters in which SURTASS LFA sonar may operate. However, marine mammals also occur in areas in which SURTASS LFA sonar will not be operated, including polar regions, rivers, lakes, and extremely shallow, nearshore waters. Since one of the basic criteria for a species to be evaluated for potential impacts from exposure to SURTASS LFA sonar is that the species must occur in waters in which LFA sonar may operate[5], many of these marine mammal species can immediately be excluded from further consideration. The marine mammal species excluded from further consideration are:

- Narwhal (*Monodon monoceros*)—Occurrence principally only in high Arctic (polar) waters, where SURTASS LFA sonar will not be operated.
- Antarctic Seals—Antarctic fur seal (*Arctocephalus gazella),* crabeater seal (*Lobodon carcinophaga*), Ross seal (*Ommatophoca rossii*), leopard seal (*Hydrurga leptonyx*), and Weddell seal (*Leptonychotes weddellii*), which occur in Antarctic (polar) waters
- Walrus—Occurrence discontinuously only in Arctic and subarctic waters of the Northern Hemisphere. The Pacific walrus subspecies is generally found in the Bering Sea, Chukchi Sea, East Siberian Sea, and western Beaufort Sea, and Laptev Sea, while the Atlantic walrus subspecies occurs in the eastern Canadian Arctic, Hudson Bay, Greenland, Svalbard, the Barents Sea, and Kara Sea (Jefferson et al., 2015; Kastelein et al., 2009).
- Inland Phocid Seals—Essentially land-locked species, the Baikal seal (*Pusa sibirica*), Caspian seal (*Pusa caspica*), Lake Ladoga seal (*Phoca vitulina ladogensis),* and Ladoga seal *(Phoca vitulina mellonae)* which occur in freshwater and brackish lakes, inland seas, or freshwater rivers.
- Ursids and Mustelids—The polar bear (*Ursus maritimus*) occurs only in Arctic regions. The sea otter (*Enhydra lutris*) and the marine otter (chungungo) (*Lontra felina*) occur almost exclusively in shallow, nearshore waters, where SURTASS LFA sonar vessels are unlikely to operate.
- Coastal Porpoises—Porpoise species, including the Burmeister's porpoise *(Phocoena spinipinnis*), vaquita (*P. sinus)*, and finless porpoise (*Neophocaena phocaenoides)* are excluded due to their

5 Generally, SURTASS LFA sonar operations are conducted in waters deeper than 200 m (656 ft). However, with the new CLFA source array and TL-29A receive array, operations could be conducted in shallower water, depending upon the operational circumstances.

distribution in nearshore, shallow coastal waters where SURTASS LFA sonar is highly unlikely to be operated.

- River Dolphins—Dolphin species, such as the Chinese river dolphin (*Lipotes vexillifer)*, Franciscana (*Pontoporia blainvillei*), boto/Amazon River dolphin (*Inia geoffrensis*), South Asia river dolphins (Ganges River dolphin [*Platanista gangetica gangetica]* and Indus River dolphin [*Platanista gangetica minor*]), and the baiji (*Lipotes vexillifer)* (which may possibly be extinct) whose distribution is restricted to riverine waters of Asia and South America. Although occasionally river dolphins may enter coastal waters, they occur well inshore of the areas where SURTASS LFA sonar would be employed.
- Coastal Dolphins—Delphinid species, including the Tucuxi/boto (*Sotalia fluviatilis*), Irrawaddy dolphin (*Oracella brevirostris*), Australian snubfin dolphin (*Oracella heinsohni*), Indo-Pacific humpbacked dolphin (*Sousa chinensis*), costero (*Sousa guianensis*), Atlantic humpbacked dolphin (*Sousa teuszii*), and humpback dolphin (*Sousa plumbea*) all occur in shallow, coastal waters close to shore. Also, these dolphin species are not known to hear sounds in the range at which the SURTASS LFA sonar system transmits.
- Sirenians—Globally, four sirenian species exist including three manatee species, the West Indian (*Trichechus manatus*), Amazonian (*T. inunguis*), and West African (*T. senegalensis*) manatees, and one dugong species (*Dugong dugon*). The West Indian and West African manatees occur in coastal and inshore tropical to subtropical marine, brackish, and freshwater waters while the Amazonian manatee is restricted solely to the freshwater river habitats of the Amazon River and its tributaries (Jefferson et al., 2015). Dugongs are widely but discontinuously distributed in coastal and estuarine tropical and subtropical waters along the northern Indian and western North Pacific Oceans in waters that are typically less than 16.4 ft (5 m) deep (Jefferson et al., 2015). Although principally inshore and coastal dwellers, manatees have been known to travel great distances, and dugongs and have sighted near reefs up to 43.2 nmi (80 km) from shore in waters up to 75 ft (23 m) deep (DoN, 2005; Marsh et al., 2002). These sightings have been considered atypical and represent very rare occurrences. Moreover, the water depths of the offshore reefs where dugongs have uncommonly been observed are so shallow that the operation of the SURTASS LFA sonar is likely precluded. Accordingly, the manatee and dugong are eliminated from further evaluation.

In this SEIS/SOEIS, the remaining marine mammal species to be evaluated for potential impacts associated with exposure to SURTASS LFA sonar are organized by basic taxonomic suborder groupings: Mysticeti, Odontoceti, and Pinnipedia, which respectively are baleen whales, toothed whales (including dolphins and porpoises), as well as seals and sea lions[6]. Marine mammal taxonomy follows that defined by the Society for Marine Mammalogy (2016).

3.3.1.6.1 Mysticetes

All 14 species of baleen whales or mysticetes produce LF sounds. Although there are no direct data on auditory thresholds for any mysticete species, anatomical evidence strongly suggests that their inner ears are well adapted for LF hearing, with the resonant properties of the mysticete basilar membrane suggesting their functional hearing range is 15 Hz to 20 kHz, with good sensitivity from 20 Hz to 2 kHz (Ketten, 1998). Parks et al. (2007) analyzed 18 inner ears from 13 stranded North Atlantic right whales

6 The walrus is also a pinniped, but it has been excluded from further consideration herein.

(*Eubalaena glacialis*) to develop a preliminary model of their frequency hearing range; from measurements of the basilar membrane, the hearing range was estimated to range from 10 Hz to 22 kHz, based on established marine mammal models. Therefore, sound perception and production are assumed to be critical for mysticete survival. Since all mysticete species are considered sensitive to LF sound and occur within the ocean areas proposed for SURTASS LFA sonar operations, all mysticete species are considered for further evaluation herein.

3.3.1.6.2 Odontocetes

All odontocete species studied to date hear best in the mid- to high-frequency range, and as a consequence, are less likely to be affected by exposure to LF sounds than mysticetes. Odontocetes depend upon acoustic perception and sound production for communication, prey location, and probably for navigation and orientation as well, since many odontocete species are known to use high-frequency (HF) clicks for echolocation[7]. Although 74 species of marine mammals are currently defined as odontocetes, several species of odontocetes have already been excluded from further consideration (i.e., river and coastal dolphins and porpoises). The remaining 60 species of globally occurring odontocetes will be further analyzed in this SEIS/SOEIS for the potential for impacts associated with exposure to SURTASS LFA sonar.

3.3.1.6.3 Pinnipeds

The suborder Pinnipedia consists of eared seals (family Otariidae), earless or true seals (family Phocidae), and walruses (family Odobenidae). Several pinniped species, including the walrus, have already been excluded from further consideration due to their polar range or occurrence in land-locked or freshwater and brackish lakes. The functional hearing ranges of the remaining Otariid and Phocid pinniped species is 100 Hz to 40 kHz and 75 Hz to 100 kHz, respectively (NOAA, 2016a). These remaining 30 pinniped species are thus potentially capable of hearing SURTASS LFA sonar transmissions, although their LF hearing sensitivity is relatively poor, and occur in waters that the sonar system may be operated. As such, these 30 pinniped species merit further consideration.

3.3.2 Potentially Affected Marine and Anadromous Fishes

Of the 33,200 living species of fish (Froese and Pauly, 2016), two taxonomic classes of fish are considered for analysis in this SEIS/SOEIS: Chondrichthyes (cartilaginous fish including sharks and rays) and Osteichthyes (bony fish). The bony fish comprise the largest of all vertebrate groups with over 29,000 extant species (Nelson, 2006). The ecological distribution of fish is extraordinarily wide, with different species having adapted to a diverse range of environmental conditions.

Pelagic fish live in the water column, while demersal fish live near or on the seafloor, and both types of fishes may potentially be exposed to LFA sounds. Additionally, many fish species are protected and are commercially important. It is likely that all species of fish can hear, and that many fish species produce and/or use sound for communication. However, data on hearing and/or sound production are not available for many species. For example, there is reason to suggest that a number of deep-sea species that live where there is little or no light, such as myctophids (lanternfish) (Mann and Jarvis, 2004; Popper, 1980a), macrourids (rattails–relatives of cod) (Deng et al., 2013), and deep sea eels (Buran et al.,

7 Echolocation is the ability of some animals, like bats and some marine mammals, to get information about their surroundings, to find food, and detect objects by using biosonar; the animals produce HF (40 to 130 kHz) sounds or sonar clicks that are reflected back to them after the sound strikes an object.

2005) all potentially hear well and/or use sound for communication, but this cannot be confirmed until more research has been conducted on these fish groups. Information on the hearing capabilities of representative marine and freshwater fish was detailed in Appendix B of the Navy's 2012 SEIS/SOEIS on SURTASS LFA sonar (DoN, 2012).

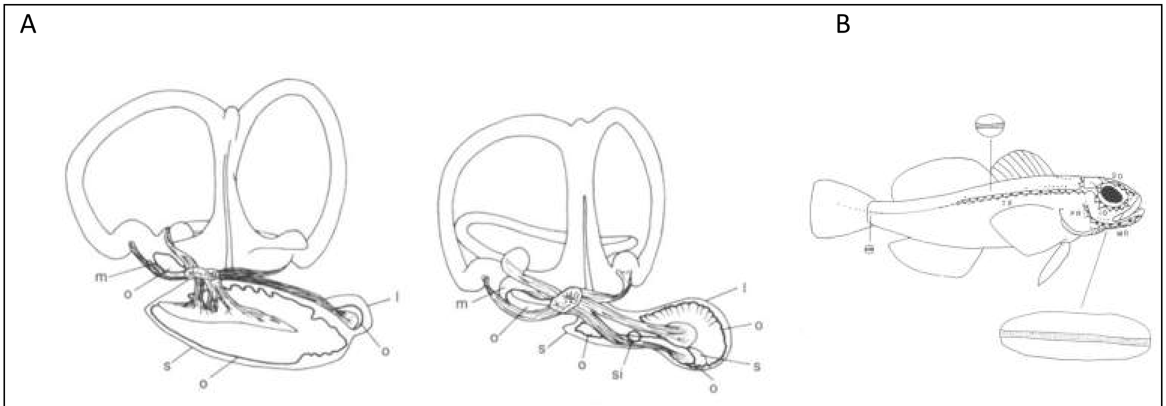
3.3.2.1 Fish Physiology and Hearing

Sensitivity to sound differs among fish species. One factor affecting hearing sensitivity is the proximity of the fish inner ear to the swim bladder. A swim bladder is a gas filled organ in some fishes that is used for buoyancy control and hearing in some fishes. Popper et al. (2014) developed sound exposure guidelines for three types of fishes, depending on how they might be affected by underwater sound. The categories include fishes with no swim bladder or other gas chamber (e.g., flatfish and elasmobranchs); fishes with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g., salmonids such as steelhead trout and Pacific salmon); and fishes with a swim bladder or gas chamber that is involved in hearing (e.g., catfish, carp, sardines, anchovies). Fishes with a swim bladder involved in hearing are most sensitive to sound since they are able to detect particle motion and pressure. Chapter 4 discusses impacts to fishes according to these categories.

3.3.2.2 Osteichthyes (Bony Fishes)—Hearing Capabilities, Sound Production, and Detection

The octavolateralis system of fish is used to sense sound, vibrations, and other forms of water displacement in the environment, as well as to detect angular acceleration and changes in the fish's position relative to gravity (Popper et al., 2003; Popper and Schilt, 2008). The major components of the octavolateralis system are the inner ear and the lateral line (Figure 3-1). The basic functional unit in the octavolateralis system is the sensory hair cell, a highly specialized cell that is stimulated by mechanical energy (e.g., sound, motion) and converts that energy to an electrical signal that is compatible with the nervous system of the animal. The sensory cell found in the octavolateralis system of fish and elasmobranchs is the same sensory cell found in the ears of terrestrial vertebrates, including in humans (Coffin et al., 2004). Both the ear and the lateral line send their signals to the brain in separate neuronal pathways. However, at some levels the two systems are likely to interact to enable the fish to detect and analyze a wide range of biologically relevant signals (Coombs et al., 1989) and the lateral line may directly contribute to the 'hearing' ability of fish (Higgs and Radford, 2016).

The lateral line is divided into two parts: the canal system and the free neuromasts. Each neuromast is a grouping of sensory hair cells that are positioned so that they can detect and respond to water motion around the fish. The canal neuromasts are spaced evenly along the bottom of canals that are located on the head and extending along the body (in most, but not all, species) (Figure 3-1). The free neuromasts are distributed over the surface of the body. The specific arrangement of the lateral line canals and the free neuromasts vary with different species (Coombs et al., 1992; Webb et al., 2008). The pattern of the lateral line canal suggests that the receptors are laid out to provide a long baseline that enables the fish to extract information about the direction of the sound source relative to the animal. The latest data suggest that the free neuromasts detect water movement (e.g., currents), whereas the receptors of the lateral line canals detect hydrodynamic signals. By comparing the responses of different hair cells along such a baseline, fish should be able to use the receptors to locate the source of vibrations (Coombs and Montgomery, 1999; Montgomery et al., 1995; Webb et al., 2008). Moreover, the lateral line appears to be most responsive to relative movement between the fish and surrounding water (its free neuromasts are sensitive to particle velocity; its canal neuromasts are sensitive to particle acceleration).



The octavolateralis system of fish includes the inner ear (A) and the lateral line system (B). (A) Medial view of the inner ear of a zander (*Stizostedion lucioperca*) on the left and an ide (*Levciscus idus*) on the right (from Popper and Fay, 1973). (Internal structures not labeled.) Anterior (front of the animal) is to the left and dorsal (top of the animal) is to the top. (B) Enlargement of the canal and surface neuromasts on the body of the mottled sculpin (*Cottus bairdii*), showing the dorsal surface of neuromasts found on the mandible, trunk, and a superficial neuromast; stippling represents hair cells. (From Coombs et al., 1989).

Figure 3-1. Octavolateralis System of Bony Fish Including the Inner Ear and Lateral Line System (Coombs et al., 1989).

The ear and the lateral line overlap in the frequency range to which they respond. The lateral line appears to be most responsive to signals ranging from below 1 Hz to between 150 and 200 Hz (Coombs et al., 1992; Webb et al., 2008), while the ear responds to frequencies from about 20 Hz to several thousand Hz in some species (Popper and Schilt, 2008; Popper and Fay, 1993; Popper et al., 2003)[8] The specific frequency response characteristics of the ear and lateral line varies among different species and is probably related, at least in part, to the life style of the particular species.

The inner ear in fish is located in the cranial (brain) cavity of the head just behind the eye. Unlike terrestrial vertebrates, there are no external openings or markings to indicate the location of the ear in the head. The ear in fish is generally similar in structure and function to the ears of other vertebrates. It consists of three semicircular canals that are used for detection of angular movements of the head, and three otolith organs that respond to both sound and changes in body position (Schellart and Popper, 1992) (Popper, 2003) (Ladich and Popper, 2004; Popper and Schilt, 2008). The sensory regions of the semicircular canals and otolith organs contain many sensory hair cells (Figure 3-2). In the otolith organs, the ciliary bundles, which project upward from the top surface of the sensory hair cells, contact a dense structure called an otolith (or ear stone). It is the relative motion between the otolith and the sensory cells that results in stimulation of the cells and responses to sound or body motion. The precise size and shape of the ear varies in different fish species (Popper and Coombs, 1982; Schellart and Popper, 1992; Popper et al., 2003; Ladich and Popper, 2004; Popper and Schilt, 2008).

Hearing is better understood for bony fish than for cartilaginous fish like sharks and jawless fish (class Agnatha) (Popper and Fay, 1993; Ladich and Popper, 2004). Bony fish with specializations that enhance their hearing sensitivity have been referred to as hearing "specialists", whereas, those that do not possess such capabilities are called "nonspecialists" (or "generalists"). However, in a recent review, Popper and Fay (2009) have argued that the terms hearing "generalist" and "specialist" should be

8 Some fish species are now known to detect sounds well below 20 Hz and others sounds that are in the ultrasound range.

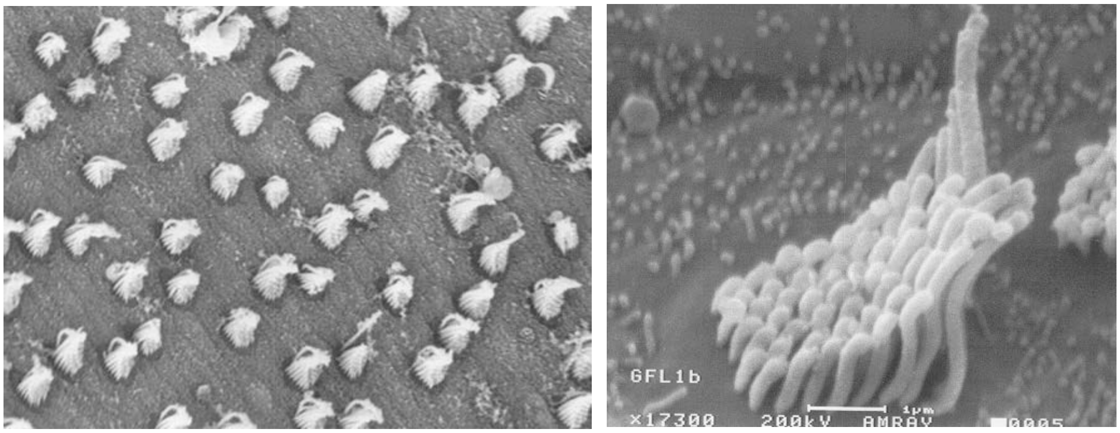
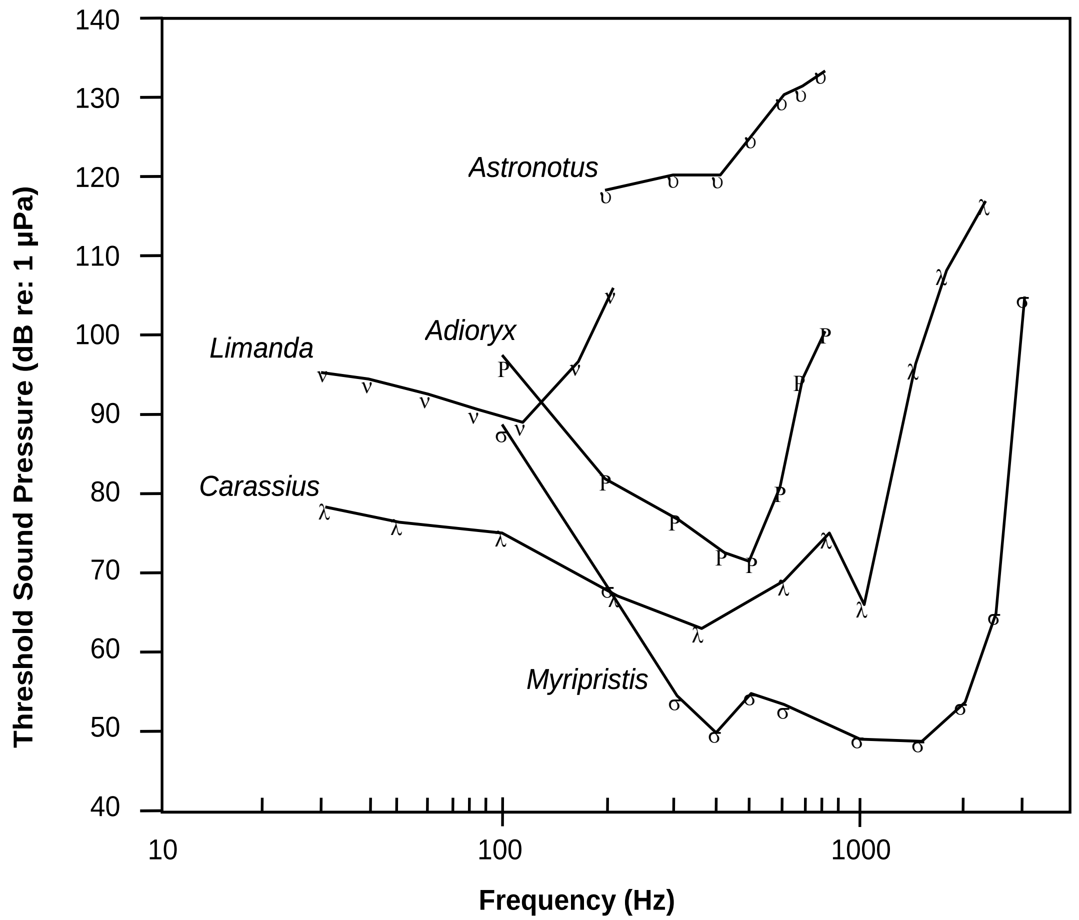


Figure 3-2. Scanning Electron Micrographs of the Ciliary Bundles of Hair Cells From a Goldfish (*Carassius Auratus*) Lagena (Unpublished Photographs by M.E. Smith). The Hair Cell on the Right Is Magnified (17,300x) from the General Area Shown on the Left. The Scale Bar Represents 1 µm).

dropped, since there is so much overlap in hearing capabilities and mechanisms among different species. Instead, Popper and Fay (2009) suggest that different hearing capabilities should be treated on a "continuum" of capabilities. Popper and Fay (1993) suggested that in the bony fish species possessing specializations that enhance their hearing sensitivity, one or more of the otolith organs may respond to sound pressure as well as to acoustic particle motion. The response to sound pressure is thought to be mediated by mechanical coupling between the swim bladder (the gas-filled chamber in the abdominal cavity that enables a fish to maintain neutral buoyancy) or other gas bubbles and the inner ear. With this coupling, the motion of the gas-filled structure, as it expands and contracts in a pressure field, is brought to the ear. In fish species without any hearing specializations, however, the lack of a swim bladder, or its lack of coupling to the ear, probably results in most of the energy in the signal from the swim bladder attenuating before it gets to the ear. As a consequence, these fish detect little of the pressure component of the sound (Popper and Fay, 1993).

The vast majority of fish studied to date appear to have no specializations to enhance their hearing sensitivity (Schellart and Popper, 1992; Popper et al., 2003; Popper and Schilt, 2008), and only a few species known to possess hearing specializations inhabit the marine environment (although lack of knowledge about the marine fish with hearing specializations may be due more to limited data on many marine species, rather than on there being few species with specializations in this environment). Some of the better known marine fishes with hearing specializations are found among the Orders Beryciformes (especially the Holocentridae family, which includes soldierfish and squirrelfish) (Coombs and Popper, 1979), and Clupeiformes (which includes herring and shad) (Mann et al., 2001; Mann et al., 1997). Even though there are species with hearing specializations in each of these taxonomic groups, most of these groups also contain numerous species with no hearing specializations. In the family Holocentridae, for example, there is a genus, *Myripristis*, with hearing specializations and a genus, *Adioryx,* with no hearing specializations (Coombs and Popper, 1979).

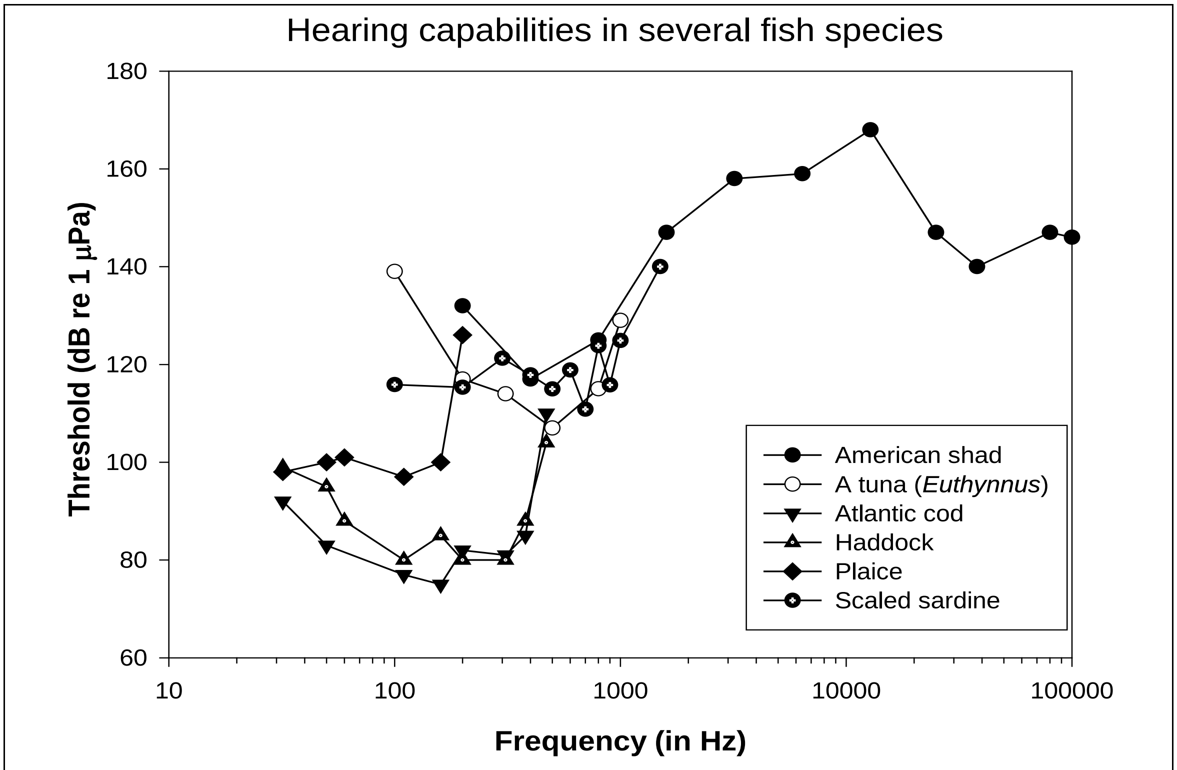
Audiograms (measures of hearing sensitivity) have been determined for over 50 fish (mostly fresh water) and several elasmobranch species (Casper and Mann, 2006; Fay, 1988) (Figures 3-3 and 3-4). An



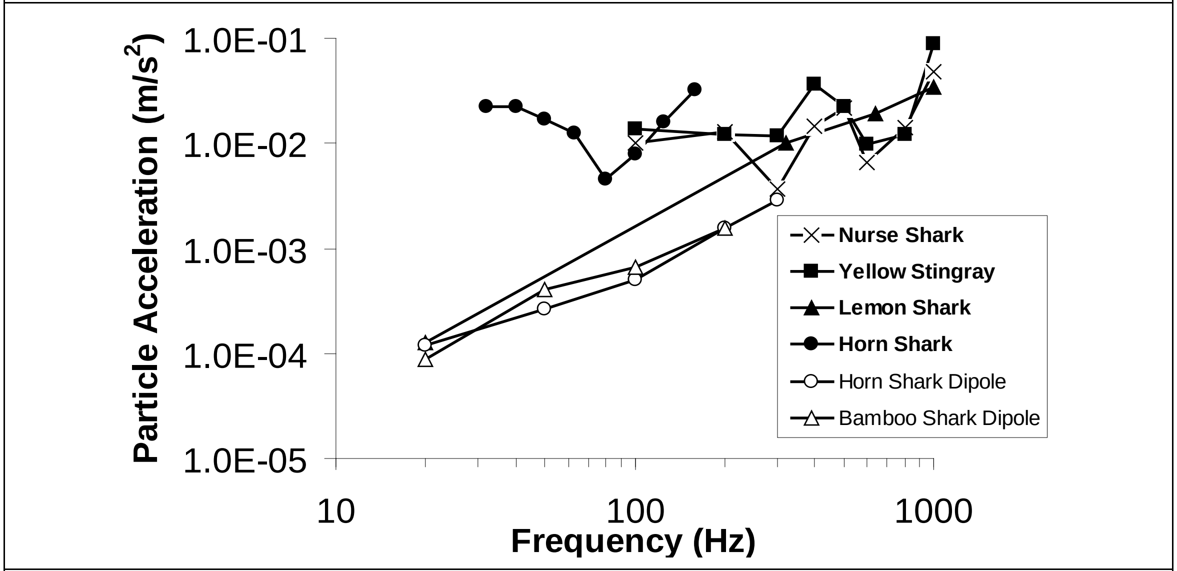
Two fish species with hearing specializations—*Carassius auratus* (goldfish) (Fay, 1969) and *Myripristis kuntee* (squirrelfish) (Coombs and Popper, 1979); two fishes with no hearing specializations but possessing a swimbladder—*Adioryx xantherythrus* (another squirrelfish) (Coombs and Popper, 1979) and *Astronotus ocellatus* (the Oscar) (Yan and Popper, 1992); and a fish with no hearing specializations or a swimbladder— *Limanda limanda* (lemon sole) (Chapman and Sand, 1974).

Figure 3-3. Behavioral Audiograms for Selected Freshwater Fish Species (Fay, 1969; Yan and Popper, 1992).

audiogram plots auditory thresholds (minimum detectable levels) at different frequencies and depicts the hearing sensitivity of the species. It is difficult to interpret audiograms because it is not known whether sound pressure or particle motion is the appropriate stimulus and whether background noise determines threshold. The general pattern that is emerging indicates that those species with hearing specializations detect sound pressure with greater sensitivity over a wider bandwidth (to 3 kHz or above) than those species with no hearing specializations. Also, the limited behavioral data available suggest that frequency and intensity discrimination performance may not be as acute in those species with no hearing specializations (Fay, 1988). Furthermore, there are multiple physiological methods to measure hearing (e.g. AEP, saccular potentials and single-neuron recordings). A comparison of these different methods in the same species of fish found that while the overall pattern of hearing sensitivity was similar, the absolute sensitivity levels varied between methods (Maruska and Sisneros, 2016).



Data for select marine species: American shad (*Alosa sapidissima* [Mann et al., 2001]); tuna (*Euthynnus affinis*) [Iverson, 1967]), Atlantic cod (*Gadus morhua* [Chapman and Hawkins, 1973]); haddock (*Melanogrammus aeglefinus* [Chapman, 1973]); plaice (*Pleuronectes platessa* [Chapman and Sand, 1974]); and scaled sardine (*Harengula jaguana* [Mann et al., 2001]).



Nurse shark, *Ginglymostoma cirratum*, and yellow stingray, *Urobatis jamaicensis*, are modified from Casper and Mann (2006), with thresholds determined using auditory evoked potentials (AEP). Data for the lemon shark, *Negaprion brevirostris*, was by Banner (1967) and that for the horn shark, *Heterodontus francisi*, (black circle, monopole) from Kelly and Nelson (1975). The lemon shark and horn shark data were obtained using classical conditioning methods in which the animals were trained to respond behaviorally when they heard a sound; the data for these two species was measured in terms of particle displacement and then converted to particle accelerations (Figure from Casper and Mann, 2007).

Figure 3-4. Behavioral Audiograms for Selected Marine Fish Species.

Popper and Fay (1993) point out that threshold values are expressed as sound pressure levels because that quantity is easily measured, although this value is strictly correct only for the fish that respond in proportion to sound pressure. It is uncertain if the thresholds for the Oscar and lemon sole should be expressed in terms of sound pressure or particle motion amplitude. In comparing best hearing thresholds, fishes with hearing specializations are similar to most other vertebrates, when thresholds determined in water and air are expressed in units of acoustic intensity (i.e., Watts/cm^2) (Popper and Fay, 1993) (Figure 3-3). However, it is becoming more common for investigators to report audiograms in terms of both pressure and particle acceleration (e.g., Dale et al., 2015). Radford et al. (2012) tested the hearing of three species of fish using an underwater speaker to determine pressure thresholds and a shaker table to measure particle motion thresholds. The species were triplefin (has no swim bladder), a goldfish (with webberian ossicles) and New Zealand bigeye (has a connection between the swim bladder and the inner ear). The shaker table created relative particle motion in the water in the absence of acoustic sound pressure. When measured with the shaker table stimulating particle motion, there was not a significant difference in the hearing ability of the three species. When sound pressure was the stimulus, there was a significant difference in hearing ability. The goldfish was the most sensitive, the New Zealand bigeye was intermediate, and the triplefin, lacking a swimbladder, was the least sensitive (Figure 3-5). Radford et al. (2012) use these results to argue that most particle motion hearing is likely to be similar between species. The differences in hearing ability that are seen when fish are stimulated with pressure signals are most likely due to changes in their anatomical specializations.

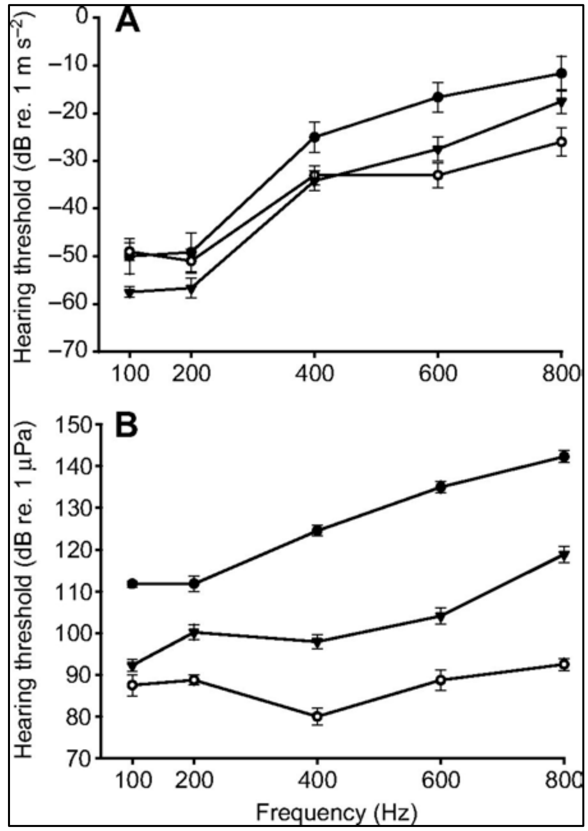


Figure 3-5. The Hearing Sensitivity Measured by Radford et al. (2012) of the Triplefin (Filled Circles), Goldfish (Open Circles), and New Zealand Bigeye (Filled Triangles) are Shown for Particle Acceleration (Panel A) While Sensitivity to Pressure is Illustrated in Panel B. The Differences in Particle Acceleration Sensitivity Between the Three Species are not Statistically Significant. The Triplefin is Least Sensitive, the New Zealand Bigeye is Intermediate, and the Goldfish is the Most Sensitive to Sound Pressure.

Those fish species with hearing specializations whose best hearing is below about 1,000 Hz appear well adapted to this particular range of frequencies, possibly because of the characteristics of the signals they produce and use for communication, or the dominant frequencies that are found in the general underwater acoustic environment to which fish listen (Popper and Fay, 1997; Popper and Fay, 1999; Popper et al., 2003; Schellart and Popper, 1992). The region of best hearing in the majority of fish for which there are data is from 100 to 200 Hz up to 800 Hz. Most species, however, are able to detect sounds to below 100 Hz, and often there is good detection in the LF range of sounds. It is likely that as data are accumulated for additional species, investigators will find that more species are able to detect LF sounds fairly well.

There is a growing literature to suggest that at least some fish species can detect infrasound, often defined as sounds below about 30 Hz, using the ear. This has been demonstrated in Atlantic salmon (*Salmo salar*) (Knudsen et al., 1992); Atlantic cod (*Gadus morhua*) (Sand and Karlsen, 1986); the plaice (*Pleuronectes platessa*) (Karlsen, 1992a), a flatfish lacking a swim bladder; and a perch (*Perca fluvitalis)* (Karlsen, 1992b). All species had a threshold at 0.1 Hz is about $4 * 10^{-5}$msec^{-2} (Karlsen, 1992a), which corresponds to the particle motion thresholds previously determined for this species between 30 and 150 Hz (Chapman and Sand, 1974). Most recently, infrasound detection was also demonstrated in Atlantic eel, *Anguilla anguilla* (Sand et al., 2000). In all cases studied so far, however, detection only seems to occur when the fish is within a few body lengths of the sound source and not when the fish are further away.

Many species of fish produce sounds for communication. Myrberg (1981) states that members of more than 50 fish families produce some kind of sound using special muscles or other structures that have evolved for this role, or by grinding teeth, rasping spines and fin rays, burping, expelling gas, or gulping air. Sounds are often produced by fish when they are alarmed or presented with noxious stimuli (Bass and Ladich, 2008; Myrberg, 1981; Zelick et al., 1999). Some of these sounds may involve the use of the swim bladder as an underwater resonator. Sounds produced by vibrating the swim bladder may be at a higher frequency (400 Hz) than the sounds produced by moving body parts against one another. The swim bladder drumming muscles are correspondingly specialized for rapid contractions (Zelick et al., 1999; Bass and Ladich, 2008). Sounds are known to be used in reproductive behavior by a number of fish species, and the current data lead to the suggestion that males are the most active producers. Sound activity often accompanies aggressive behavior in fish, usually peaking during the reproductive season. Those benthic fish species that are territorial in nature often produce sounds regardless of season but particularly during periods of high-level aggression (Myrberg, 1981). Further detail of these sound production mechanisms is given in Ladich (2014).

A recent finding is that some fish larvae will orient toward playback of reef sound recordings (summarized in Mann et al., 2007). Mann et al (2007), using reef noise levels as point sources, estimated that larval fishes cannot detect reefs at distances greater than 0.54 nmi (1 km). However reefs have definite physical extents and thus may be better represented as distributed sources. Indeed measurements and modeling efforts have shown that there is an extended “reef effect” zone that extends offshore as far as the length of the reef in which there is effectively no transmission loss (Radford et al., 2011). Beyond this distance, sound levels decrease normally. Using this reef effect model and the source levels and hearing sensitivity value of the tropical damselfish, Radford et al. (2011) calculated that this species could detect a reef at distances of approximately 10.8 nmi (20 km).

The ability of fish to process complex soundscapes is also being better defined. Fay (2009) reviewed the literature on directional hearing abilities in fish. A number of species have been shown to be able to discriminate and orient to different sound sources. All fish are capable of detecting particle motion, and recent studies have shown that plainfin midshipmen fish follow the path of particle motion, not pressure, when orienting to and approaching sound sources (Zeddies et al., 2012). Possessing directional hearing in mammals helps reduce the effects of noise on signal detection ability, and presumably does so in fish as well. Likewise, the ability to segregate (i.e., differentiate between) two signals that are presented simultaneously has been demonstrated in goldfish (Fay, 2009). These demonstrated abilities suggest that fish are capable to acoustic scene analysis, as has been shown in mammals, birds, and insects.

This directional hearing ability also offers at least some fish a release by masking. As reviewed in Sisneros and Rogers (2016), fish were able to lower their masking levels when sources were separated by 20° and 85°. Thus their directional hearing provides them the ability to spatially filter sound to increase their signal detection ability.

Kastelein et al. (2008) tested startle responses of fish to tones between 100 Hz and 64 kHz. In general, reaction thresholds were lowest at the low frequencies, and increased at higher frequencies. This trend is seen in most fish audiograms. However, the response thresholds did not parallel the audiogram curves. In some species at some frequencies the response thresholds were markedly higher than the detection threshold values. The authors conclude that different fish species react differently to anthropogenic sound and expect that the context of the presentation has an important effect on the magnitude of any potential response. Similar arguments have been made for marine mammals (Ellison et al., 2011). This is reinforced with the finding that the hearing sensitivity of female plainfin midshipman fish changes between reproductive and non-reproductive seasons. Male fish produce hums that are used to advertise for females. Female fish treated with estradiol or testosterone show marked increase in their sensitivity to those signals (Sisneros, 2009). Thus the females are better able to detect the advertising males. Whether or not this alters their sensitivity to anthropogenic noise remains an unanswered question.

3.3.2.3 Chondrichthyes (Cartilaginous Fish)—Hearing Capabilities, Sound Production, and Detection

Sharks are also of interest because of their LF sound detection capability, which is particularly important for detecting sounds produced by potential prey (Casper, 2011; Casper and Mann, 2009; Myrberg, 1978a; Myrberg et al., 1976; Nelson and Gruber, 1963; Nelson and Johnson, 1976). Since elasmobranchs (sharks, rays, and skates) lack any internal air-filled volume, they can only detect particle motion and not pressure (Casper, 2011). The function of the lateral line system of sharks is likely, as in other fish, to detect and respond to low frequency hydrodynamic stimuli (Au and Hastings, 2008; Higgs and Radford, 2016). In general, sharks appear to only detect frequencies that are in a range that is similar to that of fish classified as hearing generalists, and hearing sensitivity (the lowest sound levels detectable) is probably poorer than hearing generalist fishes (Banner, 1967; Casper et al., 2003; Kelly and Nelson, 1975; Nelson, 1967).

Olla (1962) observed that hammerhead sharks detect sounds below 750 Hz, with best sensitivity from 250 to 275 Hz, Kritzler and Wood (1961) reported that the bull shark responded to signals at frequencies between 100 and 1,400 Hz, with best hearing from 400 to 600 Hz. Lemon sharks responded to sounds from 10 to 640 Hz, with the greatest sensitivity at 40 Hz, but the lowest frequency may not accurately represent the lower limit of lemon shark hearing due to limitations in the test tank (tank acoustics) used in the experiments (Nelson, 1967). Moreover, lemon sharks may have responded at higher frequencies, but sounds of sufficiently high intensity could not be produced to elicit attraction responses (Nelson, 1967). Banner (1972) reported that lemon sharks he studied responded to sounds varying from 10 to 1,000 Hz. In a conditioning experiment with horn sharks, Kelly and Nelson (1975) discovered the sharks responded to frequencies of 20 to 160 Hz and that the lowest particle motion threshold was at 60 Hz.

The most recent studies of several elasmobranch species show hearing ranges that are comparable to those of earlier studies but were measured in terms of particle motion, the stimulus parameter that is most likely the most important to animals without a swim bladder, such as elasmobranchs (Casper et al., 2003; Casper and Mann, 2006, 2007), and unlike that done in earlier studies (Van Den Berg and Schuijf, 1983). Casper et al. (2003) showed that the little skate, *Raja erinacea* is able to detect sounds from 100 to over 800 Hz, with best hearing up to and possibly slightly greater than 500 Hz. Similar thresholds and hearing range have been reported for the nurse shark (*Ginglymostoma cirratum*) and the yellow stingray (*Urobatis jamaicensis*) (Casper and Mann, 2006) and the horn shark *Heterodontus francisci* and the white-spotted bamboo shark *Chiloscyllium plagiosum* (Casper and Mann, 2007) (Figure 3-4). Casper and Mann (2009) demonstrated that the Atlantic sharpnose shark had best hearing at 20 Hz, with higher thresholds at higher frequencies, up to 1 kHz.

Researchers doing field studies on shark behavior found that several species appear to exhibit withdrawal responses to broadband noise (500 to 4,000 Hz, although it is not likely that sharks heard the higher frequencies in this sound since there is no evidence that their hearing range ever gets much above 1,000 Hz). The oceanic silky shark (*Carcharhinus falciformis*) and coastal lemon shark (*Negaprion brevirostris*) withdrew from an underwater speaker playing low frequency sounds (Klimley and Myrberg, 1979; Myrberg et al., 1978). Lemon sharks exhibited withdrawal responses to broadband noise that was raised 18 dB, at an onset rate of 96 dB/sec, and to a peak amplitude of 123 dB RL from a continuous level, just masking broadband noise (Klimley and Myrberg, 1979). Myrberg et al. (1978) reported that a silky shark withdrew 33 ft (10 m) from a speaker broadcasting a 150 to 600 Hz sound with a sudden onset and a peak sound pressure level of 154 dB SL. These sharks avoided a pulsed LF attractive sound when its sound level was abruptly increased by more than 20 dB. Other factors enhancing withdrawal were sudden changes in the spectral or temporal qualities of the transmitted sound. Myrberg (1978b) has also reported withdrawal response from the pelagic whitetip shark (*Carcharhinus longimanus*) during limited testing.

The effects of pulse intermittency and pulse-rate variability on the attraction of five species of reef sharks to low frequency pulsed sounds were studied at Eniwetok Atoll, Marshall Islands in 1971 (Nelson and Johnson, 1972). The species tested were gray reef, blacktip reef, silvertip, lemon, and reef white tip. Nelson and Johnson (1972) concluded from these tests that the attractive value of 25 to 500 Hz pulsed sounds is enhanced by intermittent presentation, and that such intermittency contributes more to attractiveness than does pulse-rate variability. All tested sharks exhibited habituation to the sounds during the course of the experiment. It is also possible that sharks in these field tests responded to stimuli other than sound. The behavior of other animals near the speaker, or the electromagnetic field of the speaker itself may have cued the sharks (Casper, 2011; Casper and Mann, 2009).

One caveat regarding the data collected on shark hearing is that the majority of the earlier work (1960s to 1970s) was based on studies of single animals, which means the data do not reflect inter-animal variability in sensitivity and bandwidth within a single species, something widely known to occur in all vertebrate groups due to age, health, and other differences (Hill, 2005; Houser and Finneran, 2006). While the thresholds reported for sharks give an indication of the sounds they can detect, it would be of great value to replicate these analyses using modern methods for monitoring hearing in multiple animals of the same species.

3.3.2.4 Threatened and Endangered Marine and Anadromous Fish Species

Among the species of Osteichthyes and Chondrichthyes fishes considered for acoustic impact analysis in this SEIS/SOEIS are 21 species of ESA-listed marine and anadromous fish species as well as 12 additional species of marine and anadromous fish species proposed for listing under the ESA (Table 3-1). Additional globally-occurring fish species are also listed under the ESA but have been already been excluded from

Table 3-1. Marine and Anadromous Fish Species Listed and Those Proposed for Listing Under the ESA that are Evaluated in this SEIS/SOEIS for Potential Impacts Associated with Exposure to SURTASS LFA Sonar and their Status under the ESA. Species Listed in Alphabetical Order by Family.

Family	*Fish Species*	*ESA Status*	
		Threatened	*Endangered*
Salmonidae	Atlantic salmon (*Salmo salar)*		Gulf of Maine DPS
	Chinook salmon (*Oncorhynchus tshawytscha*)	Upper Columbia River Spring-run ESU	California Coastal ESU[9]
			Central Valley Spring-run ESU
			Lower Columbia River ESU
			Puget Sound ESU
			Snake River Fall-run ESU
			Snake River Spring/Summer-run ESU
			Sacramento River Winter-run ESU
			Upper Willamette River ESU
	Chum salmon (*Oncorhynchus keta)*		Columbia River ESU
			Hood Canal Summer-run ESU
	Coho salmon (*Oncorhynchus kisutch)*	Central California Coast Coho ESU	Lower Columbia River ESU
			Oregon Coast ESU
			Southern Oregon/Northern California Coasts ESU
	Sockeye salmon (*Oncorhynchus nerka)*	Snake River Sockeye ESU	Lake Ozette ESU
	Steelhead trout (*Oncorhynchus mykiss)*	Southern California Coast DPS	California Central Valley DPS
			Central California Coast DPS
			Lower Columbia River DPS
			Middle Columbia River DPS
			Northern California-Coast DPS

9 ESU=evolutionary significant unit

Table 3-1. Marine and Anadromous Fish Species Listed and Those Proposed for Listing Under the ESA that are Evaluated in this SEIS/SOEIS for Potential Impacts Associated with Exposure to SURTASS LFA Sonar and their Status under the ESA. Species Listed in Alphabetical Order by Family.

Family	Fish Species	ESA Status	
		Threatened	Endangered
Salmonidae (continued)	Steelhead trout (continued)		Puget Sound DPS
			Snake River Basin ESU
			South Central California Coast DPS
			Upper Columbia River ESU
			Upper Willamette River DPS
Acipenseridae	Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*	Gulf of Maine DPS	Carolina DPS
			Chesapeake Bay DPS
			New York Bight DPS
			South Atlantic DPS
	Chinese sturgeon (*Acipenser sinensis)*		Throughout range
	Green sturgeon (*Acipenser medirostris)*		Southern DPS
	Gulf sturgeon (*Acipenser oxyrinchus desotoi*)		Throughout Range
	Sakhalin sturgeon (*Acipenser mikadoi)*	Throughout Range	
Coelacanthidae	African coelecanth (*Latimeria chalumnae)*	Tanzanian DPS	
Pristidae	Narrow sawfish (*Anoxypristis cuspidata*	Throughout Range	
	Green sawfish (*Pristis zijsron*)	Throughout Range	
Sphyrnidae	Scalloped hammerhead shark (*Sphyrna lewini)*	Eastern Atlantic DPS	Indo-West Pacific DPS
		Eastern Pacific DPS	Central & Southwest Atlantic DPS
Carcharhinidae	Daggernose shark (*Isogomphodon oxyrhynchus*)		Proposed Throughout Range
Rhinobatidae	Brazilian guitarfish (*Rhinobatos horkelii)*		Proposed Throughout Range
Sciaenidae	Totoaba (*Cynoscion macdonaldi*)	Throughout Range	
Serranidae	Nassau grouper *(Epinephelus striatus)*	Proposed Throughout Range	
Epinephelidae	Gulf Grouper *(Mycteroperca jordani)*		Proposed Throughout Range
	Island Grouper *(Mycteroperca fusca)*	Proposed Throughout Range	
Osmeridae	Pacific eulachon (*Thaleichthys pacificus)*		Southern DPS
Sebastidae	Bocaccio (*Sebastes paucispinis*)		Puget Sound/Georgia Basin DPS
	Canary rockfish (*Sebastes pinniger*)	Puget Sound/Georgia Basin DPS	

Table 3-1. Marine and Anadromous Fish Species Listed and Those Proposed for Listing Under the ESA that are Evaluated in this SEIS/SOEIS for Potential Impacts Associated with Exposure to SURTASS LFA Sonar and their Status under the ESA. Species Listed in Alphabetical Order by Family.

Family	*Fish Species*	*ESA Status*	
		Threatened	*Endangered*
Sebastidae (Continued)	Yelloweye rockfish (*Sebastes ruberrimus*)	Puget Sound/Georgia Basin DPS	
Squatinidae	Argentine angelshark *(Squatina argentina)*		Proposed Throughout Range
	Common angelshark (*Squatina squatina*)		Proposed Throughout Range
	Sawback angelshark (*Squatina aculeata*)		Proposed Throughout Range
	Spiny angelshark (*Squatina guggenheim)*	Proposed Throughout Range	
	Smoothback angelshark (*Squatina oculata*)		Proposed Throughout Range
Triakidae	Narrownose Smoothhound Shark *(Mustelus schmitti)*	Proposed Throughout Range	
	Striped smoothhound shark (*Mustelus fasciatus*)		Proposed Throughout Range

further consideration in this SEIS/SOEIS (Section 3.3.1.2). Anadromous fish species, such as salmon, are born in fresh water, migrate to the ocean where they grow into adults, after which they return to the fresh water streams or lakes of their birth to spawn; most Pacific salmon species die after spawning, but Atlantic salmon may become "reconditioned" sufficiently to return to the sea and repeat the migration and spawning pattern several times. Populations of the ESA-listed fish species have been delineated into DPSs or evolutionarily significant units (ESU). Brief descriptions are included here of each listed or proposed fish species' distribution, habitat, population, and hearing or sound producing capabilities.

3.3.2.4.1 Atlantic Salmon (*Salmo salar*)

Atlantic salmon are found throughout the North Atlantic Ocean and occur in three separate stocks. The North American stock ranges from Long Island Sound to Greenland and Newfoundland. The Gulf of Maine (GoM) DPS, part of the North American stock of Atlantic salmon, is listed as endangered under the ESA (Table 3-1). This DPS represents the last wild population of Atlantic salmon and includes all naturally reproducing remnant populations from the Kennebec River north to the mouth of the St. Croix River; at least eight tributaries in the geographic range of this DPS still support wild salmon. Persistent reproducing wild populations of Atlantic salmon occur within the GoM DPS but have declined to critically low numbers. Since the ESA listing, both adult and juvenile populations have declined. The extinction risk within the next 100 years is estimated at 19 to 75 percent for the GoM DPS even when current levels of hatchery supplementation are considered (Fay et al., 2006). In 2004, the adult Atlantic salmon population of the GOM DPS was estimated at 1,348 fish (Fay et al., 2006).

Critical habitat has been designated in 45 specific inland areas occupied by Atlantic salmon that comprise approximately 10,568 nmi (19,571 km) of perennial river, stream, and estuary habitat and 309 mi^2 (799 km^2) of lake habitat connected to the marine environment within the range of the GoM DPS; all critical habitat lies within the state of Maine (NOAA, 2009). The critical habitat includes sites for spawning and incubation, sites for juvenile rearing, and sites for migration. Some Department of Defense lands are excluded from critical habitat.

Atlantic salmon are anadromous and highly migratory, spending their first two to three years in freshwater, migrating to the ocean where approximately two to three years are spent, before returning to their natal river to spawn. Atlantic salmon are capable of spawning more than once in their lifetimes. Adult salmon return to freshwater native streams, beginning in spring and continuing throughout the summer, with migration peaking in June and spawning occurring generally from mid-October to mid-November when water temperatures are between 7° and 10° C (44.6° and 50° F) (Fay et al., 2006). About 20 percent of the adult salmon migrate back to the ocean immediately after spawning, while the remainder overwinters in freshwater tributaries or in estuaries before returning to the sea (Fay et al., 2006).

The marine stage of the life history of Atlantic salmon is less well known than the well-studied freshwater stages. The smolt lifestage of Atlantic salmon leaves Maine rivers in the late spring (May) of the second or third year to begin its ocean migration, moving northeasterly, to the waters off Newfoundland and Labrador, and Greenland. Atlantic salmon are widely distributed throughout the waters of the northwestern Atlantic Ocean, ranging from southern Greenland to the Labrador Sea, until they return to their natal rivers after their second winter at sea (Fay et al., 2006).

3.3.2.4.2 Chinook Salmon (*Oncorhynchus tshawytscha*)

In the North Pacific Ocean, Chinook, or king, salmon range from the Bering Strait southward to Japan and California. The Chinook salmon population in the waters of the U.S. Pacific northwest has been divided into 17 ESUs. Of these Chinook salmon ESUs, seven are listed as threatened under the ESA while two others are listed as endangered (Table 3-1). The Trinity River and Upper Klamath Rivers ESU is a candidate for listing under the ESA. Critical habitat has been established for all nine ESA-listed ESUs and includes the freshwater spawning, rearing, and migration sites, as well as estuarine and marine juvenile and adult forage and migrational areas in the inland waters of California, Oregon, and Washington states. After significantly declining throughout its U.S. range, some Chinook ESUs have shown increasing abundance population trends in recent years (Good et al., 2005).

Largest of the Pacific salmon species, the Chinook salmon is an anadromous fish that is highly migratory. After hatching in freshwater, Chinook salmon spend 3 months to 2 years in freshwater inland habitats before migrating seaward to estuaries and finally to the ocean, where they mature and remain for 1 to 6 years, but more commonly between 2 and 4 years (USFWS, 2009). As adults, these fish return to their natal river or streams to mate, spawn, and die.

Populations of Chinook salmon exhibit a great deal of variability in size, age of maturation, and habitat preference with at least some portion of this variation being genetically determined. For instance, a small population of male Chinooks remains in fresh water to mature and only spends 2 to 3 months in saltwater before returning back to freshwater. There is also at least one resident population of Chinook salmon in Lake Cushman, Washington that never migrates to saltwater (Good et al., 2005).

Additionally, not all Chinook salmon migrate back to freshwater at the same time of year. Different seasonal (i.e., spring, summer, fall, or winter) migration "runs" of Chinook salmon from the ocean to freshwater exist, even within an individual river system. These runs are identified on the basis of the season when adult Chinook salmon enter freshwater to begin their spawning migration. Entry into freshwater systems is thought to be mediated by water temperature and the water flow regime of the tributary.

Two types of Chinook salmon have evolved: the ocean- and stream-types. Ocean-type Chinook salmon tend to migrate along the coast while stream-type Chinooks are found offshore in the central North Pacific. Stream-type Chinooks, found most commonly in headwater streams of large river systems, perform extensive offshore migrations in the central North Pacific before returning to their natal streams in the spring or summer months. Stream-type Chinook salmon migrate during their second or sometimes their third spring to summer season (Busby et al., 1997). At the time of saltwater entry, stream-type (yearling) smolts are much larger, averaging 73 to 134 mm (3 to 5.25 inches [in]) depending on the river system, than their ocean-type counterparts, and are able to move offshore relatively quickly. Ocean-type Chinook salmon live in estuaries for longer periods in earlier lifestages and tend to utilize estuaries and coastal areas more extensively in the juvenile lifestage and also spend their ocean life in coastal waters. Ocean-type Chinook salmon return to their natal streams or rivers as spring, winter, fall, summer, and late-fall runs, with summer and fall runs predominating. In most rivers, migration in the late summer or autumn of the first year represents the majority of the ocean-type emigrants. If environmental conditions are not conducive to emigration, ocean-type Chinook salmon may remain in fresh water for their entire first year.

3.3.2.4.3 Chum Salmon (*Oncorhynchus keta*)

The chum salmon has the widest natural geographic and spawning distribution of any Pacific salmonid, primarily because its occurrence extends farther north into the Arctic Ocean. With spawning populations ranging from Korea and Japan as far north as Russia in the western North Pacific, major spawning populations chum salmon occur only as far south as Tillamook Bay on the northern Oregon coast in the eastern North Pacific. Two of four ESUs in U.S. waters, the Columbia River and Hood Canal summer-run ESUs, are listed as threatened under the ESA. Once the most abundant of all Pacific salmon species, seven of the 16 historical spawning populations in the Hood Canal summer-run ESU are now extinct, with the overall population of this ESU estimated at several thousand per year and declining by 6 percent per year (Good et al., 2005). The population of the Columbia River ESU is even lower, with an estimated 500 fish and 14 of 16 spawning populations now extinct (Good et al., 2005). Critical habitat has been designated in Washington and northwestern Oregon transboundary inland waters to protect freshwater spawning, rearing, and migrational sites as well as estuarine migrational and rearing areas (NOAA, 2005).

Chum salmon are second only to Chinook salmon in size and are identified by the enormous canine-like fangs and striking body color of spawning males. Like other Pacific salmon species, the chum salmon is anadromous and migrates from freshwater tributaries to saltwater, returning to the freshwater river of birth to spawn once and die, although there is a population in Puget Sound that never leaves those waters (USFWS, 2009a). As chum salmon enter fresh water, their color and appearance changes dramatically. Most chum salmon mature and return to their birth stream to spawn between 3 and 5 years of age, with 60 to 90 percent of the fish maturing at 4 years of age (USFWS, 2009a). The species has only a single form, the sea-run. Chum salmon spawn in the lowermost reaches of rivers and streams, typically within 100 km (62 mi) of the ocean, with spawning sites often located near springs. They migrate almost immediately after hatching to estuarine and ocean waters, in contrast to other Pacific salmonids, which migrate to sea after months or even years in freshwater (Pauley et al., 1998). This means that survival and growth of juvenile chum salmon depends less on freshwater conditions than on favorable estuarine and marine conditions.

3.3.2.4.4 Coho Salmon (*Oncorhynchus kisutch*)

The distribution of coho salmon ranges from central California and Japan to Alaska and Russia. Four of the seven coho salmon ESUs in the U.S. are listed under the ESA with an additional ESU, the Puget Sound/Strait of Georgia, listed currently as a species of concern. The Central California Coast ESU is listed as endangered while the Lower Columbia River, Oregon Coast, and Southern Oregon/Northern California Coast ESUs are listed as threatened. Critical habitat has been established for three of the four listed ESUs; critical habitat for the Lower Columbia River has been proposed but has not yet been designated. Critical habitat for the Central California Coast ESU encompasses accessible reaches of all rivers (including estuarine areas and tributaries) between Punta Gorda and the San Lorenzo River (inclusive) in California, including two streams entering San Francisco Bay: Arroyo Corte Madera Del Presidio and Corte Madera Creek, while critical habitat for the Southern Oregon/Northern California Coasts ESU encompasses accessible reaches of all rivers (including estuarine areas and tributaries) between the Mattole River in California and the Elk River in Oregon, inclusive (NOAA, 1999). Critical habitat for the Oregon Coast ESU includes 72 of 80 occupied watersheds, contained in 13 sub-basins, totaling approximately 6,665 stream miles along the Oregon Coast, south of the Columbia River and north of Cape Blanco (Oregon) (NOAA, 2008).

The abundance of coho salmon south of Alaska has declined despite the establishment of large hatchery programs. Hatchery programs have been so successful that most runs of salmon consist of more than twice the number of hatchery versus natural coho salmon. The overall population trend for the ESA-listed ESUs is declining, particularly in the Central California Coast ESU, although abundances for some years show promising increases (Good et al., 2005).

Coho salmon are anadromous, migrating from the marine environment into the freshwater streams and rivers of their birth to mate, spawn once, and die. Although anadromy is the norm, some coho salmon remain resident in freshwater; some coho salmon spend their entire lives in Puget Sound/Strait of Georgia (Emmett et al., 1991). Coho salmon exhibit a simple, 3-year life cycle, with adults beginning their spawning migration in summer to fall with spawning occurring by mid-winter. Juvenile cohos spend about 15 months developing in freshwater, and then in spring through summer (April to August) with a peak in May, migrate to the North Pacific Ocean, where they spend two years before returning to freshwater to complete their life cycle (Emmett et al., 1991). Some males known as "jacks" return to freshwater as two-year-old spawners. Spawning males develop the characteristic strongly hooked snout and large teeth. Spawning occurs earlier at the northern extent of the coho's geographic range (PFMC, 2000). Upon entering the ocean, coho may spend several weeks or their entire first summer in coastal waters before migrating into open ocean waters (PFMC, 2000). The extent of coho migrations appears to extend westward along the Aleutian Island chain ending somewhere around Emperor Seamount (PFMC, 2000).

3.3.2.4.5 Sockeye Salmon (*Oncorhynchus nerka*)

Sockeye salmon range from about 44°N to 49°N and occur around the Pacific Rim of the north Pacific Ocean from the Klamath River and its tributaries and Hokkaido, Japan to the Kuskokwim River, Alaska and the Anadyr River, Russia (Gustafson et al., 1997). Kuril Lake in the Ozernaya River Basin on the Kamchatka Peninsula produces nearly 90 percent of Asian sockeye salmon (Gustafson et al., 1997). Sockeye salmon prefer cooler ocean conditions than most other species of Pacific salmon. Two of seven sockeye salmon ESUs in the U.S. have been listed under the ESA; the Ozette Lake ESU is listed as threatened while the Snake River ESU is listed as endangered. Critical habitat for the Snake River ESU consists of the river reaches of the Columbia, Snake, and Salmon Rivers and Valley and Alturas Lake Creeks, as well as Stanley, Redfish, Yellowbelly, Petitt, and Alturas Lakes (NOAA, 1993). The Hoh/Quillayute Sub-basin is the focus of critical habitat for the Ozette Lake ESU and specifically includes all bodies of water in the watershed of Ozette Lake, which contains five rivers and three creeks (NOAA, 2005).

Sockeye salmon are the third most abundant, after pink salmon and chum salmon, of the seven species of Pacific salmon. However, the Snake River ESU has remained at very low levels of only a few hundred fish, though there have been recent increases in the number of hatchery reared fish returning to spawn (Good et al., 2005). Data quality for the Ozette Lake ESU makes differentiating between the number of hatchery and natural spawners difficult, but in either case the size of the population is small, though possibly growing (Good et al., 2005).

Sockeye salmon are primarily anadromous and only spawn once before dying but exhibit a more varied life history than other species of Pacific salmon, reflecting varying dependency on the freshwater environment; e.g., there are distinct landlocked populations (kokanee) that never migrate to marine waters, spending their entire life cycle in freshwater habitats (Burgner, 1991; Emmett et al., 1991). With the exception of certain river- and sea-type populations, the vast majority of sockeye salmon spawn in or near lakes (lake-type), where the juveniles rear for 1 to 3 years prior to migrating to sea. For this reason, the major distribution and abundance of large sockeye salmon stocks are closely related to the location of rivers that have accessible lakes in their watersheds for juvenile development, so that their occurrence is more intermittent than that of other Pacific salmon. Sockeye spend approximately the first half of their life cycle rearing in lakes and the remainder of their four to six year life cycle is spent foraging in estuarine and marine waters of the Pacific Ocean. “Lake-type” juvenile sockeye salmon rear in lakes for 1 to 3 years before migrating to the sea, while “river-type” sockeyes spawn in rivers without spending any time in the lake developmental habitat and spend 1 to 2 years in the slow-velocity sections of rivers as the juvenile rearing environment. In Washington and British Columbia, lake residence is typically closer to 1 to 2 years, whereas it is closer to 3 to 4 years in Alaska. “Sea-type” salmon migrate to the sea after spending only a few months in freshwater. Sockeye salmon spend between 1 and 4 years in the ocean before migrating back up the rivers to spawn and die (Gustafson et al., 1997). After entering saltwater, the young sockeye spend the first season in coastal waters before moving in deeper offshore waters. Upon maturity, sockeye salmon in the Pacific Northwest return to freshwater from June to August, peaking in early July (Emmett et al., 1991).

Adult sockeye salmon enter Puget Sound tributaries from mid-June through August, whereas Columbia River populations begin river entry in May. Salmon in Puget Sound spawn from late September to late December, sometimes into January, while salmon in the Columbia River spawn from late September to early November, with a small number of fish in the Cedar River spawning into February (Gustafson et al., 1997).

3.3.2.4.6 Steelhead Trout (*Oncorhynchus mykiss*)

The current distribution of steelhead trout ranges from central California to the Bering Sea and Bristol Bay coastal streams of Alaska and the Kamchatka Peninsula in Russia. Most streams in the Puget Sound region and many Columbia and Snake River tributaries have populations of steelhead trout present (Pauley et al., 1986). Steelhead trout exhibit one of the most complex life histories of any salmonid species. In the Pacific Northwest region*,* steelhead trout are split into two phylogenetic groups, inland and coastal steelheads (Busby et al., 1996). These two groups both occur in Washington, Oregon, and British Columbia waters (Busby et al. 1996) but are separated by the Columbia and Fraser tributary systems in the Cascade Mountains. Coastal steelheads occur in a diverse array of populations in Puget Sound, coastal Washington, and the lower Columbia River with modest genetic differences between populations (Busby et al., 1996). Inland steelhead trout are represented only by populations in the basins of the Columbia and Fraser Rivers, and consistent genetic differences have been found between populations in the Snake and Columbia Rivers (Busby et al., 1996).

Steelhead trout are divided into 15 DPSs, with the Southern California DPS listed as endangered and 10 other DPSs listed as threatened under the ESA, with the an additional DPS, the Oregon coast DPS, listed as a Species of Concern (NOAA, 2006a, 2007a). Critical habitat has been established for the 10 listed DPSs as inland and coastal river and stream habitat as well as marine habitat of California, Oregon, Washington, and Idaho (including Puget Sound) (NOAA, 2005). The population status of steelhead trout in the U.S. is variable, with some DPSs declining and some increasing. No overall abundance is available for the entire steelhead population.

Steelhead trout are capable of spawning more than once but most die after spawning twice (NOAA, 1997). North of Oregon, repeat spawning is uncommon, and more than two spawning migrations are rare. In Oregon and California, the frequency of two spawning migrations is higher, but more than two spawning migrations are rare. The largest number of spawning migrations known is five, which occurred in the Siuslaw River in Oregon. Steelheads may exhibit an anadromous life cycle during which they migrate as juveniles from freshwater habitats to the marine environment, returning to freshwater habitats to spawn (steelhead trout), or they may exhibit a freshwater residency life cycle, in which the fish spend their entire life in freshwater (rainbow trout). The relationship between the two life history types has not been well-studied (NOAA, 1997). Steelhead trout can also be divided into two biological or reproductive ecotypes[10], stream-maturing and ocean-maturing, which are differentiated by their state of sexual maturity at the time of river entry and the duration of their spawning migration. Stream-maturing steelhead are sexually immature when they enter freshwater from the ocean and require several months to mature and spawn while ocean-maturing steelhead are sexually mature when they freshwater and spawn thereafter. These two reproductive ecotypes are more commonly referred to by their season of freshwater entry (e.g., summer or fall steelhead). The stream-maturing type of steelhead trout is also known as the fall steelhead in Alaska and the summer steelhead in the Pacific Northwest and northern California. The ocean-maturing type is known as spring-run steelhead in Alaska and winter-run steelhead elsewhere, entering freshwater between November and April. In the Pacific Northwest, summer-run steelheads enter fresh water between May and October and winter steelheads enter fresh water between November and April (Busby et al., 1996).

Steelhead trout live as long as 11 years. Steelheads typically migrate to marine waters after spending two to four years in freshwater, but some juvenile steelheads have been known to live up to seven years in freshwater before migrating to the ocean. Males generally mature at two years of age with females maturing at three years. In marine waters, steelhead trout typically remain for two to three years prior to returning to their natal stream to spawn. Spawning migrations occur throughout the year and adults typically spawn between December and June (Busby et al., 1996). Some populations of trout actually

10 An ecotype is a locally adapted population of a widespread species that show minor morphological or physiological changes resulting from selection of a particular habitat and which are genetically induced.

return to freshwater after their first season in the ocean, but do not spawn in freshwater, and then return to the sea after one winter season in freshwater. Timing of return to the ocean can vary, and even within a stream system there can be different seasonal runs.

3.3.2.4.7 *Acipenser* (Sturgeon) Hearing and Vocalization Capabilities

No information is available on the hearing or vocalization abilities of the Gulf sturgeon but some limited information is available on other sturgeon species. Popper (2005) reported that studies measuring responses of the ear using physiological methods suggest that one sturgeon species likely can detect sounds from below 100 Hz to about 1 kHz, suggesting that sturgeon should be able to localize or determine the direction of origin of sound. Meyer and Popper (2002) recorded auditory evoked potentials of varying frequencies and intensities for lake sturgeon (*Acipenser fulvescens*) and found that lake sturgeon can detect pure tones from 100 Hz to 2 kHz, with best hearing sensitivity from 100 to 400 Hz. Lovell et al. (2005), using a combination of morphological and physiological techniques, determined that lake sturgeon were responsive to sounds ranging in frequency from 100 to 500 Hz, with the lowest hearing thresholds acquired from frequencies in a bandwidth of between 200 and 300 Hz; lake sturgeon do not appear to be sensitive to sound pressure.

Little information is available on sound production in the ESA-listed sturgeons, but information is available on the sound production capabilities of several other members of the sturgeon family. Lake sturgeon produce LF sounds during spawning bouts, principally consisting of drumming sounds that range from 5 to 8 Hz, but LF rumbles and hydrodynamic sounds as well as high frequency sounds have also been reported (Bocast et al., 2014). The pallid sturgeon (*Scaphirhynchus albus*) and shovelnose sturgeon (*S. albus*) are known to produce at least four types of sounds during the breeding season, ranging from squeaks and chirps from 1 to 2 kHz, with LF knocks and moans ranging in frequency between 90 and 400 Hz (Johnston and Phillips, 2003).

3.3.2.4.8 Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*)

Four DPSs of the Atlantic sturgeon are listed as endangered under the ESA (New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs) while one DPS, Gulf of Maine, is listed as threatened. NMFS and USFWS share jurisdiction over this anadromous, long-lived species. Although critical habitat is not currently designated for the Atlantic sturgeon, a total of 3,696 nmi (6,845 km) of riverine habitat of eastern U.S. coastal rivers has been proposed as critical habitat for all five DPSs of the Atlantic sturgeon (NOAA 2016e, NOAA, 2016f, NOAA, 2016g). The IUCN Red List designates the Atlantic sturgeon as near threatened (St. Pierre, 2006). No estimate is available for the entire Atlantic sturgeon population, but St. Pierre (2006) has suggested a likely overall population of 10,000 Atlantic sturgeons. Only two estimates of spawning populations have been reported, Peterson et al. (2000) estimating 4,600 wild Atlantic sturgeons occur in the Hudson River, NY (New York Bight DPS), while unpublished NMFS data show that 2,000 subadult Atlantic sturgeons have been captured in fishery research surveys in the Altamaha River, GA (South Atlantic DPS), which represents one of the healthiest subpopulations of Atlantic sturgeon in the southeast U.S. (NMFS, 2010).

The Atlantic sturgeon is distributed in river and marine waters along the eastern U.S. and Canadian coasts from Labrador to Atlantic Florida. In U.S. waters, Atlantic sturgeon migrate up rivers from estuaries and the Atlantic Ocean to spawn in late winter through spring, with most age classes returning to estuarine and marine environments following spawning. Recently, a second, fall spawning migration was documented in North Carolina and Georgia rivers (NOAA, 2016e). Atlantic sturgeon have been documented traveling long distances in oceanic waters, aggregate in both estuarine and marine waters during specific times of the year, and exhibit seasonal coastal migrations in the spring and fall (Vladykov and Greeley, 1963; Oliver et al., 2013).

3.3.2.4.9 Chinese Sturgeon (*Acipenser sinensis*)

Although some scholarly disagreement exists regarding the taxonomy of the two populations of this species, with some Chinese taxonomists dividing the species into Yangtze and Pearl River subpopulations (Qiwei, 2010), Chen (2007) reported that the Chinese sturgeon is extirpated from the Pearl River. The Chinese sturgeon is listed under the ESA as endangered throughout its range and is listed as critically endangered on the International Union for Conservation of Nature (IUCN)'s Red List of Threatened Species (Qiwei, 2010). No critical habitat will be designated for this species since its geographical range is entirely outside U.S. jurisdiction (NOAA, 2014b). Available data from acoustic surveys between 2005 and 2007 indicate that the total spawning population of Chinese sturgeon was 203 to 257 individuals, which was indicative of a 97.5 percent reduction in the total spawning population over a 37 year period (Qiwei, 2010).

Relatively long-lived (34 years), the Chinese sturgeon has the most southerly distribution of all sturgeons. Chinese sturgeons are anadromous fish that spawn in the middle to lower Yangtze River (below the Gezhouba and Three Gorges dams) in fall and winter and spend later lifestages in the nearshore marine waters of the Yellow and East China Seas. Prior to construction of the Gezhouba Dam in 1981, Chinese sturgeons migrated distances of 2,500 to 3,300 km (1,350 to 1,782 nmi) to spawn in the upper Yangtze River but have since been extirpated from the middle and upper reaches of the river by the construction of the Gezhouba and Three Gorges dams (Qiwei, 2010). Today, only one spawning area in the Yangtze River remains, a 4-km (2.1-nmi) region of the river below the Gezhouba dam (Qiwei, 2010). Habitat destruction and fragmentation (due to construction of dams), water pollution, overfishing, low reproductive productivity, inadequate protective regulations, and potential competition from introduced sturgeon species are the leading causes for this sturgeon's large population decline (Meadows and Coll, 2013).

3.3.2.4.10 Green Sturgeon (*Acipenser medirostris*)

The green sturgeon is the most widely distributed member of the sturgeon family, ranging in the northeastern Pacific Ocean from nearshore waters in Mexico to the Bering Sea, including inland river and bay systems; this fish occurs only rarely in the southern parts of their distributional range (Adams et al., 2002). Spawning only occurs in three river systems along the U.S. west coast, in the Klamath, Sacramento, and Rogue Rivers. Green sturgeon juveniles are found throughout the Delta and San Francisco Bay in small numbers but sometimes as many as one hundred. No adequate population estimates or population trend information are available for the green sturgeon, but the sturgeon is not an abundant species (Adams et al., 2002; NMFS, 2005).

Two DPS of the green sturgeon have been identified, a Northern and Southern DPS. The Southern green sturgeon DPS is listed as threatened under the ESA while the Northern DPS is listed as a species of concern. The Southern DPS is comprised of northern California coastal and Central Valley populations south of the Eel River (essentially including the Sacramento River and its tributaries, the Russian River, and the San Joaquin River), with the only known spawning population in the Sacramento River, while the Northern DPS includes populations in Northern California and Oregon coastal watersheds northward of and including the Eel River (NOAA, 2006). Critical habitat for the Southern green sturgeon DPS consists of 515 km (320 mi) of freshwater river habitat, 897 mi^2 (2,323 km^2) of estuarine habitat, 11,421 mi^2

(29,581 km^2) of marine habitat, 487 mi (784 km) of habitat in the Sacramento-San Joaquin Delta, and 135 mi^2 (350 km^2) of habitat within the Yolo and Sutter bypasses (Sacramento River, CA) (NOAA, 2009a).

Green sturgeons are anadromous, long-lived, slow-growing, and far-moving fish that are the most marine-oriented of the sturgeon species. Maximum ages of adult green sturgeon are likely to range from 60 to 70 years (Moyle, 2002). Green sturgeons are believed to spend the majority of their lives in nearshore oceanic waters, bays, and estuaries. Early life-history stages reside in freshwater for one to three years, with adults returning to freshwater to spawn every three to five years when males are more than 15 years of age and females are 20 to 25 years old (Nakamoto et al., 1995; Van Eenennaam and Doroshov, 2001). Green sturgeons are thought to spawn every two to five years from March to July, with a peak in mid-April to mid-June (Tracy, 1990; Moyle, 2002). These sturgeons disperse widely in the ocean after migrating from freshwater and move northward along the coast. Spawning in the Southern DPS occurs only in the upper Sacramento River that is still available to the fish (NMFS, 2005).

3.3.2.4.11 Gulf Sturgeon (*Acipenser oxyrinchus desotoi*)

In 1991, the Gulf sturgeon was listed under the ESA as threatened throughout its entire Gulf of Mexico range (Florida, Alabama, Louisiana, and Mississippi). Since the Gulf sturgeon is anadromous, NMFS and the USFWS share jurisdiction. NMFS has jurisdiction over marine habitats but both agencies share jurisdiction for estuarine habitats (USFWS and NMFS, 2003). Critical habitat was designated in 14 geographic areas (seven riverine and seven estuarine/marine) along the coasts of Florida, Alabama, Mississippi, and Louisiana in 2003 that encompassed approximately 2,783 km of rivers and tributaries and 6,042 km^2 of estuarine and marine habitat (USFWS and NMFS, 2003). The Gulf sturgeon is also designated as near threatened on the IUCN Red List (St. Pierre and Parauka, 2006). No estimate of the entire Gulf sturgeon population is available, but summing counts of reproducing Gulf sturgeon in seven rivers results in an estimated 20,000 individuals (USFWS and NMFS, 2009). Since sturgeon don't spawn every year, counts from spawning rivers can result in highly variable results. In the Suwanee River, FL, the annual population fluctuated from 2,097 to 5,312 over the 10-year period from 1987 through 1996 (Chapman et al., 1997).

The Gulf sturgeon occurs furthest south of all sturgeon species. The current range of the Gulf sturgeon extends from the north-central to northeastern Gulf of Mexico from about the Mississippi River to Tampa Bay, FL and includes most major river systems in this range. Gulf sturgeons migrate seasonally in spring from estuarine or Gulf of Mexico waters to its natal river habitat in preparation for spawning, and returns to the gulf and estuarine habitats in fall, with all but young-of-the-year age classes having entered gulf waters by December (Heise et al., 2004).

3.3.2.4.12 Sakhalin Sturgeon (*Acipenser mikadoi*)

Endangered throughout its range under ESA, the Sakhalin sturgeon is listed as critically endangered on the IUCN's Red List of Threatened Species (Mugue, 2010). No critical habitat will be designated for this species since its geographical range is entirely outside U.S. jurisdiction (NOAA, 2014b). Apparently never abundant, the population size of Sakhalin sturgeon has been declining for over 100 years to the extent that now only a few sturgeons are observed each year. The most current population estimate ranges from 10 to 30 adults entering the Tumnin River, Russia to spawn annually, with only three Sakhalin sturgeon caught in 2005 and two in 2008 (Mugue, 2010). Introduced into the Amur River estuary, five to 10 Sakhalin sturgeons are caught annually (Meadows and Coll, 2013).

The Sakhalin sturgeon, an anadromous fish that lives about 20 years, spends most of its lifestages in marine waters of the Sea of Japan as far south as the eastern shores of Hokkaido, Japan and Wonsan, North Korea; Sea of Okhotsk; and the northwestern Pacific Ocean along the coast of Russia to the Bering Strait; migrating to fresh water to spawn, principally now only in the Tumnin River, Russia, but rare adults have been observed in the Viyakhtu and Koppi rivers, Russia (Shmigirilov et al., 2007). Japanese researchers believe the Sakhalin sturgeon to be extinct in Hokkaido, Japan (Omoto et al., 2004). Illegal poaching during spawning migration, habitat degradation due to water pollution and the construction of dams, fisheries bycatch, inadequate protective regulations, and low reproductive productivity are chief causes of this sturgeon's declining population (Mugue, 2010; Meadows and Coll, 2013).

3.3.2.4.13 Scalloped Hammerhead Shark (*Sphyrna lewini*)

The scalloped hammerhead shark is listed under the ESA, with the Eastern Atlantic and Eastern Pacific DPSs listed as endangered and the Central and Southwest Atlantic and Indo-West Pacific DPSs listed as threatened. Based on the known geographic range of the species and genetic studies, the Indo-West Pacific DPS is bounded to the south by 36° S; to the north by 40° N; to the west by 20° E; and to the east, the boundary line extends from 130° W due north to 4° S, due west to 150° W, and then due north to 10° N (NOAA, 2014c). NMFS has not yet designated critical habitat for the scalloped hammerhead shark (NOAA, 2014c). The IUCN's Red List of Threatened Species lists the scalloped hammerhead shark as endangered (Baum et al., 2007). No global estimates for the scalloped hammerhead shark are available, but where fisheries catch data are available, significant population declines have been shown, with suggestions of decreases in abundance of 50 to 90 percent over 32 year periods in some parts of the species range (Baum et al., 2007). Clarke et al. (2006) estimated from Asian shark fin market data and statistical analysis that from 1 to 3 million hammerhead sharks (*Sphyrna* spp.) are traded per year. Due to the extensive areal extent and complexity of the Indo-West Pacific DPS, NMFS estimates that although it is still observed throughout the entirety of the DPS range, there are likely to be multiple patterns of declining abundance within the DPS (NOAA, 2014c). For example, in Australian waters, the abundance of the scalloped hammerhead shark has declined about 58 to 85 percent (Heupel and McAuley, 2007); off South Africa, from 1978 to 2003, the catch per unit effort (CPUE) declined 64 percent (Baum et al., 2007); and decreases in CPUE in Papua New Guinea and Indonesia suggests localized population declines (NOAA, 2014c).

The scalloped hammerhead shark is a coastal and semi-oceanic species with a circumglobal distribution in warm-temperate to tropical coastal and oceanic waters, including bays and estuaries, to water depths as deep as 902 ft (275 m), with occasional dives to even deeper depths (1,680 ft [512 m]) (Compagno, 1984; Compagno, 2005; Jorgensen et al., 2009). Scalloped hammerheads are highly mobile and partially migratory (Maguire et al., 2006). In the western Pacific Ocean, the scalloped hammerhead shark occurs in the waters of Thailand, Vietnam, Indonesia, China, Japan, Philippines, Australia (Queensland, Western Australia), and New Caledonia (Compagno et al., 2005). Tagging and genetic studies indicate wide-ranging movements and occasional long-distance dispersals in waters with similar oceanographic conditions, but DPSs are isolated by bathymetric barriers and oceanographic conditions (NOAA, 2014c). The greatest threats to the Indo-West Pacific DPS is from overfishing, especially for its fins; illegal fishing; fisheries bycatch; habitat degradation; and inadequate protective regulations and weak enforcement in some parts of the DPS' range (Miller et al., 2014).

Sharks have no organs for producing sound and apparently do not communicate with sound. Data on shark hearing are limited and in need of additional experimental replication and expansion to include more species. Generally, elasmobranch species are able to detect LF sounds from ~20 Hz to 1 kHz, with similar thresholds for all measured species above 100 Hz (Casper and Mann, 2009). Sound appears to be sensed solely through particle motion (Myrberg, 2001), and Casper and Mann (2009) noted that because elasmobranchs do not possess swim bladders or other air filled cavities that they are not capable of detecting sound pressure. Nelson and Gruber (1963) reported that free-ranging sharks, including hammerheads, were attracted to LF sounds of <60 Hz that were rapidly and irregularly pulsed, as these sounds represented the vibrations caused by struggling prey. Some actively swimming, fish-eating sharks such as lemon and Atlantic sharpnose sharks have most hearing below 100 Hz, suggesting that hearing may be more important than other senses in the detection of prey for some species (Casper et al., 2012). Very sparse data on hearing in hammerhead sharks is available; Olla (1962) observed that hammerheads were able to detect sounds below 750 Hz, with best sensitivity from 250 to 275 Hz.

3.3.2.4.14 Pacific Eulachon (*Thaleichthys pacificus*)

The Pacific eulachon, also known as smelt or candlefish, occurs only in the northeastern Pacific Ocean in waters from northern California to the southeastern Bering Sea (Hay and McCarter, 2000). Eulachon only spawn in a limited number of rivers in this range, principally those with a pronounced spring run-off (Beacham et al., 2005). In continental U.S. waters, the majority of eulachon have been observed in the Columbia River Basin but are also known to occur in the Sacramento, Russian, Klamath, Rogue, and Umpqua Rivers and Humboldt Bay in Oregon and northern California, as well as smaller coastal rivers (e.g., Mad River), and infrequently in coastal rivers and tributaries to Puget Sound, Washington. However, populations of eulachon in the Klamath, Mad, and Sacramento Rivers are considered to be extirpated or nearly so. While in at sea, eulachon occur in nearshore ocean waters as well as pelagic waters to 1,000 ft (300 m) in depth. There is considerable interannual variability in the abundance of eulachon, but the spawning populations from California to southeastern Alaska have declined in the past 20 years, especially since the mid 1990s (Hay and McCarter, 2000).

The Southern DPS includes Pacific eulachon in the waters from the Skeena River in British Columbia (inclusive) south to the Mad River in Northern California (inclusive) (NOAA, 2010a). This Southern DPS is listed as threatened under the ESA. Critical habitat for the Pacific eulachon has been proposed in 12 specific areas within the states of California, Oregon, and Washington. The proposed critical habitat areas are a combination of freshwater creeks and rivers from the Mad River in northern California to the Elwha River in Washington and their associated estuaries, which comprise approximately 292 mi (470 km) of habitat (NOAA, 2011).

Eulachon are anadromous, spawning in the lower reaches of rivers and moving to the sea as small, pelagic larvae. Although Pacific eulachon spawn in freshwater rivers and streams, they are principally considered a marine fish as they spend 95 percent of their lives in the marine environment; the early lifestages of this species develop in freshwater for about 4 weeks with another 4 weeks spent spawning as adults in natal freshwater rivers (Hay and McCarter, 2000). Eulachon spend from two to five years in the ocean maturing to before returning to spawn in natal tributaries, with most of the fish dying after spawning. Spawning usually begins in January or February in southern rivers such as the Columbia River and extends into June in northern Alaskan rivers; although, within specific river drainages, eulachons generally have a characteristic timing for spawning (Beacham et al., 2005).

3.3.3 Potentially Affected Sea Turtles

Seven species of living marine turtles are distributed circumglobally in the Atlantic, Pacific, and Indian Oceans and throughout the Caribbean and Mediterranean Seas. The distributions of these species span tropical and temperate waters and, in the case of the leatherback turtle (Dermochelys coriacea), extends northward to the subarctic and as far south as New Zealand and the Southern Ocean. All sea turtles are protected under Appendix I of the Convention on International Trade in Endangered Species

Table 3-2. Sea Turtle Species Evaluated for Potential Effects in this SEIS/SOEIS Associated with Exposure to SURTASS LFA Sonar and their Status Under the ESA. Species Listed in Alphabetical Order by Family.

Family	***Species***	***ESA Status***	
		Threatened	***Endangered***
Cheloniidae	Flatback turtle (*Natador depressus*)	Foreign Species; Not Listed	
	Green turtle (*Chelonia mydas)*	Central South Pacific DPS	Central North Pacific DPS
		Central West Pacific DPS	East Indian-West Pacific DPS
		Mediterranean DPS	Southwest Pacific DPS
			East Pacific DPS
			North Atlantic DPS
			Southwest Indian DPS
			North Indian DPS
			South Atlantic DPS
	Hawksbill turtle (*Eretmochelys imbricata)*		Throughout Range
	Kemp's ridley turtle (*Lepidochelys kempii)*		Throughout Range
	Loggerhead turtle (*Caretta caretta*)	Northwest Atlantic Ocean DPS	Northeast Atlantic Ocean DPS
		South Atlantic Ocean DPS	Mediterranean Sea DPS
		Southeast Indo-Pacific Ocean DPS	North Indian Ocean DPS
		Southwest Indian Ocean DPS	North Pacific Ocean DPS
			South Pacific Ocean DPS
	Olive ridley turtle (*Lepidochelys olivacea)*	All Other Populations	Pacific Coast of Mexico (Breeding Population)
Dermochelyidae	Leatherback turtle (*Dermochelys coriacea)*		Throughout Range

of Flora and Fauna (CITES), which prohibits international trade to and from signatory countries. Six of the seven sea turtle species are listed under the ESA as threatened and/or endangered (Table 3-2). The seventh sea turtle species, the flatback turtle (*Natator depressus*), is not listed under the ESA as its distribution is restricted to coastal waters off Australia, Papua New Guinea, and Guinea. In addition, the IUCN considers the Kemp's ridley and hawksbill turtles to be critically endangered, the green turtle to be endangered, the olive ridley, loggerhead and Leatherback turtles to be vulnerable, and the flatback turtle to be data deficient (IUCN, 2015).

3.3.3.1 Sea Turtle Hearing Capabilities

There are only very limited data on sea turtle sound production and hearing. A few data are available about the mechanism of sound detection by sea turtles, including the pathway by which sound gets to the inner ear and the structure and function of the inner ear (Bartol, 2008; Bartol and Musick, 2003; Bartol et al., 1999; Ketten, 2008). Additional assumptions have been made about sea turtle hearing based on research on terrestrial species. Based on the structure of the inner ear, there is some evidence to suggest that marine turtles primarily hear LF sounds, and this hypothesis is supported by the limited amount of physiological data on turtle hearing (e.g., Ketten and Bartol, 2006; Bartol, 2008). A description of the ear and hearing mechanisms can be found in Bartol and Musick (2003) (see also Ketten, 2008).

The few studies completed on the auditory capabilities of sea turtles suggest that they could be capable of hearing LF sounds. Studies completed on the auditory capabilities of green, loggerhead, Kemp's ridley, and leatherback turtles suggest that they could be capable of hearing LF sounds. Electrophysiological studies on hearing have been conducted on juvenile green turtles (Ridgway et al., 1969; Bartol and Ketten, 2006; Dow Piniak et al., 2012a), juvenile Kemp's ridley turtles (Bartol and Ketten, 2006), post-hatchling, juvenile, and adult loggerhead turtles (Bartol et al., 1999; Lavender et al., 2011, 2012; Martin et al., 2012), and hatchling leatherback turtles (Dow Piniak et al., 2012b). No published studies to date have reported audiograms of olive ridley or hawksbill turtles (Ridgway et al., 1969; O'Hara and Wilcox, 1990; Bartol et al., 1999). Additional investigations have examined adult green, loggerhead, and Kemp's ridley sea turtles (Mrosovsky, 1972; O'Hara and Wilcox., 1990). Ridgway et al. (1969) used airborne and direct mechanical stimulation to measure the cochlear response in three juvenile green sea turtles in air. The study concluded that the maximum sensitivity for one animal was 300 Hz, and for another 400 Hz. At 400 Hz, the turtle's hearing threshold was about 64 dB (re: 20 µPa). At 70 Hz, it was about 70 dB (re: 20 µPa). Sensitivity decreased rapidly in the lower and higher frequencies. From 30 to 80 Hz, the rate of sensitivity declined approximately 35 dB. However, these studies were done in air, up to a maximum of 1 kHz, and thresholds were not meaningful since they only measured responses of the ear; moreover, they were not calibrated in terms of pressure levels.

Bartol et al. (1999) measured the hearing of juvenile loggerhead sea turtles using auditory evoked potentials (AEP)[11] to LF tone bursts; the authors found the range of hearing via AEP to be from at least 250 to 750 Hz. The lowest frequency tested was 250 Hz and the highest was 1,000 Hz. However, an ONR-funded study provides the underwater hearing range and hearing sensitivity for loggerhead, green, and Kemp's ridley turtles of different ages (Figure 3-6) (Ketten and Bartol, 2006). The investigators found that all three turtle species detected sounds to as low as 100 Hz (the lower limit of hearing tested but not necessarily the lowest frequency that the animals could hear) while maximum hearing was to 900 Hz. These data support the earlier results of in-air studies cited above. Interestingly, the widest hearing range (to 900 Hz) was in the hatchling loggerheads, the smallest animals tested. There is some evidence from this study that older animals did not detect higher frequencies as well as the hatchlings, a loss that is found in many terrestrial animals and marine mammals as they age. In older animals, the authors

11 AEP is a non-invasive method in which the brain's response to sound is recorded. The advantages of using the AEP method are animals do not have to be trained to make a response (which can take days or weeks), it can be used on an animal that is unable to move, and results can be obtained within a few minutes of the sound exposure. The disadvantage of AEP is that they are a measure strictly of the sound that is detectable by the ear, without any of the sophisticated processing provided by the nervous system of any vertebrate. However, AEP does give an excellent indication of basic hearing loss and is an ideal method to quickly determine if hearing loss has occurred when results are compared to control animals with no sound exposure.

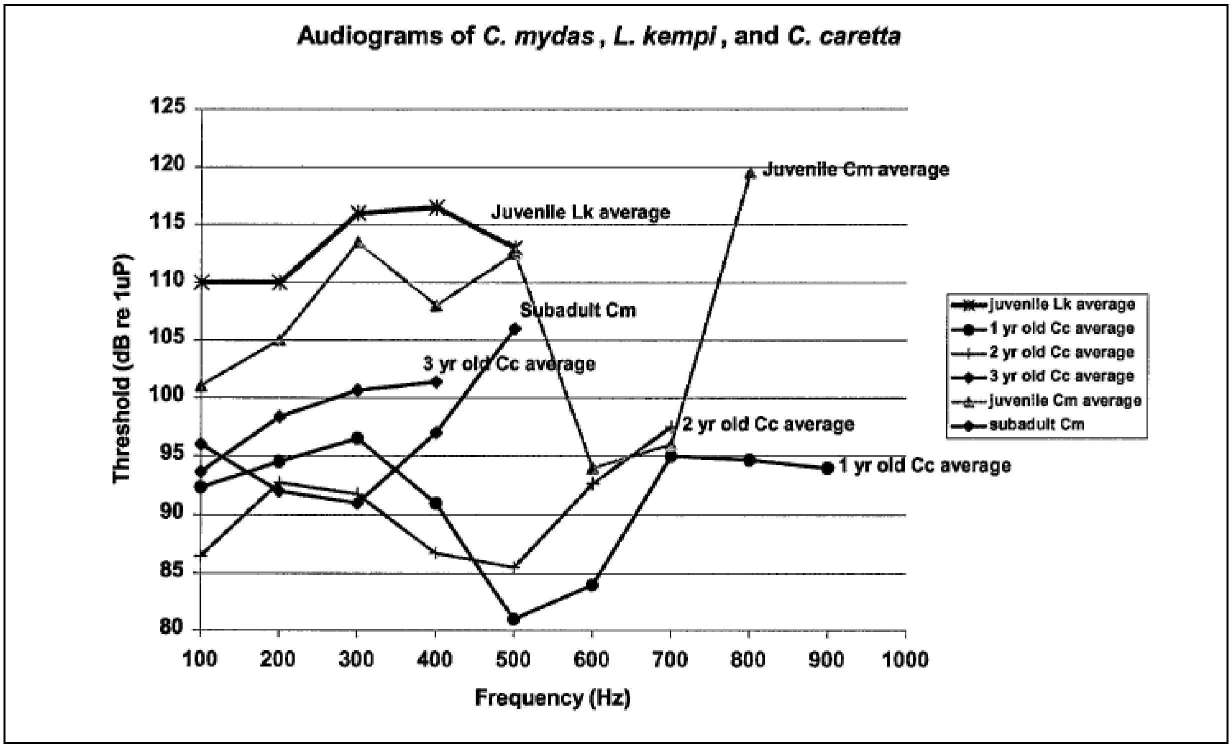


Figure 3-6. Auditory Evoked Potential Audiograms of Juvenile Kemp's Ridley (Lk), Juvenile and Subadult Green (Cm), as well as Hatchling and Juvenile Loggerhead (Cc) Turtles (Ketten And Bartol, 2006).

found that two year old loggerheads responded (with AEP responses) to sounds from 100 to 700 Hz, while three year old animals responded to sounds from 100 to 400 Hz. Similar age/size range changes were encountered in green sea turtles (Figure 3-6). The juvenile Kemp's ridley had the narrowest hearing range, from 100 to 500 Hz, with best hearing from 100 to 200 Hz.

Several caveats should be noted on the Ketten and Bartol (2006) and Dow Piniak et al. (2012) data, however. First, as with all AEP-derived data, these data do not necessarily represent the full hearing range or hearing sensitivity of the animals, as would be obtained in behavioral tests where animals are "asked" to respond to a sound and where the complete nervous system is used to process signals.

Second, the data on changes with age suggest that results for older and larger animals may be rather different than the younger animals and this may have important consequences for detection, or non-detection, of anthropogenic sounds. These concerns have been illustrated, and partially answered in a study conducted by Martin et al. (2012). They produced both behavioral and AEP audiograms for a single turtle. As is typical for marine mammal studies, the behavioral threshold was lower than that derived by AEP. The mean difference was 8 dB. However the difference was not uniform. At 50 Hz, they were able to determine a behavioral hearing threshold, while AEP techniques could not detect one. Furthermore the larger differences were at low frequencies, while the differences at and above 400 Hz were quite small (Figure 3-7). If this study is representative of other individuals and species, it does suggest that the AEP results are underestimating the low-frequency hearing sensitivity of sea turtles. While AEP data are of importance, more comprehensive data on turtle hearing, such as ability to detect signals in the

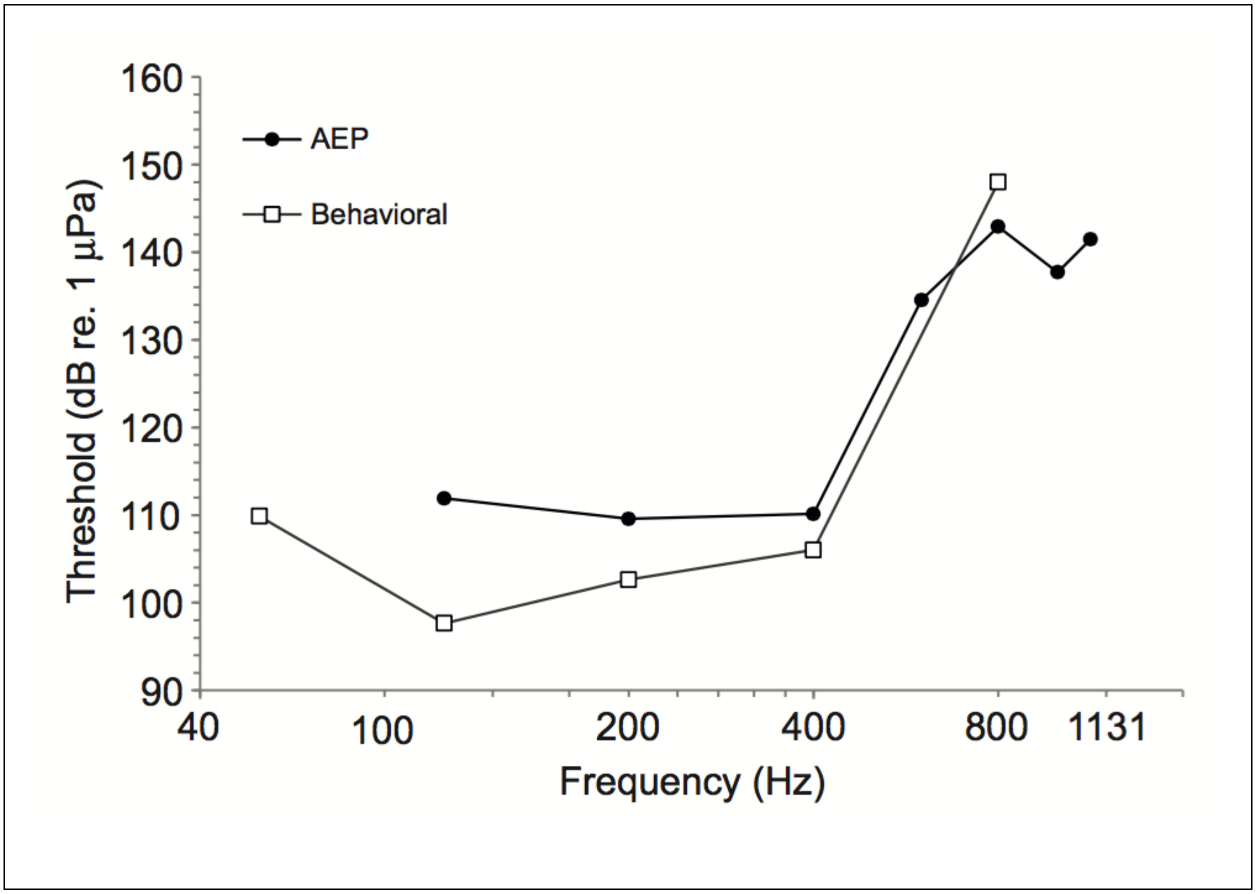


Figure 3-7. AEP and Behavioral Audiograms for the Same Loggerhead Turtle are Shown (Martin et al. 2012). The Behavioral Audiogram is ss Much as 14 Db Lower than the AEP-Derived Audiogram. The Differences are Particularly Notable at the Lower Frequencies.

presence of noise and ability to detect signal direction, are of great importance in understanding the behavioral effects of sound on turtles.

Lavender et al. (2011, 2012) recorded underwater AEP's from post-hatchlings to juvenile loggerhead turtles, with both age classes responding to frequencies between 50 Hz and 1.1 kHz. Post-hatchlings responded with the greatest sensitivity at 200 Hz (116 dB re 1 µPa), and juveniles were most sensitive at 50, 100, and 400 Hz (117 to 118 dB re 1 µPa) (Lavender et al., 2011 and 2012). Martin et al. (2012) acquired AEP's from a single adult loggerhead and reported thresholds between 100 Hz and 1.13 kHz, with the highest sensitivity occurring from 100 to 400 Hz (threshold levels approximately 109 dB re 1 µPa). Lavender et al. (2014) recently reported that in hearing assessments of post-hatchling and juvenile loggerhead turtles using both behavior-derived and AEP-derived auditory thresholds, no significant differences were detected, but both post-hatchlings and juveniles had significantly higher AEP-derived than behavior-derived auditory thresholds, indicating that behavioral assessment is a more sensitive testing approach. These experimental results suggest that post-hatchling and juvenile loggerhead sea turtles are LF hearing specialists, exhibiting little differences in threshold sensitivity or frequency bandwidth (Lavender et al., 2014).

It is questionable whether sufficient data exist on anthropogenic sounds in the normal ambient environment of sea turtles to suggest that hearing might be masked. While there are no masking studies on marine turtles, an indirect study looked at the potential for masking by examining sounds in an area known to be inhabited by turtles. These underwater sound recordings were made in one of the major coastal foraging areas for juvenile sea turtles (mostly loggerhead, Kemp's ridley and green sea turtles) in the Peconic Bay Estuary system in Long Island, NY (Samuel et al., 2005). The recording season of the underwater environment coincided with the sea turtle activity season in an inshore area where there is considerable boating and recreational activity, especially during the July to September timeframe.

During this time period, RLs at the data collection hydrophone system in the 200 to 700 Hz band ranged from 83 dB (night) up to 113 dB (weekend day). Therefore, during much of the season when sea turtles are actively foraging in New York waters, they are undoubtedly exposed to these levels of noise, most of which is anthropogenic in origin. However, there were no data collected on any behavioral changes in the sea turtles as a consequence of anthropogenic noise or otherwise during this study and so it cannot be stated whether this level of ambient sound would have any physiological and/or behavioral impacts on the turtles.

3.3.3.2 Sea Turtle Sound Production and Acoustic Communication

Very little is known about sound production or use of sound in communication by marine turtles (reviewed in Giles et al., 2009). There is evidence that some species produce sounds when they come onto a beach to mate, but there apparently is no clear evidence for the biological importance of such sounds. More importantly, there are no data on underwater sound production by marine turtles.

Leatherback sea turtles are known to vocalize in air (Mrosovsky, 1972), but there are no recordings of them underwater. The most germane data comes from a study of the underwater repertoire of the long-necked freshwater turtle, *Chelodina oblonga* (Giles et al., 2009), and it is not clear if the results of this study have relevance to marine species. In the study, Giles et al. (2009) found that Chelodina produces at least 17 different sounds, and concludes that this species uses sound to communicate since the range of visibility in their aquatic habitats is very limited. The investigators found that call length ranged from less than a tenth of a second to several seconds. All calls contained broadband energy, some starting at 100 Hz and some going to 3.5 kHz. The authors noted some energy in clicks to over 20 kHz (the upper limit of their recording equipment).

Interestingly, this range of frequencies does not overlap well with the hearing range of most turtles studied to date, all of which appear not to hear sounds above about 900 Hz (Bartol, 1999; Ketten and Bartol, 2006). However, there are no hearing data on Chelodina and it is possible that this species, which lives in shallow water, would adapt to hearing higher frequency sounds due to the limitations on transmission of lower frequencies in shallow waters (Rogers and Cox, 1988). This would be similar to evolution of higher frequency hearing in freshwater fishes living in shallow water (Popper et al., 2003).

One reason for the ability of Giles et al. (2009) to get data on Chelodina is that it lives in shallow freshwater areas. Comparable data are needed on truly marine turtles, and it is not clear that the data from Chelodina may give guidance on sound production in marine species. However, these data provide the first quantitative information on sound production in any turtle in an aquatic environment, and suggest that marine species might have evolved use of sounds for communication.

3.3.3.3 Sea Turtle Population Estimates

Population sizes or abundances of sea turtles are generally derived worldwide from estimates of breeding females as they return to shore to nest, when they are more visible and easily counted. Even the best available sea turtle population estimates derived from nest counts, however, always under-estimate sea turtle populations, as they only represent counts of nesting females on nesting beaches and do not account for non-nesting females, males, or juveniles of the species. Unless otherwise noted herein, sea turtle abundances are counts of nesting females. Nearly all species of sea turtles occur in low numbers over most of their ranges, resulting in distributions in the open ocean environment that are greatly dispersed and often are only present seasonally when turtles may be transiting between nesting and foraging grounds. Few density data are available for sea turtles, except for some densities estimated at nesting beaches.

3.3.3.4 Flatback turtle (*Natador depressus*)

The flatback turtle is listed under Appendix 1 of CITES, is considered data deficient by the IUCN, and is not listed under the ESA. Since this species is currently listed as data deficient by the IUCN, no species' status can be correctly assessed. No estimate of the overall flatback turtle population size is available. Whiting et al. (2009) estimated an annual abundance of 3,250 flatback turtles at Cape Domett, Western Australia, and Sutherland and Sutherland. (2003) estimated that 4,234 flatback female turtles came ashore at one the largest flatback rookeries on Crab Island, Australia during the austral winter in 1997. These abundances are the only estimates available for two of the four flatback genetic stocks in Australia.

Flatback turtles have the most restricted distributional range of all sea turtle species. Flatback turtles occur principally in habitats with soft sediments throughout the continental shelf waters of northern Australia (including the waters off Western Australia, Northern Territory, and Queensland), Papua New Guinea, and Papua, Indonesia and are not found elsewhere in the world (Limpus, 2007). Flatback turtles do not have a pelagic or oceanic lifestage, which is thought to be the cause for this species remaining endemic to Australia and parts of southern Indonesia (Walker and Parmenter, 1990). Nesting only occurs along the coast of northern Australia. Once thought to be non-migratory, tagged flatback turtles have been recorded moving up to 702 nmi (1,300 km) between nesting beaches in northern Australia to foraging areas in Indonesia (southern Irian Jaya) (Limpus et al., 1983). Nesting occurs year-round at some beaches but only seasonally at other rookeries.

Very little is known about the diving or swimming behavior of the flatback turtle. Sperling (2007 and 2008) found that flatback turtles spend about 10 percent of their time at or near the water's surface; dive as deep as 98 ft (30 m); and dive for long periods of time, with a mean dive duration of 50 min and a maximum of 98 min. Sperling (2008) also discovered two apparent distinct dive types for flatback turtles that had not been described for other turtle species, which accounted for 2 to 5 percent of the dives the tagged turtles made during the study

3.3.3.5 Green Turtle (*Chelonia mydas)*

The green turtle as a species has been listed as threatened under the ESA throughout its range since 1978, with the exception of the breeding populations in Florida and the Mexican Pacific coast, which were listed as endangered. In 2016, these range-wide and breeding population listings were replaced by the designation of 11 green turtle DPSs (NOAA, 2016b). Three DPSs were listed as endangered (Central

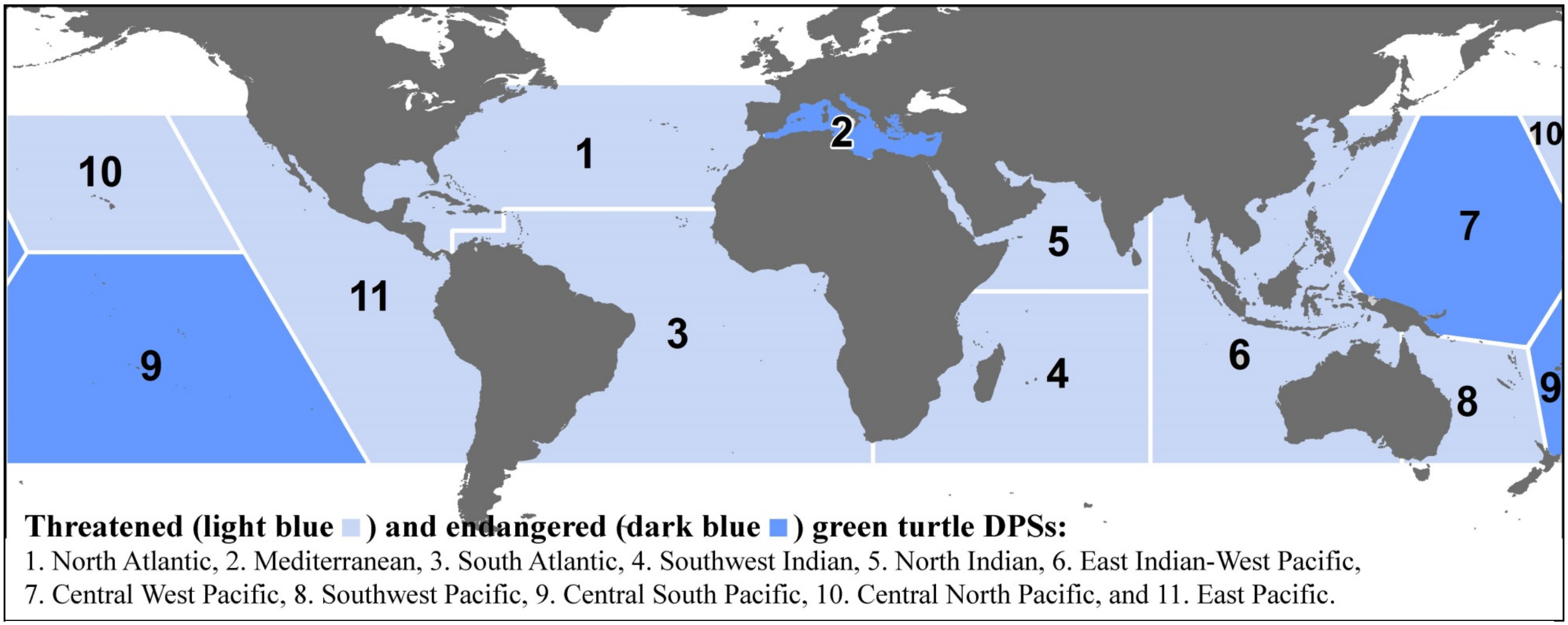


Figure 3-8. Global Distribution of the Threatened and Endangered Distinct Population Segments (Dpss) Under the ESA for the Green Turtle (NOAA, 2016b).

South Pacific, Central West Pacific, and Mediterranean DPSs) with eight DPSs listed as threatened (Table 3-2; Figure 3-8[12]). Critical habitat under the ESA was established in 1998 in the coastal waters around Culebra Island, Puerto Rico and its outlying keys from the mean high water line seaward to 3 nmi (5.6 km); this critical habitat remains in effect for the North Atlantic DPS. NMFS has determined that additional critical habitat is not determinable at this time (NOAA, 2016b). The green turtle is protected under CITES and is listed as endangered by the IUCN.

No complete global population estimates exist for the green turtle. Due to the difficulty observing and censusing sea turtles at sea, worldwide or even localized population sizes or abundances of sea turtles are generally derived from estimates of the number of breeding females as they come ashore to nest, when they are more visible and easily counted, or of the number of nests at each nesting beach. Although these abundances represent underestimations of the sea turtle populations as they do not include counts of male or juvenile turtles, they are the best available abundance data available. By summing the nesting abundances estimated for each green turtle DPS, the best estimate of the global population of green turtles is 570,926 turtles (NOAA, 2016b; Table 3-3). The largest nesting populations occur at Tortuguero, on the Caribbean coast of Costa Rica, where 22,500 females nest per season on average and Raine Island in the Great Barrier Reef, Australia, where 18,000 females nest per season on average (Seminoff et al., 2015). Green turtles occur year-round in the Commonwealth of the Northern Mariana Islands of Tinian and Pagan with resident populations of juveniles, and an estimated abundance of 795 to 1,107 green turtles occurring in the waters around Tinian and 297 green turtles estimated in Pagan waters, where 97 percent of that number is composed of juveniles and subadults (DoN, 2014). Nesting of green turtles occurs only on Tinian Island from February through August with highest nesting occurring at Unai Dankulo beaches (DoN, 2014).

Table 3-3. Green Turtle Global Nesting Abundances by DPS and Total Green Turtle Global Nesting Abundance (Seminoff et al., 2015).

Green Turtle DPS	*Nesting Abundance*
North Atlantic	167,424
Mediterranean	698[13]
South Atlantic	63,332
Southwest Indian	91,059
North Indian	55,243
East Indian-West Pacific	77,009
Central West Pacific	6,518
Southwest Pacific	83,058
Central South Pacific	2,677
Central North Pacific	3,846
East Pacific	20,062
Total	570,926

12 The DPS ranges depicted in Figure 3-8 correspond to the nesting beach ranges for each DPS.

13 Median value

Green turtles are widespread throughout tropical and subtropical waters of the Atlantic, Pacific, and Indian Oceans but have been recorded as far north as the temperate waters of Cape Cod and Georges Bank in the northwestern Atlantic Ocean (DoN, 2005; Lazell, 1980). These turtles inhabit the neritic zone, typically occurring in nearshore and inshore waters where they forage primarily on sea grasses and algae (Mortimer, 1982). Green turtles primarily occur in coastal regions as juveniles and adults but make long pelagic migrations, swimming thousands of kilometers across the open ocean, between foraging and nesting grounds (Bjorndal, 1997; Pritchard, 1997). However, during the time period between nesting, they are likely to remain nearby. Blanco et al. (2013) found that the mean time between nesting was 12 days and they stayed within 8 nmi (15 km) of the original nest.

Green turtles typically make shallow dive to no more than 98 ft (30 m) (Blanco et al., 2013; Hays et al., 2000; Hochscheid et al., 1999) with a maximum recorded dive to 361 ft (110 m) in the Pacific Ocean (Berkson, 1967). Migrating turtles in Hawaii had a strong diurnal pattern, with maximum dive depths during the day of 13 ft (4 m), while diving deeper than 44.3 ft (13.5 m) at night (Rice and Balazs, 2008). Most dives of green turtles are typically 9 to 23 min in duration with a maximum dive having been recorded at 66 min (Brill et al., 1995). Godley et al. (2002) reported travel speeds for three individuals in nesting, open-ocean, and coastal areas. Speeds ranged from 0.35 to 3 knots (kt) (0.6 to 2.8 kilometers per hour [kph]).

3.3.3.6 Hawksbill Turtle (*Eretmochelys imbricata*)

The hawksbill turtle is listed as critically endangered under the (International Union for the Conservation of Nature and Natural Resources (IUCN), 2015), endangered throughout its range under the ESA, and is protected by CITES. Critical habitat for the hawksbill turtle has been established in the Caribbean Sea coastal waters surrounding Mona and Monito Islands, Puerto Rico from the mean high water line seaward 3 nmi (5.6 km) (NOAA), 1998).

Although there is a lack of data to determine good population estimates, the best estimate of the number of annual nesting females worldwide is 22,004 to 29,035 turtles, which represents about 88 nesting areas (NMFS and USFWS, 2013). The largest nesting populations in the Pacific Ocean occurs in eastern Australia, with some 6,500 females nesting per year; while in the Atlantic Ocean, an estimated 534 to 891 and 400 to 833 females nested on the Yucatan Peninsula, Mexico and Cuba, respectively; and in the Indian Ocean, about 2,000 females nest in western Australia and 1,000 nest in Madagascar annually (NMFS and USFWS, 2013). Although very few hawksbills nest in U.S. waters, nesting does occur on four Puerto Rico locations (341 to 636 female turtles annually), U.S. Virgin Islands (76 to 287 females annually), Hawaii (<20 females annually), and fewer than 10 females annually in the north Pacific U.S. territories (NMFS and USFWS, 2013; Spotila, 2004). Juvenile populations of hawksbill turtles occur year-round in the waters of the Commonwealth of Northern Mariana Islands of Pagan and Tinian, although no nesting occurs on the beaches of these islands (DoN, 2014). The population of principally juvenile and subadult hawksbill turtles was estimated as 151 turtles around Pagan Island, while 50 to 71 hawksbill turtles occur around Tinian Island (DoN, 2014).

Hawksbill turtles occur in coastal tropical and subtropical waters in the Atlantic, Pacific, and Indian Oceans (NMFS and USFWS, 2013), and are especially in often encountered in shallow lagoons and coral reefs. The largest populations live in the Caribbean Sea, the Seychelles, Indonesia, and Australia. There are no hawksbills in the Mediterranean Sea (Spotila, 2004). In the western Atlantic, they range from Brazil to Massachusetts, but are considered rare north of Virginia (Wynne and Schwartz, 1999). They tend to remain in shallow water of 66 to 164 ft (20 to 50 m) but make the longest routine dives of all sea turtles, with routine dives ranging from 34 to 74 min (Starbird et al., 1999).

Hawksbills were once thought to be non-migratory residents of reefs adjacent to their nesting beaches, but recent tagging, telemetry, and genetic studies confirm that hawksbills migrate hundreds to thousands of kilometers between feeding and nesting grounds (Plotkin, 2003). While the migratory habits of hawksbills are still largely unknown, it appears that, like many of the hard-shelled turtles, hawksbill turtle hatchlings spend their “lost years” associated with Sargassum mats in the open ocean, driven there by the prevailing currents. Then, at about three years of age, they swim toward shore and settle on a suitable foraging site. Juveniles remain at these sites until they are reproductively mature, then females migrate back to their natal No apparent patterns have emerged to explain why some females migrate short distances, while others bypass reefs close to their nesting beaches and migrate greater distances (Plotkin, 2003; Spotila, 2004).

Hawksbills appear to have at least two dive types, a shallow diver and a deep diver (Blumenthal et al., 2009). Their maximum reported dive depth is 299 ft (91 m) with mean dive depths between 16 to 26 ft (5 and 8 m) (Blumenthal et al., 2009; Van Dam and Diez, 1996). In the eastern Pacific dive depths were strongly concentrated around 33 ft (10 m), strongly suggesting that this species is primarily a shallow diver (Gaos et al., 2012). They were also able to show that there was no strong diurnal pattern in diving behavior in hawksbills turtles. Mean dive durations range between 16 min during the day and 25 minutes (min) at night (Blumenthal et al., 2009). In the eastern Pacific, hawksbills spend most of their time at depths around 10 meters with a bimodal distribution of times, with peaks around five minutes and longer than 20 minutes (Gaos et al., 2012). Dive time has been shown to vary greatly during the three stages of the inter-nesting interval (Walcott et al., 2013), with means of 30, 60, and 45 min for stages 1, 2, and 3, respectively. Hawkes et al. (2012) reported that turtles outside Dominican Republic waters travelled an average of 19.4 nmi (36 km) per day. This produces a minimum speed estimate of 0.8 kt (1.5 kph). Turtles on the foraging areas moved 0.4 to 0.6 kt (0.67 to 1.17 kph).

3.3.3.7 Kemp’s Ridley Turtle (*Lepidochelys kempii*)

The Kemp’s ridley turtle is the rarest sea turtle worldwide and has the most restricted distribution. The Kemp’s ridley is classified as critically endangered under the IUCN, as endangered throughout their range under the ESA, and are protected by CITES. No critical habitat has been designated for the Kemp’s ridley turtle, although NMFS and USFWS have been petitioned to designate beaches along the Texas coast and the Mexican Gulf coast. When its primary nesting beach was first discovered in 1947, approximately 40,000 female Kemp’s ridleys were nesting in an arribada at Rancho Nuevo in Tamaulipas, Mexico (NMFS and USFWS, 2007c; NMFS and USFWS, 2015). Due to hunting of adults and eggs, these numbers were reduced to an estimated 2,000 females by the mid-1960s. By 1985, only 702 nests were reported at Rancho Nuevo (NMFS and USFWS, 2015). In 1977, tentative steps toward protection and recovery began with a bi-national recovery plan was established between the U.S. and Mexico to protect Kemp’s ridley turtles both on the beach and in the water. Available data from 2014 indicate 10,987 nests (NMFS and USFWS, 2015).

Kemp’s ridley turtles are found primarily in the neritic zone of the Gulf of Mexico and western Atlantic. Tagging and telemetry studies have shown that the Kemp’s ridley is a neritic migrant that swims along the U.S. and Mexican coasts, nearshore in continental shelf waters and embayments, with narrow migratory corridors extending along the entire U.S. and Mexican gulf coasts {Byles, 1994; Marquez-M., 1994; Plotkin, 2003). Adult females make relatively short annual migrations from their feeding grounds in the western Atlantic and Gulf of Mexico to their principal nesting beach at Rancho Nuevo. Unique among sea turtles, adult males are non-migratory, remaining resident in coastal waters near Rancho Nuevo year-round. In contrast, juvenile Kemp's ridleys make longer migrations from their winter feeding grounds in the Gulf of Mexico and Florida north along the U.S. East Coast—some as far as Cape Cod Bay, Massachusetts—to their summer feeding grounds in coastal waters and embayments. In the fall, these turtles retrace their path south back to warmer wintering grounds. As described previously, some juvenile ridleys stay in northern waters too long, are caught in the cold water, become cold-stunned, and may die (Plotkin, 2003; Spotila, 2004; Wynne and Schwartz, 1999). Kemp's ridley turtles, like olive ridleys nest participate in arribada nesting. The major arribada nesting site for the Kemp's ridley is at Rancho Nuevo; however, solitary nesting has been recorded at 10 beaches along 120 mi (193 km) of Mexican shoreline in Tamaulipas and another 20 mi (32 km) in Veracruz, Mexico.

Unlike their olive ridley cousins, Kemp's ridleys make shallow dives (<164 ft (<50 m) of short duration (12 to 18 min) (Lutcavage and Lutz, 1997). Additional reports found that the mean dive duration was 33.7 min, with 84 percent of the submergences <60 min (Renaud, 1995). Sasso and Witzell (2006) reports that dive times are longer during the day, and highly skewed toward short dive times Gitschlag (1996) reported mean surfacing times that ranged from 1.0 to 1.9 min. Mean swimming speeds were reported to range from 0.4 to 0.7 kt (0.7 to 1.3 kph), with over 95 percent of the actual velocity values <2.7 kt (<5 kph) (Renaud, 1995).

3.3.3.8 Loggerhead Turtle (*Caretta caretta*)

The loggerhead turtle is listed as endangered under the IUCN and is protected under CITES. Five loggerhead DPS are listed as endangered under the ESA (Northeast Atlantic Ocean, Mediterranean Sea, North Indian Ocean, North Pacific Ocean, and South Pacific Ocean) while four DPS are listed as threatened (Northwest Atlantic Ocean, South Atlantic Ocean, Southeast Indo-Pacific Ocean, and Southwest Indian Ocean) (NOAA and USFWS, 2011). In 2014, critical habitat was designated for the Northwest Atlantic Ocean DPS in the northwestern Atlantic Ocean and the Gulf of Mexico that includes nearshore reproductive habitat, winter habitat, breeding areas, constricted migratory corridors, and *Sargassum* habitat (NOAA, 2014). Critical habitat for the Northwest Atlantic Ocean DPS includes 38 marine areas along the coastlines and offshore of North Carolina, South Carolina, Georgia, Florida, Alabama, Louisiana, and Texas (Figure 3-9). Also in 2014, the U.S. Fish and Wildlife Service (USFWS), which has jurisdiction over sea turtles on land, designated critical habitat for the Northwest Atlantic Ocean DPS about 685 miles of coastal beach to protect 88 loggerhead nesting beaches in coastal counties of North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi (DoI, 2014).

One of the three major loggerhead populations occurs in southeastern U.S. and northern Gulf of Mexico waters, with the total estimated nesting in the U.S. estimated at approximately 68,000 to 90,000 nests per year. The largest nesting aggregation of loggerheads in the Indian Ocean occurs in Masirah, Oman where 20,000 to 40,000 females nest annually (Baldwin et al., 2003). The most recent reviews show that only two loggerhead nesting beaches in South Florida (U.S.) and Masirah Island (Oman) have >10,000 females nesting per year. The Cape Verde Islands support an intermediately-sized loggerhead nesting assemblage; in 2000, researchers tagged over 1,000 nesting females on just 3.1 mi (5 km) of beach on Boavista Island (Ehrhart et al., 2003). Brazil supports an intermediately-sized loggerhead nesting assemblage, with about 4,000 nests per year (Ehrhart et al., 2003). Loggerhead nesting throughout the Caribbean is sparse. In the Mediterranean, loggerhead nesting is confined almost exclusively to the eastern portion of the Mediterranean Sea. The main nesting assemblages occur in Cyprus, Greece, and Turkey. However, small numbers of loggerhead nests have been recorded in Egypt, Israel, Italy, Libya,

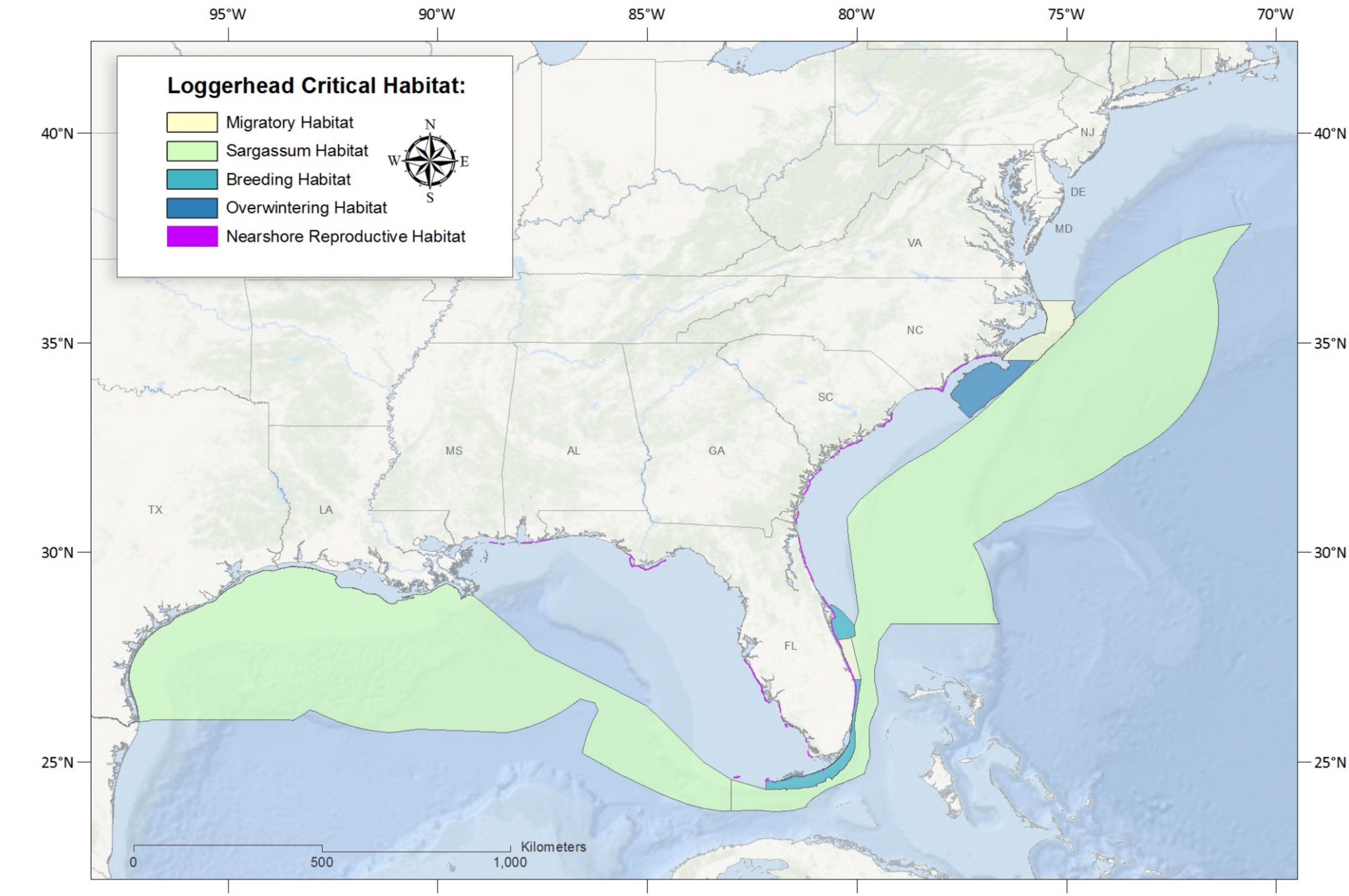


Figure 3-9. Critical habitat designated for the threatened Northwest Atlantic Ocean DPS of the loggerhead turtle off the U.S. Atlantic and Gulf of Mexico coasts (NOAA, 2014a).

1

Syria, and Tunisia. Loggerhead nesting in the Mediterranean based on the recorded number of nests per year in Cyprus, Greece, Israel, Tunisia, and Turkey, ranges from about 3,300 to 7,000 nests per season (Margaritoulis et al., 2003). Loggerheads nest throughout the Indian Ocean and, with the exception of Oman, the number of nesting females is small. Most trends in loggerhead nesting populations in the Indian Ocean are unknown. Formerly the largest worldwide nesting aggregation, the number of females nesting annually in eastern Australia has substantially declined to less than 500, while the only nesting in the North Pacific Ocean, occurs in Japan where more than 4,000 females have been documented nesting recently (NMFS and USFWS, 2007b). Loggerhead populations in Honduras, Mexico, Colombia, Israel, Turkey, Bahamas, Cuba, Greece, Japan, and Panama have been declining. This decline continues and is primarily attributed to incidental capture in fishing gear, directed harvest, coastal development, increased human use of nesting beaches, and pollution. No loggerhead turtles occur or nest in the Northern Mariana Islands; oceanographic conditions north of the Northern Mariana Islands may function as a barrier to loggerhead occurrence (DoN, 2014).

Loggerhead turtles are found in coastal and pelagic habitats of temperate, tropical, and subtropical waters of the Atlantic, Pacific, and Indian Oceans, as well as the Mediterranean Sea (Dodd, 1988). Habitat usage varies with loggerhead lifestage. Loggerheads are highly migratory, capable of traveling hundreds to thousands of kilometers between feeding and nesting grounds. In the western North Atlantic Ocean, the largest loggerhead turtle nesting aggregations are found along the southeastern U.S. coast, particularly the coast of eastern Florida (Dodd and Byles, 2003). Another area of high loggerhead nesting occurs in the northwestern Indian Ocean on Masirah Island, Oman, where along with peninsular Florida, as many as 10,000 females nest per year (Conant et al., 2009). Many of the southeast U.S. nesting turtles travel to foraging habitats in waters of the northeastern U.S. and Canada but some remain to feed in the waters of the southeastern U.S. Most of the southeast U.S. nesting turtles overwinter in the shallow waters of the Bahamas, Cuba, Hispaniola, and the southeastern U.S. (Dodd and Byles, 2003).

Along the South American coast, nesting of loggerheads only occurs in significant numbers in Brazil (Conant et al., 2009). Very few loggerheads forage along the European or African coasts of the Atlantic Ocean and nesting only occurs in the Cape Verde Islands and along the coast of West Africa (Spotila, 2004; Conant et al., 2009). Although loggerheads are widely distributed in the Mediterranean Sea and forage there, 45 percent migrate between the Atlantic Ocean and Mediterranean Sea, and nesting only occurs in the eastern Mediterranean (Margaritoulis et al., 2003). Indian Ocean loggerheads occupy foraging grounds along the coasts of southern Africa, Madagascar, Yemen, and Oman, and in the Arabian Gulf, as well as along Western Australia into Indonesian waters. Tagging data have shown that nesting turtles from the dense nesting aggregations along the Oman coast use the waters of the Arabian Peninsula for foraging and seasonal migrational movements (Conant et al., 2009). In the Pacific, loggerheads nest only in a limited number of sites in Japan and eastern Australia, New Caledonia, Vanuatu, and Tokelau, while foraging occurs in the Gulf of California and along Baja California, and in waters of Peru and Chile (Conant et al., 2009; Kamezaki et al., 2003; Limpus and Limpus, 2003). Hatchlings from nests in Japan (including the Ryukyu Archipelago) make the 5,400 nmi (10,000 km) migration to Mexican developmental and foraging habitat, using the Kuroshio and North Pacific Currents as transport, until returning to the western Pacific as large juveniles (Bowen et al., 1995). Post-hatchling loggerheads from eastern Australia are thought to also make the extensive trans-Pacific migration to the waters of Chile and Peru to forage (Boyle et al., 2009).

Polovina et al. (2003) found that loggerhead turtles spent about 40 percent of their time at the water surface and 70 percent of their dives were to no more than 5 m. Even as larger juveniles and adults, loggerheads' routine dives are only 30 to 72 ft (9 to 22 m), but adult female loggerheads have recorded dives to 764 ft (233 m), lasting 15 to 30 min (Lutcavage and Lutz, 1997). Tagged Loggerheads in the open Pacific had dive depths to 525 ft (160 m) (Polovina et al., 2003). Migrating Males along the east coast of the U.S. had dives restricted to a depth corridor of 66 to 131 ft (20 to 40 m) (Arendt et al., 2012). Five different dive types have been identified by Houghton et al. (2002) for inter-nesting loggerheads, with mean dive durations ranged from 2 to 40 min for the different dive types. Two tagged females had different diving patterns, with maximum duration of 40 min (Godley et al., 2003). Surface times ranged from 3 to 6 percent of dive time (Arendt et al., 2012). Mean inter-nesting travel speeds range from 0.3 to 0.37 kt (0.58 to 0.69 kph) (Abecassis et al., 2013). Migrating females had minimum speeds from 0.7 to 0.9 kt (1.3 to 1.7 kph) (Godley et al., 2003). Loggerheads in the Mediterranean Sea had a mean speed of 0.9 kt (1.6 kph) with a maximum speed near 1.6 kt (3 kph).

3.3.3.9 Olive Ridley Turtle (*Lepidochelys olivacea*)

Although the olive ridley turtle is the most abundant sea turtle worldwide, it has declined or disappeared from many of its historic nesting areas. The global population is protected by CITES, classified as vulnerable under the IUCN, and listed as threatened under the ESA everywhere except the Mexican Pacific coast breeding stocks, which are listed as endangered. No critical habitat has been designated for the olive ridley turtle.

Accurate abundance estimates are difficult to obtain, as most olive ridley females nest in mass aggregations of hundreds to thousands of turtles, called arribadas[14], making counts of individual turtles difficult. In addition, solitary-nesting females are often too spread out to ensure accurate data collection. Major arribada nesting beaches include Ostional (3,564 to 476,500 females) and Nancite (256 to 41,149) on Costa Rica's Pacific coast, La Flor (521,440) in Pacific Nicaragua, and Rushikulaya, India (150,000 to 200,000). Solitary nesting occurs on the beaches of 43 countries (NMFS and USFWS, 2014). Chaloupka et al. (2004) reported abundances for 1999 and 2000, respectively, of 2 and 1.1 million nesting females for two (Ostional, Costa Rica and Escobilla, Mexico) of the major olive ridley nesting populations in the eastern Pacific stock. From data collected at sea, Eguchi et al. (2007) estimated the juvenile and adult olive ridley population in the eastern tropical Pacific Ocean (area encompasses major arribada beaches in Mexico and Central America) as 1.39 million turtles.

Olive ridleys are found in the tropical to warm-temperate Pacific and Indian oceans, but are uncommon in the western Pacific and eastern Indian Ocean. They can also be found in the Atlantic along the west coast of Africa and northeastern coast of South America. Individuals are rarely sighted further into the Caribbean than Trinidad and the West Indies (NMFS and United States Fish and Wildlife Service [USFWS] 2014; Plotkin, 2003; Spotila, 2004). Unlike their other hard-shelled counterparts, olive ridleys favor an oceanic existence, rarely coming inshore except to nest. Even during the breeding season, males will often remain in the open ocean, intercepting females on their way to the nesting beaches. Copulating pairs have been seen at distances over 540 nmi (1,000 km) from the nearest nesting beach. Olive ridleys are highly migratory and spend most of their non-breeding life cycle in the oceanic zone. Their migratory

14 An arribada is a Spanish term for the mass, synchronous nesting events characteristic to olive and Kemp's ridley turtles. During a period of 1 to 10 days, large numbers (100 to 10,000) of female ridley turtles come ashore at night to nest; arribada events can reoccur over 30 day intervals (Hamann et al., 2003).

paths vary annually and no apparent migration corridors exist. Instead, they appear to wander over vast stretches of ocean in search of food, possibly using water temperature as an environmental cue and seeking oceanographic features, such as thermal fronts and convergence zones, to locate suitable feeding areas (Plotkin, 2003; Spotila, 2004).

Olive ridley turtles are capable of deep dives, having been recorded diving to 951 ft (290 m), although routine feeding dives of 262 to 361 ft (80 to 110 m) are most common (Bjorndal, 1997; Lutcavage and Lutz, 1997). Polovina et al., 2003 Polovina et al. (2003) reported that olive ridley turtles only remained at the surface for 20 percent of the time, with about 75 percent of their dives to 328 ft (100 m) and 10 percent of total dive time spent at depths of 492 ft (150 m). Inter-nesting females make routine dives of 54.3 min while breeding and post-breeding males apparently make shorter duration dives of 28.6 min and 20.5 min, respectively (Lutcavage and Lutz, 1997). Maximum dive depth has reported at 945 ft (288 m) (Polovina et al., 2003). The majority of time is spent a depths between 33 to 328 ft (10 and 100 m) (Polovina et al., 2003; Polovina et al., 2004). Migrating adults had a mean speed of 0.6 kt (1.1 kph) (Plotkin, 2010); this value is likely an underestimate, since it is based on the minimum distance between satellite locations that could be greater than 54 nmi (100 km) apart.

3.3.3.10 Leatherback turtle (*Dermochelys coriacea*)

The leatherback turtle is the largest turtle in the world and one of the largest living reptiles. It is listed as critically endangered under the IUCN, endangered throughout its range under the ESA, and is protected under CITES. Critical habitat for the leatherback turtle has been designated in the Caribbean Sea waters adjacent to Sandy Point Beach, St. Croix, U.S. Virgin Islands, as well as in the northeast Pacific Ocean waters (NOAA, 1979, 2012). Northeastern Pacific critical habitat ranges along the California coast from Point Arena to Point Arguello east of the 9,843 ft (3,000 m) depth contour and from Cape Flattery, Washington to Cape Blanco, Oregon east of the 6,562 ft (2,000 m) depth contour, which together comprise an area ~41,914 $miles^2$ (108,558 km^2) of marine habitat and include waters from the ocean surface down to a maximum depth of 262 ft (80 m) (NOAA, 2012a).

As of 2004, fewer than 1,000 leatherback turtles were estimated to occur in the eastern Pacific and were thought to possibly be extirpated from key nesting beaches in the eastern Pacific (Spotila et al., 2000; Spotila, 2004). The most recent population estimate of North Atlantic leatherback turtles is 34,000 to 94,000 (NMFS and USFWS, 2013). The Turtle Expert Working Group (2007) found stable population trends in the Atlantic Ocean, while the Pacific Ocean population has suffered a dramatic drop in nesting numbers (NMFS and USFWS, 2013). Leatherback nesting beaches are found around the world, with the largest nesting colony in South America along the coast of French Guiana (Ferraroli et al., 2004). Here, roughly 6,000 adult females nest on beaches from Trinidad to French Guiana each year. The second largest nesting colony is in Gabon, West Africa with 4,300 females per year (Spotila, 2004). The eastern Pacific coast of Mexico, particularly Michoacan, Guerrero, and Oaxaca, were once the largest nesting grounds in the Pacific. Today, however, sea turtles do not nest there regularly (NMFS and USFWS, 2013). The largest colony of eastern Pacific leatherbacks nests in Guanacaste, Costa Rica, where up to 435 females have been recorded in a given year. Western Pacific colonies in Irian Jaya, Papua New Guinea and the Solomon Islands document 1,052 females per year. The Andaman and Nicobar islands off Thailand in the Indian Ocean see about 1,000 nesting females per year. Small colonies of leatherbacks nest in U.S. waters, primarily on St. Croix in the U.S. Virgin Islands and in Puerto Rico and Florida (Spotila, 2004).

Leatherbacks are the most pelagic and most widely distributed of any sea turtle and can be found circumglobally in temperate and tropical oceans, ranging between 71°N and 47°S (Eckert et al., 2012). Highly migratory, they make yearly long-distance excursions from their nesting beaches to their feeding grounds, following their primary food source, jellyfish. In the western Atlantic, leatherbacks travel north in the spring, following the Gulf Stream and feeding opportunistically on the spring blooms of jellyfish they find en route. These turtles continue northward, arriving in waters corresponding to the continental slope by April, and finally, continuing on to continental shelf and coastal waters off New England and Atlantic Canada where they remain through October. In the fall, some leatherbacks head south essentially retracing the offshore route from which they came, while others cross the Atlantic to Great Britain and migrate south along the eastern Atlantic (James et al., 2005). Similarly, populations that nest in the eastern Atlantic and Indian oceans make annual transoceanic migrations between breeding grounds and feeding grounds (Spotila, 2004). During their migratory phases, leatherbacks rarely stop swimming, and individuals have been documented to swim greater than 7,015 nmi (13,000 km) per year (Eckert, 1998; Eckert, 1999)

Studies of leatherback turtle movements in the Pacific Ocean indicate that that there may be important migratory corridors and habitats used by the species in the Pacific Ocean (Eckert, 1998; Eckert, 1999; Morreale et al., 1996). (Shillinger et al. (2008) confirmed the existence of a persistent migration corridor for leatherbacks spanning from the Pacific coast of Central America across the equator and into the South Pacific. This migratory heading was strongly influenced by ocean currents. Across the Pacific, leatherbacks from Papua New Guinea swim northeast and travel to Monterey Bay, California, where they feed on jellyfish in the upwelling waters (Spotila, 2004). Inter-nesting turtles had movement rates ranging from 0.7 to 1.4 kt (1.25 to 2.5 kph) (Byrne et al., 2009).

Leatherback turtles make the deepest dives—the deepest dive recorded is 4,198 ft (1,280 m) (Doyle et al., 2008). Dives of 13 to 256 ft (4 to 78 m) and 256 to 827 ft (78 to 252 m) of longer duration (28 to 48 min) characterize the migratory phases of the leatherback, while shallower dives (<164 ft (50 m]) of shorter duration (<12 min) were typical on the feeding grounds (James et al., 2005). Leatherbacks have been recorded diving for as long as 86 min, but most dives are no more than 40 min (Byrne et al., 2009; López-Mendilaharsua et al., 2009; Sale et al., 2006). In the Atlantic, Hays et al. (2004) determined that migrating and foraging adult leatherbacks spent 71 to 94 percent of their diving time at depths from 230 to 361 ft. (70 to 110 m). Eckert et al. (2012) presents a summary of diving parameter values. The modal speeds of turtles ranged between 1.1 to 1.6 kt (2 to 3 kph) with absolute maximum speeds in the range of 3.5 to 5.4 kt (6.5 to 10 kph) (Eckert, 2002).

3.3.4 Potentially Affect Marine Mammals

Information about the status, stocks, abundances, distribution, dive, and swim speeds for each marine mammal species and stock is presented here. This information represents the best available information available on these species and stocks and is presented in taxonomic order (Table 3-4).

3.3.4.1 Pinnipeds

Pinnipeds (sea lions, seals, and walruses) are globally distributed amphibious marine mammals with varying degrees of aquatic specialization (Berta, 2009; Goebel, 1998). The walrus, however, is distributed only in Arctic waters, where SURTASS LFA sonar operations will not occur; thus no further discussion of the walrus is included. Twenty-nine species of pinnipeds are considered in this SEIS/SOEIS.

Table 3-4. Marine Mammal Species and Stocks Evaluated in this SEIS/SOEIS for Potential Effects Associated with Exposure to SURTASS LFA Sonar and their Status Under the ESA and MMPA. Taxonomy Follows the Society for Marine Mammalogy (2016), with Species Shown in Alphabetical Order within each Family.

Family	*Marine Mammal Species*	*ESA Status*	*MMPA Status*
	Pinnipeds		
Otariidae	Australian fur seal (*Arctocephalus pusillus doriferus)*		
	Australian sea lion (*Neophoca cinerea*)		
	California sea lion (*Zalophus californianus*)		
	Eastern (Loughlin's) Steller sea lion (*Eumetopias jubatus monteriensis)*		Depleted
	Galapagos fur seal (*Arctocephalus galapagoensis)*		
	Galapagos sea lion (*Zalophus wollebaeki)*		
	Guadalupe fur seal (*Arctocephalus philippii townsendi)*	Threatened	Depleted
	Juan Fernandez fur seal (*Arctocephalus philippii philippii)*		
	New Zealand fur seal (*Arctocephalus forsteri)*		
	New Zealand sea lion (*Phocarctos hookeri*)		
	Northern fur seal (*Callorhinus ursinus*)		Depleted—Pribilof Island/Eastern Pacific stock
	South African or Cape fur seal (*Arctocephalus pusillus pusillus)*		
	South American fur seal (*Arctocephalus australis*)		
	South American sea lion (*Otaria byronia*)		
	Subantarctic fur seal (*Arctocephalus tropicalis)*		
	Western Steller sea lion (*Eumetopias jubatus jubatus*)	Endangered—Western DPS/stock	Depleted
Phocidae	Atlantic gray seal *(Halichoerus grypus atlantica)*		
	Arctic ringed seal (*Pusa hispida hispida)*		Depleted

Table 3-4. Marine Mammal Species and Stocks Evaluated in this SEIS/SOEIS for Potential Effects Associated with Exposure to SURTASS LFA Sonar and their Status Under the ESA and MMPA. Taxonomy Follows the Society for Marine Mammalogy (2016), with Species Shown in Alphabetical Order within each Family.

Family	***Marine Mammal Species***	***ESA Status***	***MMPA Status***
Phocidae (continued)	Harbor seal (*Phoca vitulina*) (Pacific and Atlantic)		
	Harp seal (*Pagophilus groenlandicus*)		
	Hawaiian monk seal (*Neomonachus schauinslandi*)	Endangered	Depleted
	Hooded seal (*Cystophora cristata*)		
	Mediterranean monk seal (*Monachus monachus)*	Endangered	Depleted
	Northern elephant seal (*Mirounga angustirostris)*		
	Okhotsk ringed seal (*Pusa hispida ochotensis)*	Threatened	Depleted
	Pacific bearded seal *(Erignathus barbatus nauticus)*	Threatened—Okhotsk DPS	Depleted
	Ribbon seal (*Histriophoca fasciata)*		
	Southern elephant seal (*Mirounga leonina)*		
	Spotted seal (*Phoca largha*)	Threatened—Southern DPS; Sea of Okhotsk DPS	Depleted—Southern DPS
Cetaceans—Mysticetes			
Balaenidae	Bowhead whale (*Balaena mysticetus*)	Endangered	Depleted
	North Atlantic right whale (*Eubalaena glacialis*)	Endangered	Depleted
	North Pacific right whale (*Eubalaena japonica*)	Endangered	Depleted
	Southern right whale (*Eubalaena australis*)	Endangered	Depleted
Neobalaenidae	Pygmy right whale (*Caperea marginata*)		
Eschrichtiidae	Gray whale *(Eschrichtius robustus)*	Endangered—Western North Pacific DPS	Depleted—Western North Pacific DPS
Balaenopteridae	Antarctic minke whale (*Balaenoptera bonaerensis)*		
	Blue whale (*Balaenoptera musculus)*	Endangered	Depleted

Table 3-4. Marine Mammal Species and Stocks Evaluated in this SEIS/SOEIS for Potential Effects Associated with Exposure to SURTASS LFA Sonar and their Status Under the ESA and MMPA. Taxonomy Follows the Society for Marine Mammalogy (2016), with Species Shown in Alphabetical Order within each Family.

Family	*Marine Mammal Species*	*ESA Status*	*MMPA Status*
Balaenopteridae (continued)	Bryde's whale (*Balaenoptera edeni)*		
	Common minke whale (*Balaenoptera acutorostrata)*		
	Fin whale (*Balaenoptera physalus)*	Endangered	Depleted
	Humpback whale (*Megaptera novaeangliae*)[15]	Endangered—Arabian Sea DPS, Cape Verde Islands/Northwest Africa DPS; Threatened—Central America DPS, Western North Pacific DPS	Depleted
	Omura's whale (*Balaenoptera omurai*)		
	Pygmy blue whale (*Balaenoptera musculus brevicauda)*		
	Sei whale (*Balaenoptera borealis*)	Endangered	Depleted
Cetaceans—Odontocetes			
Physeteridae	Sperm whale (*Physeter macrocephalus*)	Endangered	Depleted
Kogiidae	Dwarf sperm whale (*Kogia sima*)		
	Pygmy sperm whale (*Kogia breviceps)*		
Ziphiidae	Andrew's beaked whale (*Mesoplodon bowdoini*)		
	Arnoux's beaked whale (*Berardius arnuxii)*		
	Baird's beaked whale (*Berardius bairdii)*		

15 The humpback whale is currently listed as an endangered species throughout its range, but NMFS has proposed re-listing the humpback whale under ESA in DPSs. Since the Navy assumes that NMFS will finalize the humpback re-listing before this SEIS/SOEIS is finalized, the proposed DPS listings for the humpback whale are used in this SEIS/SOEIS. In addition to the ESA-listed DPSs, several additional DPSs are not listed under the ESA: West Indies DPS, Western North Pacific DPS, Hawaii DPS, Mexico DPS, Brazil DPS, Gabon/West Africa DPS, Southeast Africa/Madagascar DPS; West Australia DPS, East Australia DPS Oceania DPS, and Southeastern Pacific DPS.

Table 3-4. Marine Mammal Species and Stocks Evaluated in this SEIS/SOEIS for Potential Effects Associated with Exposure to SURTASS LFA Sonar and their Status Under the ESA and MMPA. Taxonomy Follows the Society for Marine Mammalogy (2016), with Species Shown in Alphabetical Order within each Family.

Family	*Marine Mammal Species*	*ESA Status*	*MMPA Status*
Ziphiidae (continued)	Blainville's beaked whale (*Mesoplodon densirostris)*		
	Cuvier's beaked whale (*Ziphius cavirostris*)		
	Deraniyagala's beaked whale (*Mesoplodon hotaula)*		
	Gervais' beaked whale (*Mesoplodon europaeus)*		
	Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens)*		
	Gray's beaked whale (*Mesoplodon grayi)*		
	Hector's beaked whale (*Mesoplodon hectori)*		
	Hubb's beaked whale (*Mesoplodon carlhubbsi)*		
	Longman's beaked whale (*Indopacetus pacificus*)		
	Northern bottlenose whale (*Hyperodon ampullatus*)		
	Perrin's beaked whale (*Mesoplodon perrini)*		
	Pygmy beaked whale (*Mesoplodon peruvianus)*		
	Shepherd's beaked whale (*Tasmacetus sheperdi*)		
	Southern bottlenose whale (*Hyperodon planifrons)*		
	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—Cook Inlet DPS	Depleted—Cook Inlet DPS
Delphinidae	Atlantic spotted dolphin (*Stenella frontalis)*		

Table 3-4. Marine Mammal Species and Stocks Evaluated in this SEIS/SOEIS for Potential Effects Associated with Exposure to SURTASS LFA Sonar and their Status Under the ESA and MMPA. Taxonomy Follows the Society for Marine Mammalogy (2016), with Species Shown in Alphabetical Order within each Family.

Family	*Marine Mammal Species*	*ESA Status*	*MMPA Status*
Delphinidae (continued)	Atlantic white-sided dolphin (*Lagenorhynchus acutus)*		
	Chilean dolphin (*Cephalorhynchus eutropia)*		
	Clymene dolphin (*Stenella clymene)*		
	Commerson's dolphin (*Cephalorhynchus commersonii*)		
	Common bottlenose dolphin (*Tursiops truncatus*)		
	Dusky dolphin (*Lagenorhynchus obscurus)*		
	False killer whale (*Pseudorca crassidens*)	Endangered—Main Hawaiian Islands Insular DPS	Depleted—Main Hawaiian Islands Insular DPS
	Fraser's dolphin (*Lagenodelphis hosei*)		
	Heaviside's dolphin (*Cephalorhynchus heavisidii)*		
	Hector's dolphin (*Cephalorhynchus hectori)*		
	Hourglass dolphin (*Lagenorhynchus cruciger)*		
	Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)		
	Indo-Pacific common dolphin (*Delphinus delphis tropicalis)*		
	Killer whale (*Orcinus orca)*	Endangered—Southern Resident	Depleted—Southern Resident and AT1 Transient stocks
	Long-beaked common dolphin (*Delphinus delphis bairdii)*		
	Long-finned pilot whale (*Globicephala melas*)		
	Melon-headed whale (*Peponocephala electra*)		
	Northern right whale dolphin (*Lissodelphis borealis*)		
	Pacific white-sided dolphin (*Lagenorhynchus obliquidens)*		

Table 3-4. Marine Mammal Species and Stocks Evaluated in this SEIS/SOEIS for Potential Effects Associated with Exposure to SURTASS LFA Sonar and their Status Under the ESA and MMPA. Taxonomy Follows the Society for Marine Mammalogy (2016), with Species Shown in Alphabetical Order within each Family.

Family	*Marine Mammal Species*	*ESA Status*	*MMPA Status*
Delphinidae (continued)	Pantropical spotted dolphin (*Stenella attenuata*)		
	Peale's dolphin (*Lagenorhynchus australis*)		
	Pygmy killer whale (*Feresa attenuata*)		
	Risso's dolphin (*Grampus griseus*)		
	Rough-toothed dolphin (*Steno bredanensis*)		
	Short-beaked common dolphin (*Delphinus delphis delphis*)		
	Short-finned pilot whale (*Globicephala macrorhynchus)*		
	Southern right whale dolphin (*Lissodelphis peronii)*		
	Spinner dolphin (*Stenella longirostris)*		
	Striped dolphin (*Stenella coeruleoalba)*		
	White-beaked dolphin (*Lagenorhynchus albirostris)*		
Phocoenidae	Dall's porpoise (*Phocoenoides dalli*) (*dalli and truei types)*		
	Harbor porpoise (*Phocoena phocoena*)		
	Spectacled porpoise (*Phocoena dioptrica)*		

Otariids have retained more extensive morphological ties with land. Eared seals are distinguished by swimming with their foreflippers and moving on all fours on land. In contrast, true 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. Otariids mate on land whereas phocids mate in the water. Otariids leave calving rookeries to forage during lactation, and due to their need to hunt, otariids can only rear pups in limited sites close to productive marine areas (Gentry, 1998). Phocids, on the other hand, fast during lactation and therefore have fewer limitations on breeding site location. On average, pinnipeds range in size from 99 to 7,055 pounds (45 to 3,200 kilograms) and from approximately 3.3 ft (1 m) to 16.5 ft (5 m) in length (Bonner, 1990).

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, some populations of pinnipeds such as the northern fur seal and the Steller sea lions (Western DPS/stock) continue to decline (Gentry, 2009b). The reduction in population raises concern about the potential risk of extinction. The ESA, along with CITES and IUCN, designates a protected status generally based on natural or manmade factors affecting the continued existence of species. Pinnipeds usually feed under water, diving several times with short surface intervals. This series of diving and surfacing is known as a dive bout. Seasonal changes in temperature and nutrient availability affect prey distribution and abundance, and therefore affect foraging efforts and dive bout characteristics. Foraging areas are often associated with ocean fronts and upwelling zones. Feeding habits are most dependent on the ecology of the prey and the age of the animal. Diet composition can change with the distribution and abundance of prey. Additionally, the hunting habits of pinnipeds may change with age. For example, harbor seal pups eat pelagic herring and squid whereas adult harbor seals eat benthic animals. The amount of benthic prey in the diet of the bearded seal also increases with age (Berta, 2009; Bowen et al., 2009). Phocids are generally benthic feeders, whereas in the otariid family, fur seals feed on small fish at the surface and sea lions feed on larger fish over continental shelves (Gentry, 1998).

The abundance of pinnipeds varies by species. For example, crabeater seals have an estimated abundance of 12 million, while the Mediterranean monk seal is estimated at less than several hundred individuals. Phocid species seem to be more abundant than otariids, but the reason for this is unknown since both families have been commercially exploited. Phocids are circumpolar but are most abundant in the North Atlantic and Antarctic Ocean, found in both temperate and polar waters. The northern fur seal, South African fur seal, and Subantarctic fur seal are the most abundant of the otariid species, and the ringed, harp, and crabeater seals are the most abundant of the phocid species (Bowen et al., 2009).

Due to the need to give birth on land or on ice, pinniped distribution is affected by ice cover or the location of land, prey availability, predators, habitat characteristics, population size, and effects from humans (Bowen et al., 2009). Most species of pinnipeds reside year round in areas bounded by land in a confined range of distances, although some pinnipeds undergo seasonal migrations to forage. Migration patterns consist of moving offshore between breeding seasons. Pinniped habitats range from shelf to surface waters in tropical, temperate, and polar waters. Some species have even adapted to life in fresh and estuarine waters (Berta, 2009).

Social systems are based on aggregations of pinnipeds forming large colonies for polygynous breeding and raising young. The size of the colonies may correlate with resource availability and predation pressure. Pinnipeds are generally long-lived with longevity estimates of 40 years or more (Berta, 2009). Sexual maturity is usually attained at ages from 2 to 6 years (Boyd, 2009). All pinnipeds produce single young on land or ice and most gather to bear young and breed once a year. Pinnipeds are known for their diving ability. On average, smaller species dive for roughly 10 min and larger pinnipeds can dive for over an hour. Maximum depths vary from less than 328 ft (100 m) to over 4,921 ft (1,500 m) (Berta, 2009).

Hearing capabilities and sound production are highly developed in all pinniped species studied to date. It is assumed that pinnipeds rely heavily on sound and hearing for breeding activities and social interactions (Berta, 2009; Frankel, 2009; Schusterman, 1978). They are able to hear and produce sounds in both air and water. Pinnipeds 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. However, there have been few studies on their sensitivity to low frequency sounds. Various studies have examined the hearing capabilities of some pinniped species, particularly ringed seals, harp seals, harbor seals, California sea lions, and northern fur seals (Kastak and Schusterman, 1996; Kastak and Schusterman, 1998; Møhl, 1968b; Terhune and Ronald, 1972, 1975a, 1975b). Kastak and Schusterman (1998) suggest that the pinniped ear may respond to acoustic pressure rather than particle motion[16] when in the water. Sound intensity level and the measurement of the rate of energy flow in the sound field was used to describe amphibious thresholds in an experiment studying low-frequency hearing in two California sea lions, a harbor seal, and an elephant seal. Results suggest that California sea lions are relatively insensitive to most anthropogenic sound in the water, as sea lions have a higher hearing threshold (116.3 to 119.4 dB RL) at frequencies of 100 Hz than typical anthropogenic noise sources at moderate distances from the source. Harbor seals are approximately 20 dB more sensitive to signals at 100 Hz, compared to California sea lions, and are more likely to hear low-frequency anthropogenic noise. Elephant seals are the most sensitive to low-frequency sound under water with a threshold of 89.9 dB RL at 100 Hz. Kastak and Schusterman (1996 and 1998) also suggest that elephant seals may not habituate well to certain types of sound (in contrast to sea lions and harbor seals), but in fact may become more sensitive to disturbing noises and environmental features associated with the noises.

Past sound experiments have shown some pinniped sensitivity to LF sound. The dominant frequencies of sound produced by hooded seals are below 1,000 Hz (Terhune and Ronald, 1973). Ringed, harbor, and harp seal audiograms show that they can hear frequencies as low as 1 kHz, with the harp seal responding to stimuli as low as 760 Hz. Hearing thresholds of ringed, harbor, and harp seals are relatively flat from 1 to 50 kHz with thresholds between 65 and 85 dB RL (Møhl, 1968a; Terhune, 1991; Terhune and Ronald, 1972, 1975a, 1975b). In a recent study, Kastak et al. (2005) found hearing sensitivity in the California sea lion, harbor seals, and the elephant seal decreased for frequencies below 6.4 kHz (highest frequency tested), but the animals are still able to perceive sounds below 100 Hz.

The California sea lion is one of the few otariid species whose underwater sounds have been well studied. Other otariid species with documented vocalizations are South American sea lions and northern fur seals (Fernández-Juricic et al., 1999; Insley, 2000). Otariid hearing abilities are thought to be

16 This is in contrast to fish that are able to detect sound by particle motion.

intermediate between Hawaiian monk seals and other phocids, with a cutoff in hearing sensitivity at the high frequency end between 36 and 40 kHz. Underwater low frequency sensitivity is between approximately 100 Hz and 1 kHz. The underwater hearing of fur seals is most sensitive with detection thresholds of approximately 60 dB RL at frequencies between 4 and 28 kHz (Babushina et al., 1991; Moore and Schusterman, 1987).

Phocid seals probably hear sounds underwater at frequencies up to about 60 kHz. Above 60 kHz, their hearing is poor. Richardson et al. (1995) indicate that phocids have flat underwater audiograms for mid and high frequencies (1 to 30 kHz and 30 to 50 kHz) with a threshold between 60 and 85 dB RL (Møhl, 1968a; Terhune, 1989, 1991; Terhune and Ronald, 1972, 1975a, 1975b; Terhune and Turnbull, 1995). As mentioned, the elephant seals are the most sensitive to underwater low-frequency sound with a threshold of 89.9 dB RL at 100 Hz (Kastak and Schusterman, 1998).

The sounds produced by pinnipeds vary across a range of frequencies, sound types, and sound levels. The seasonal and geographic variation in distribution and mating behaviors among pinniped species may also factor into the diversity of pinniped vocalizations. The function of sound production appears to be socially important as they are often produced during the breeding season (Kastak and Schusterman, 1998; Van Parijs and Kovacs, 2002).

Information about the Pinniped species considered in this SEIS/SOEIS is presented in taxonomic order by family, per the Society of Marine Mammalogy (SMM) (2016), with each species in alphabetical order within each family (Table 3-4).

<u>Otariidae</u>

<u>Australian Fur Seal (*Arctocephalus pusillus doriferus*)</u>

Australian fur seals are listed as a species of least concern (lower risk) by the IUCN. 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 110,000 to 120,000 animals (Jefferson et al. 2015).

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., 2015). 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., 2015).

Australian fur seals forage at shallow depths along the continental shelf and continental slope waters (Kirkwood et al., 2006). An average dive depth and duration of a male off the coast of Australia was 46 ft (14 m) and 2.3 min; the maximum dive depth and duration that were recorded was 335 ft (102 m) and 6.8 min (Hindell and Pemberton, 1997). No swim speed data are available for this species.

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).

<u>Australian Sea Lion (*Neophoca cinerea*)</u>

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. 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 14,780 animals (Jefferson et al. 2015).

The Australian sea lion is a temperate species found only along the south and west coast of Australia (Jefferson et al., 2015). About 73 colonies exist, with 47 colonies documented in southern Australia and 26 reported 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).

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 138 to 272 ft (42 to 83 m) and 2.2 to 4.1 min, with maximum dives ranging from 197 to 345 ft (60 to 105 m) (Jefferson et al., 2015). The average duration of all foraging dives was 3.3 min, with a maximum dive time of 8.3 min (Costa and Gales, 2003). No information is available on the hearing abilities of this species. Australian sea lions bark and produce clicks under water (Poulter, 1968).

California Sea Lion (*Zalophus californianus*)

California sea lions are listed as a least concern (lower risk) species under the IUCN. The population size of the U.S. stock, or Pacific Temperate stock, is estimated as 296,750 seals (Carretta et al., 2015). California sea lions are common along the Pacific coast of the U.S. 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 (Heath and Perrin, 2009; Jefferson et al., 2015). The U.S. stock includes rookeries within the U.S. but the population ranges into Canada (Carretta et al., 2016). 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 (Heath and Perrin, 2009).

Lactating females have recorded dives to 810 ft (247 m) and lasting over 10 min. Foraging California sea lions had a mean dive time of four minutes, with a maximum time of 10 minutes. Mean dive depth was 453 ft (138 m) with a deepest dive of 1,378 ft (420 m) (McDonald and Ponganis, 2014). Swim speeds for California sea lions have been estimated at 4.9 kt (9 kph) (Feldkamp et al.,1989).

California sea lions can hear sounds in the range of 75 Hz 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; Mulsow et al., 2012). However, their hearing abilities when presented with complex stimuli (as opposed to pure tones) are 33 dB better than expected based on energetic calculations (Cunningham et al., 2014). 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, 1966). Buzzing sounds are generally from less than 1 kHz to 4 kHz, with the dominant frequencies occurring below 1 kHz (Schusterman, 1966).

Eastern (Loughlin's) (*Eumetopias jubatus monteriensis)* and Western Steller Sea Lion (*Eumetopias jubatus jubatus*)

The Steller sea lion is divided taxonomically into two species that effectively represent the Western and Eastern stocks and DPSs of Steller sea lions (SMM, 2016). The species is classified as an endangered species under IUCN. Only the Western stock/DPS is listed as endangered under the ESA, while the Eastern stock/DPS was delisted under the ESA in 2013. All Steller sea lions are considered depleted under the MMPA. The worldwide population size for this species is estimated to be 160,867 (Gelatt and Sweeney, 2016). The Eastern U.S. stock (east of Cape Suckling, Alaska) of Steller sea lions is estimated at between 60,131 and 74,448 individuals, while the Western U.S. stock (west of Cape Suckling, Alaska) is estimated at 49,497 sea lions (Muto et al., 2016). The Steller sea lion population in the Western U.S. and Russian stocks has been estimated to include 82,516 individuals (Allen and Angliss, 2015), while the Western Asian stock (Russia to Japan) has been estimated as 68,218 individuals (Muto et al., 2016).

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. 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 Año 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.

Female Steller sea lions on foraging trips during the breeding season had a maximum dive depth of 774 ft (236 m), while the longest dive was greater than 16 min. The average dive depth for foraging females was 97.1 ft (29.6 m). Average dive time was recorded at 1.8 min (Rehberg et al., 2009). Swim speed has been estimated at 1.5 kt (2.82 kph), with a range of 0.2 to 3.3 kt (0.4 to 6.05 kph) (Raum-Suryan et al., 2004).

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 sea lions 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.

Steller sea lion underwater sounds have been described as clicks and growls (Frankel, 2009; Poulter, 1968). 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.

Galapagos Fur Seal (*Arctocephalus galapagoensis*)

The Galapagos fur seal is listed as endangered under the IUCN. The population is estimated currently as 10,000 to 15,000 individuals (Jefferson et al., 2015).

Galapagos fur seals are non-migratory. 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., 2015).

The diving habits of Galapagos fur seals are dependent on age. Six-month-old seals have been recorded to dive up to 20 ft (6 m) for 50 sec. Yearlings dive to 150 ft (47 m) for 2.5 min, and 18-month-old juveniles dive up to 200 ft (61 m) for 3 min (Stewart, 2009). The longest and deepest dive recorded by a Galapagos fur seal was 5 min at a depth of 377 ft (115 m) (Jefferson et al., 2015). Galapagos fur seals swim at about 3.1 kt (1.6 m/sec) (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).

Galapagos Sea Lion (*Zalophus wollebaeki*)

Galapagos sea lions are classified as endangered under IUCN. The current population is estimated to be between 10,000 and 15,000 seals (Jefferson et al., 2015). 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 (Heath and Perrin, 2009).

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

Guadalupe Fur Seal (*Arctocephalus philippii townsendi*)

The Guadalupe fur seal is currently classified as threatened under ESA and considered a near-threatened species under IUCN. The current worldwide population size for this species is unknown. In 1993, 7,408 seals were estimated, which remains the most recent population estimate of Guadalupe fur seals available (Caretta et al., 2016).

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., 2015). Guadalupe fur seals have been observed as far north as Blind Beach, CA and as far south as Zihuatanejo, Mexico and the Gulf of California (Carretta et al., 2016). These seals prefer either a rocky habitat or volcanic caves.

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

No direct measurements of auditory threshold for the hearing sensitivity of Guadalupe fur seals are available (Thewissen, 2002). Male Guadalupe fur seals produce airborne territorial calls during the breeding season, including a bark (Pierson, 1987). When disturbed by humans, Guadalupe fur seals have been reported to produce roar type of calls and females produce specific prolonged "bawls" when interacting with their pups (Belcher and Lee, 2002).

Juan Fernandez Fur Seal (*Arctocephalus philippii philippii)*

The Juan Fernandez fur seal is classified as near threatened under the IUCN. The species was believed to have been hunted to extinction until 1965 when a small remnant population was located. Juan Fernandez fur seals are restricted to the Juan Fernandez island group off the coast of north central Chile (Jefferson et al., 2015) and is estimated to number 12,000 individuals (Jefferson et al., 2015). Currently this seal occupies four major breeding colonies and hauls out on rocky shorelines (Arnould, 2009).

Juan Fernandez fur seals can travel an average distance of 353 nmi (653 km) from breeding grounds to feeding grounds, where they forage at depths between 35 and 295 ft (10 and 90 m) (Jefferson et al., 2015). Maximum dive depths for this seal range from 163 to 295 ft (50 to 90 m), with most dives less than 33 ft (10 m) (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.

No information is available on the hearing abilities of the Juan Fernandez fur seal. The Juan Fernandez fur seal has been recorded producing downswept pulses from 200 to 50 Hz (Norris and Watkins, 1971). Other information about this species' sound production capabilities is not available.

New Zealand Fur Seal (*Arctocephalus forsteri*)

The New Zealand fur seal is listed as a least concern (lower risk) species under the IUCN. The global population estimate is 200,000 to 220,000 seals, split evenly between New Zealand and Australia (Jefferson et al., 2015). 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., 2015). Their principal breeding colonies occur along the coast of South and Stewart Islands of New Zealand as well as along the coast of western and southern Australia, including off Tasmania at Maatsuyker Island (Arnould, 2009). Breeding colonies also exist at the Subantarctic Chatham, Campbell, Antipodes, Bounty, Aukland, and Macquarie islands (Arnould, 2009). The New Zealand fur seal prefers rocky and windy habitats that are protected from the sun for breeding (Jefferson et al., 2015).

New Zealand fur seals forage at night, with varying dive depths and times depending on age and sex. New Zealand fur seal pups were recorded at a maximum dive depth of 144 ft (44 m) for 3.3 min (Baylis et al., 2005). Adult females recorded a maximum dive depth of 1,024 ft (312 m), and a maximum dive time of 9.3 min off the southern coast of Australia (Page and Goldsworthy, 2005). Adult male New Zealand fur seals had a maximum dive of more than 1,247 ft (380 m), and a maximum dive time of 14.8 min (Page et al., 2005). Swim speeds for New Zealand fur seals have been estimated to be similar to congeneric Antarctic fur seals (Harcourt et al., 2002).

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 the frequency range of this species' vocalizations.

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 sea lion has an estimated abundance of <10,000 individuals (Jefferson et al. 2015).

This rarely occurring sea lion is endemic to New Zealand waters and has one of the most restricted ranges of all pinnipeds (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 percent of New Zealand sea lion pups are born in the Auckland Islands (Gales, 2009).

New Zealand sea lions are among the deepest and longest divers of the otariids, diving to a mean water depth of 404 ft (123 m), with average dive durations of 3.9 min (Gales, 2009). The maximum foraging dive depth recorded for a lactating female was reported as 1,804 ft (550 m) and the longest dive time was 11.5 min (Costa and Gales, 2000). Swim speeds are about 2.5 kt (4.7 kph) (Williams, 2009) and from 3.1 to 4.7 kt (5.8 to 8.6 kph while diving and from 1.7 to 3.5 kt (3.2 to 6.5 kph) while surface swimming (Crocker et al., 2001).

No information is available on the hearing abilities of this species and little information is available on the vocalizations of New Zealand sea lions except that all bark and produce clicks under water (Poulter, 1968).

<u>Northern Fur Seal (*Callorhinus ursinus*)</u>

Northern fur seals are currently classified as a vulnerable species under IUCN and depleted under the MMPA. No current global population estimate is available for this species. The Eastern Pacific stock is estimated as 648,534 seals (Allen and Angliss, 2015), while the California (San Miguel Island and the Farallon Islands) stock is estimated to include 14,050 seals (Carretta et al., 2016), and the Western Pacific stock of northern fur seals is estimated as 503,609 individuals (Gelatt et al., 2015; Kuzin, 2014).

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., 2015). Breeding sites include the Commander Islands, Kurile Islands, Pribilof Islands, Robben Island, Bogoslof Island, Farallon Islands, and San Miguel Island (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 (Gentry, 2009).

Routine swim speeds during migration for this species are 1.54 kt (2.85 kph), and during foraging, swim speeds averaged between 0.48 to 1.23 kt (0.89 and 2.28 kph) (Ream et al., 2005). Maximum recorded dive depths of breeding females are 680 ft (207 m) in the Bering Sea and 755 ft (230 m) 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 57.4 ft (17.5 m) (Sterling and Ream, 2004) with a maximum depth of 328 ft (100 m) (Lee et al., 2014).

The northern fur seal can hear sounds in the range of 500 Hz to 40 kHz (Babushina et al., 1991; Moore and Schusterman, 1987), with best hearing ranging from 2 and 12 kHz (Gentry, 2009a). Northern fur seals are known to produce clicks and high-frequency sounds under water (Frankel, 2009). Estimated source levels and frequency ranges are unknown.

South African or Cape Fur Seal (*Arctocephalus pusillus pusillus*)

South African or Cape fur seals are one of two *Arctocephalus pusillus* sub-species that are separated by an ocean. South African fur seals are listed as a species of least concern (lower risk) by the IUCN. Censuses in 2004 indicate that the population of South African fur seals is stable at an estimated 2 million animals, with about two-thirds of the population occurring in Namibia (Hofmeyr, 2015; Jefferson et al., 2015). South African fur seals bred at some 40 colonies or colony groups in 2009 (Hofmeyr, 2015). Kirkman et al. (2013) reported an increase in the number of colonies, a northward shift in the range, and an increase in abundance in some areas of the South African fur seal's range (northern Namibia and northwestern South Africa).

South African fur seals occur along the southern and southwestern African coast from southern Angola, Namibia, to eastern South Africa (Jefferson et al., 2015). Breeding occurs at 25 colonies along the coasts of South Africa and Namibia, including four mainland colonies (Arnould, 2009). These fur seals are not migratory, spend most of their year at sea, but don't range far from land, typically feeding within approximately 2.7 nmi (5 km) of land and traveling no more than a maximum of 86 nmi (160 km) from land (King, 1983).

The majority of recorded dives of Cape fur seals on the west coast of South Africa are to less than 164 ft (50 m) of water depth (Kooyman and Gentry, 1986), while those on the southeast coast are to more than 197 ft (60 m) with dives typically lasting from 1 to 2.1 min (Stewardson, 2001). The maximum dive depth and duration are 669 ft (204 m) and 8.9 min (Arnould and Hindell, 2001; Kooyman and Gentry, 1986). Cape fur seal dives show two peaks in the daily distribution with most dives taking place at dusk or during the first half of the night, with a smaller peak after dawn (Kooyman and Gentry, 1986; Stewardson, 2001). No swim speed data are available for this species.

There is also no information available on the hearing abilities of the South African fur seal. South African fur seals make "pup calls" and males make exhibit threat and mating calls during breeding season.

South American Fur Seal (*Arctocephalus australis*)

There are two currently recognized sub-species: the Peruvian fur seal, found from Peru to northern Chile with an estimated population size of 12,000, and the South American fur seal, found from southern Chile to the Straits of Magellan and northward to southern Brazil as well as the Falkland Islands, with an estimated Chilean population of 30,000 seals and 15,000 to 20,000 seals estimated in the Falklands. Along the east coast of South America, 250,000 to 300,000 Southern fur seals occur, with most occurring in Uruguay (Jefferson et al., 2015). The South American fur seal is listed as a least concern (lower risk) species under the IUCN.

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 324 nmi (600 km) offshore (Jefferson et al., 2015). These fur seals are believed to occur predominantly in continental shelf and continental slope waters.

South American fur seals have been recorded diving to mean water depths of 112 ft (34 m) and a maximum depth of 558 ft (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 2.9 kt (1.5 m/sec).

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

<u>South American Sea Lion (*Otaria byronia*)</u>

South American sea lions are listed as a least concern (lower risk) species under the IUCN. The current total population is estimated to be between 200,000 and 300,000 seals (Jefferson et al., 2015), 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., 2015).

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

No information is 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 (Feŕnandez-Juricic et al., 1999). Frequencies of the measured South American sea lion vocalizations ranged widely from 240 to 2,240 Hz (Fernández-Juricic et al., 1999).

<u>Subantarctic Fur Seal (*Arctocephalus tropicalis*)</u>

Subantarctic fur seals are considered a least concern (lower risk) species under the IUCN. The current population of this widely dispersed fur seal is more than 310,000 animals (Jefferson et al. 2015). 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., 2015). 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., 2015).

In the summer, subantarctic fur seals commonly dive to water depths averaging 54.5 to 62 ft (16.6 to 19 m) 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 682 ft (208 m) and 6.5 min (Jefferson et al., 2015). No swim speed data are available. No information or data are available on subantarctic fur seal hearing or vocalization capabilities.

Phocidae

Atlantic Gray Seal *(Halichoerus grypus atlantica*)

Gray seals are classified as a least concern (lower risk) species by the IUCN. Gray seals have a global population estimate of 400,000 to 500,000 seals, including 22,000 in the Baltic Sea (Jefferson et al., 2015). The gray seal's Northwest Europe population has been estimated to include 116,800 individuals (Special Committee on Seals [SCOS], 2015).

Gray seals occur in temperate and sub-polar regions mostly in the North Atlantic Ocean, Baltic Sea, and the eastern and North Atlantic Ocean (Jefferson et al., 2015). Gray seals breed on remote islands that are typically uninhabited or on fast ice. The largest island breeding colony is on Sable Island (Hall and Thompson, 2009). This species is not known to undergo seasonal movements.

Swim speeds average 2.4 kt (4.5 kph). 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 984 ft (300 m) has been recorded for this species, but most dives are relatively shallow, from 197 to 328 ft (60 to 100 m) 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 are no available data regarding seasonal or geographical variation in the sound production of gray seals.

Arctic Ringed Seal (*Pusa hispida hispida*) and Okhotsk Ringed Seal (*Pusa hispida ochotensis*)

Two of the subspecies of ringed seals, the Arctic and Okhotsk, occur in the potential global operating areas for SURTASS LFA sonar. The Okhotsk ringed seal is listed as threatened under the ESA while both the Arctic and Okhotsk subspecies are considered depleted under the MMPA. Critical habitat under the ESA has been proposed for the Arctic ringed seal in the northern Bering, Chukchi, and Beaufort seas, marine habitat that is not included in SURTASS LFA sonar's potential operating area. No accurate global population estimates for the ringed seal exist due to the widely disbursed distribution over vast geographic regions, but Miyazaki (2002) estimated the global population as 2.5 million ringed seals. Even though the Arctic ringed seal population is the most abundant of all the ringed seal subspecies, an overall population estimate doesn't exist. In the Atlantic Arctic region, including the Labrador Sea, the Arctic ringed seal population has been estimated population was 787,000 individuals (Finley et al., 1983; Kelly et al., 2010), and an estimated 300,000 seals in the Beaufort and Chukchi seas region of the Arctic (Allen and Angliss, 2015; Kelly et al., 2010). The population of Okhotsk ringed seals was estimated recently as 676,000 seals (Fedeseev, 2000; Kelly et al., 2010).

Ringed seals have a circumpolar distribution generally north of 35°N and are found at least seasonally in all ice-covered seas of the Northern Hemisphere as well as in certain freshwater lakes (King, 1983). The Arctic ringed seal occurs in the Arctic Ocean and its adjacent seas, including the Bering Sea and Hudson Bay, while the Okhotsk ringed seal occurs in the Sea of Okhotsk and the waters off northern Japan (Kovacs et al., 2008). Ringed seals are considered ice seals, being well adapted to living on firm ice, including both pack ice and shorefast ice, and aren't commonly found in open ocean waters. These seals maintain contact with the ice, migrating in response to the seasonal ice advances and retreats.

Ringed seals spend about 20 percent of their time at sea diving, with average dive times ranging from 1 to 2.7 min, although Lydersen (1991) reported a maximum ringed seal dive of 17 min. Ringed seals typically make the majority of their dives to water depths ranging from 33 to 164 ft (10 to 50 m), with few daily dives to depths greater than 492 ft (150 m) (Gjertz et al., 2000a; Lydersen, 1991; Simpkins et al., 2000). The maximum dive depth reported for ringed seals is 1,181 ft (360 m) (Born et al., 2004). Ringed seal swim speeds average between about 0.9 to 1.2 kt (1.6 to 2.2 kph), with the maximum speed recorded as 5.8 kt (10.8 kph) (Born et al., 2004; Lowry et al., 1998; Simpkins et al., 2001; Teilmann et al., 1999).

Terhune and Ronald (1975a, 1975b) reported that ringed seal audiograms show that they can hear frequencies as low as 1 kHz but their hearing thresholds are relatively flat from 1 to 50 kHz, with thresholds between 65 and 85 dB RL. Terhune and Ronald (1976) measured the upper frequency limit of ringed seal hearing as 60 kHz. More recently using psychophysical methods to measure the in-air and underwater hearing of ringed seals, Sills et al. (2015) reported the best hearing sensitivity of ringed seal hearing in water as 12.8 kHz (49 dB re 1 µPa), which was lower than previously reported by Terhune and Ronald (1975a and 1975b), while the in air best hearing sensitivity was reported as 4.5 kHz (−12 dB re 20 µPa). Sills et al. (2015) also reported critical ratio measurements that ranged from 14 dB at 0.1 kHz to 31 dB at 25.6 kHz, which suggested that ringed seals possess enhanced signal detection capabilities such that they can efficiently extract signals from background noise across a broad range of frequencies. Moreover, critical ratios were measured over the full vocal range of ringed seals, but no correlation was shown with the frequencies of ringed seal vocalizations (Sills et al., 2015).

Ringed seal underwater vocalizations have been hypothesized to support the maintenance of social structure around breathing holes in winter and spring (Stirling, 1973; Stirling et al., 1983). Stirling (1973) described barks, yelps, high-pitched growls, and chirps of ringed seals that extended up to a maximum of about 6 kHz. Cummings et al. (1981) described a gargle-type vocalization with peak energy at 1 kHz and a rub sound that extended from 0.7 to 2.6 kHz in range. The typical energy of ringed seal calls is between 0.1 and 5 kHz (Stirling, 1973; Stirling et al., 1983; Cummings et al., 1984; Jones et al., 2014). Sills et al. (2015) reported that contrary to the notion that animals vocalize in the same frequency range of their hearing, the range of ringed seals' best hearing extends to more than three octaves above the upper limit of ringed seals dominant vocalization energy.

Harbor Seal (*Phoca vitulina*)

Harbor seals are also known as common seals. This species is classified as least concern (lower risk) by the IUCN. The global population of harbor seals is estimated to be between 400,000 and 500,000 seals (Jefferson et al., 2015). Five subspecies of the harbor seal have been classified throughout the Northern Hemisphere. In the western North Atlantic there are an estimated 75,834 seals (Waring et al., 2015). In Alaska including the Gulf of Alaska and the Bering Sea, the statewide population of harbor seals is estimated to be 152,592 individuals (Allen and Angliss, 2015). The California stock estimate of harbor seals is estimated to be 30,968 seals (Carretta et al., 2015). The numbers in Oregon and Washington are currently unknown. The Northwest Europe population of harbor seals has been estimated to include 40,414 individuals (SCOS, 2015).

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., 2015). They also can be found in the southern Arctic Ocean (Jefferson et al., 2015). 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., 2015). 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).

Maximum swim speeds have been recorded over 7 kt (13 kph) (Bigg, 1981). The deepest diving harbor seal was located in Monterey Bay, California, and dove to a depth of 1,578 ft (481 m), and the longest dive lasted 35.25 min (Eguchi and Harvey, 2005). In general, seals dive for less than 10 min, and above 492 ft (150 m) (Jefferson et al., 2015).

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 (Kastak and Schusterman, 1998; Møhl, 1968a; Terhune, 1991). In a study by Wolski et al. (2003), harbor seals' aerial 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^2s (Wolski et al., 2003). Underwater hearing thresholds are ~ 53 dB @ 4 kHz (Kastelein et al., 2010).

Harp Seal (*Pagophilus groenlandicus*)

The harp seal is considered least concern by the IUCN. Worldwide population is estimated at 9 million seals (Jefferson et al., 2015). Three populations of harp seals are recognized: western North Atlantic, White Sea-Barents Sea, and the Greenland Sea. Only the western North Atlantic population of harp seals potentially occurs in waters in which SURTASS LFA sonar may operate. The western North Atlantic population of harp seals was estimated as 7,411,000 seals for 2014 (Division of Fisheries and Oceans [DFO], 2014).

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 (Harris et al., 2002; McAlpine and Walker, 1990; McAlpine and Walker, 1999), 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). One seal was found in poor condition and died in the Mediterranean Sea (Bellido 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 percent 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 (Folkow et al., 2004; Lydersen and Kovacs, 1993).

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, 1971). In-water, harp seals hearing was measured by free-field 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 (Richardson et al., 1995; Terhune and Ronald, 1972), 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, 2001). Source levels range between 103 and 180 dB re 1μPa at 1 m (Rossong and Terhune, 2009).

Hawaiian Monk Seal (*Neomonachus schauinslandi*)

Hawaiian monk seals are listed as endangered under the ESA, classified as endangered under IUCN, and protected under CITES. Critical habitat for the Hawaiian monk seal has been established from the shore to 121 ft (37 m) of water depth in 10 areas of the Northwest Hawaiian Islands (NWHI) (NOAA, 1988). In 2015, revisions to the Hawaiian monk seal's critical habitat were established (NOAA, 2015a). The critical habitat now includes all of Kure Atoll, Midway Islands, Pearl and Hermes Reef, Lisianski Island, Laysan Island, Maro Reef, Gardner Pinnacles, French Frigate Shoals, Necker Island, Nihoa, Kaula Island and Niihau and Lehua Islands to the 628-ft (200-m) isobath It also includes selected portions of the remaining main Hawaiian Islands and all waters to the 200 m isobath (excluding National Security Exclusion zones off Kauai, Oahu and Kahoolawe) (NOAA, 2015a). The best available population estimate for this species is 1,112 individuals (Carretta et al., 2016).

Hawaiian monk seals range throughout the Hawaiian Archipelago and Johnson Atoll (NOAA, 2011). Since the early 1990s, a small but increasing population of monk seals and an increasing number of annual births has been documented in the Main Hawaiian Islands (NOAA, 2011). Hawaiian monk seals exhibit high site fidelity to their natal island (Gilmartin and Forcada, 2009). Monk seals spend a greater proportion of their time at sea, in water depths ranging from 3 to 984 ft (1 to 300 m) in shelf, slope, and bank habitats but come ashore (haul out) on a variety of substrates, including sandy beaches, rocky shores, rock ledges, and emergent reefs. Pupping only occurs on sandy beaches adjacent to protected waters.

Sparse swim speed data are available. Parrish and Abernathy (2006) reported Hawaiian monk seals swimming with a velocity of 3.9 kt (7.2 kph). This species commonly dive to depths of less than 328 ft (100 m) but have been recorded diving down to depths of 984 to 1,640 ft (300 to 500 m) (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 33 to 131 ft (10 to 40 m) (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 a relatively low upper frequency limit (Thomas, Moore, Withrow, et al., 1990); it should be noted that this information may not be representative as the Hawaiian monk seal tested was an older, captive animal. Above 30 kHz, high-frequency hearing sensitivity dropped markedly (Thomas et al., 1990). No underwater sound production has been reported for this species. Recorded in-air vocalizations of Hawaiian monk seals consist of a variety of sounds, including 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).

Hooded Seal (*Cystophora cristata*)

Hooded seals are classified as a vulnerable species by the IUCN. The global population of hooded seals is estimated at 660,000 seals (Kovacs, 2009), with the western North Atlantic population estimated to include 592,100 seals (Waring et al., 2008). 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 for the last 20 years (Kovacs, 2009) and is currently estimated as 84,020 hooded seals (ICES, 2013).

Hooded seals are found in the high latitudes of the North Atlantic Ocean, and in the Arctic Ocean (Jefferson et al., 2015). 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 (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., 2015). Hooded seals are associated with the outer edge of pack ice and drifting ice throughout much of the year, moving with the drifting pack ice; seals congregate on ice floes for both mating and pupping (Kovacs, 2009). Hooded seals are a migratory species and are often seen far from their haul-outs and foraging sites. Records of migrant hooded seals are not unusual, with juveniles having been observed as far south as Portugal, the Caribbean Sea, and California (Mignucci-Giannoni and Odell, 2001).

No data on hooded seal swim speeds are available. Hooded seals appear to dive nearly continuously when at sea, being submerged for over 90 percent of time at sea (Folkow and Blix, 1999). Diving behavior differs between males and females as well as during different behaviors and life phases (e.g., migrating, molting, and breeding). The mean surface time for both sexes is 1.8 min. Andersen et al. (2013) reported mean dive durations of 13.9 min and a maximum dive duration of 57.3 min, with mean dive depth of 837 ft (255 m) and a maximum depth of 5,420 ft (1,652 m). Hooded seals generally dive deeper and longer at night (Folkow and Blix, 1999). Hooded seals have been observed to perform drift dives (Andersen et al., 2014).

There is no direct measurement of auditory threshold for the hearing sensitivity of the hooded seal (Thewissen, 2002). They have been shown to respond to sonar signals between 1 and 7 kHz (Kvadsheim et al., 2010). 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.

Mediterranean Monk Seal (*Monachus monachus)*

Mediterranean monk seals are listed as endangered under the ESA, classified as critically endangered under IUCN, and protected under CITES. The worldwide population size for this species is estimated to be between 500 and 600 animals (Jefferson et al., 2015), with the largest population of 250 to 300 seals found in the eastern Mediterranean (Gilmartin and Forcada, 2009). One hundred seals are thought to remain in Turkey (Jefferson et al. 2015), and they have been sighted there recently (Emek Inanmaz et al., 2014). The two breeding populations at Cap Blanc, with about 220 seals (Karamanlidis et al., 2015), and in the Desertas Islands of the Madeira Islands group, with about 25 seals, remain (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 (Gilmartin and Forcada, 2009; Jefferson et al., 2008). 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). A monk seal was recently found off Libya. It is not known if this was an extralimital sighting or evidence of another colony (Alfaghi, 2013).

No direct data are available on swim speed for Mediterranean monk seals. Dendrinos et al. (2007) reported a maximum water depth of 404 ft (123 m) 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 256 ft (78 m) and 15 min while the mean dive depth and duration of the dives of a lactating female were 98 ft (30 m) 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).

Northern Elephant Seal (*Mirounga angustirostris)* and Southern Elephant Seal *(M. leonina)*

The total population estimate for the northern elephant seal is over 171,000 (Jefferson et al., 2015). The population estimate for the California breeding stock of this species is 179,000 (Carretta et al., 2015). The population of southern elephant seals has been estimated at 650,000 seals (Jefferson et al., 2015). 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., 2015). They occur during the breeding season from central Baja, Mexico to central California in about 15 colonies (Le Boeuf 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).

Elephant seals spend as much as 90 percent of their time submerged and are remarkable divers, diving to depths (>4,921 ft (>1,500 m) for 120 min (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 2.1 kt (1.1 m/sec). Le Boeuf et al. (1989) reported that northern elephant seals dive to average depths of 1,640 to 2,297 ft (500 to 700 m) 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 have multiple different dive types. There are six generally recognized: A, B, C, D E_b, E_f (Dragon et al., 2012; Sala et al., 2011). A and B type dives are associated with travelling, C dives are resting periods, D are considered to be prey pursuit dives, and E_b and E_f are associated with benthic feeding and resting.

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. They 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, 1998). 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.

Pacific Bearded Seal (*Erignathus barbatus nauticus*)

Two DPS of Pacific bearded seals have been recognized but only the Okhotsk DPS is listed as threatened under the ESA and depleted under the MMPA. Only the Alaska stock is located in U.S. waters. While not considered accurate, the global bearded seal population has been estimated at over 500,000 seals. The population of bearded seals in in the Sea of Okhotsk is estimated as 200,000 seals (Cameron et al., 2010; Fedeseev, 2000; Laidre et al. 2015); the Okhotsk DPS is thought to have declined from this estimate from the 1960s to early 1990s (Cameron et al., 2010). An outdated estimate of the Beringia DPS (Pacific bearded seals that occur in continental shelf waters of the Bering, Chukchi, Beaufort, and East Siberian seas) reported the DPS as including about 155,000 seals, but uncompleted analysis of a 2012 to 2013 survey report a preliminary population estimate of the Bering Sea bearded seals as 299,174 (Allen and Angliss, 2015).

Bearded seals have a circumpolar distribution in the Northern Hemisphere that does not extend further north than 80°N. The Pacific bearded seal is distributed from the Laptev Sea eastward to the central Canadian Arctic and southward to the Sea of Okhotsk and northern Japan (Kovacs et al. 2008a). Bearded seals commonly occur in association with sea ice and individual seals move north and south as the pack ice advances and recedes seasonally, although some bearded seals remain near shorefast ice year-round. The distribution of bearded seals appears to be strongly associated with shallow water (650 ft [200 m]) due to depth at which they feed on benthic prey.

Bearded seals most routinely dive between 5 and 80 m (Gjertz et al., 2000b; Krafft et al., 2000). Dive studies of female bearded seals in the Svalbard Archipelago indicate that bearded seals make shallow dives, generally <328 ft (<100 m) in depth, and for short periods, generally less than 10 min in duration (Cameron et al., 2010). By the time bearded seal pups are 6 weeks of age, they are capable of diving to maximum dive depths similar to that of lactating females 1470 to 1575 ft (448 to 480 m) (Gjertz et al., 2000b). Adult females spent most of their dive time (47 to 92 percent) performing U-shaped dives, believed to represent bottom feeding (Krafft et al., 2000). Gjertz et al. (2000b) reported a mean maximum dive depth of 951 ft (290 m). Routine dive times range from 1 to 5.4 min., with a maximum dive time of about 10 min (Gjertz et al., 2000b). Bearded seals are capable of swimming from 1.2 to 3.1 kt (2.2 to 5.8 kph).

Little is known about the hearing of bearded seals. Phocid seals probably hear sounds underwater at frequencies up to about 60 kHz. Above 60 kHz, their hearing is poor. Male bearded seals vocalize during the spring breeding season using four types of calls: trills, ascents, sweeps, and moans that have described as FM vocalizations (Davies et al. 2006, Risch et al. 2007; Van Parijs et al. 2004, Van Parijs and Clark 2006). They produce distinctive, stereotyped calls ranging from 0.02 to 11 kHz in frequency. As they sing, bearded seals dive slowly in a loose spiral, releasing bubbles and finally surfacing in the center of the circle they've made. Each male's vocalizations are unique and they return to a specific breeding territory each year for mating, with a peak in calling occurring during and after pup rearing (Chapskii, 1938; Dubrovskii, 1937; Freuchen, 1935; Wollebaeck 1927). Trills show marked individual and geographical variation, are uniquely identifiable over long periods, can propagate up to 30 km, are up to 60 s in duration, and are usually associated with stereotyped dive displays (Cleator et al. 1989, Van Parijs et al. 2001, Van Parijs 2003, Van Parijs et al. 2003, Van Parijs et al. 2004, Van Parijs and Clark 2006). The vocalizations are only heard during the breeding season which lasts for about 90 days, from about late March through mid July.

Ribbon Seal (*Histriophoca fasciata*)

Ribbon seals are classified as a data deficient species by the IUCN. Although no current abundance estimates are available for the global population, Fedoseev (2000) reported an average population of 370,000 ribbon seals in the Sea of Okhotsk between 1968 and 1990, but more recently, 124,000 ribbon seals have been estimated to occur in the Sea of Okhotsk (Boveng et al., 2013). The Alaska stock of ribbon seals is estimated to include 184,000 individuals (Conn et al., 2014; Muto et al., 2016) and the North Pacific stock is estimated to include 61,100 individuals (Allen and Angliss, 2015).

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 (Fedoseev, 2009; Jefferson et al., 2015). 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 are unknown and few dive data are known for this species. Fedoseev (2002) reported that ribbon seals are well adapted for fast swimming and deep diving. Boveng et al. (2013) noted that ribbon seal diving patterns are tied to season, with a tendency for the dive depths to increase as the ice edge expands south, nearer to the continental shelf break. When ribbon seals on are on the sea ice in shallow water during spring, they dive to the sea floor, typically to depths of 233 to 328 ft (71 to 100 m), but when not tied to sea ice, ribbon seals dive deeper, up to 1640 ft (500 m) and rarely to 1,969 ft (600 m) (Boveng et al., 2013).

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 sec 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.

<u>Spotted Seal (*Phoca largha*)</u>

Spotted or largha seals are classified as a data deficient species by the IUCN. The Southern DPS 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. The global population for this species is unknown. Fedoseev (2000) reported that 180,000 seals occur in the Sea of Okhotsk stock/DPS, while Mizuno et al. (2002) reported an average abundance of 10,099 seals in the southern Sea of Okhotsk off Hokkaido, Japan during March and April 2000. The last reliable population estimate for the Alaska stock/Bering Sea DPS was 460,268 seals (Allen and Angliss, 2015). Additionally, Trukhin and Mizuno (2002) reported 1,000 spotted seals in Peter the Great Bay and that this population had maintained this stable number of seals for at least 10 years. The total population in the Southern DPS/stock of spotted seals is estimated as 3,500 individuals (Boveng et al., 2009; Han et al., 2010; Nesterenko and Katin, 2008).

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., 2015). 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 seas to maintain association with drifting ice. Peak haul-out time is during molting and pupping from February to May (Burns, 2009). Swim speeds range from 0.2 to 2.8 kt (0.4 to 5.2 kph), with an average speed of 1.2 ± 0.4 kt (2.2 ± 0.8 kph) have been observed (Lowry et al., 1998). Dive times of this species are not known. Dives as deep as 984 to 1,312 ft (300 to 400 m) have been reported for adult spotted seals with pups diving to 263 ft (80 m) (Bigg, 1981).(

Spotted seals can hear underwater from 300 Hz to 56 kHz. Their best sensitivity is between 2 and 30 kHz, with threshold of ~ 55 dB (Sills et al., 2014). 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).

3.3.4.2 Cetaceans

Cetaceans (whales, dolphins, and porpoises) are wholly aquatic and never purposefully return to land. Cetaceans are ecologically diverse and include over 89 species that are classified in two suborders: baleen, or mysticete, whales and toothed, or odontocete, whales (also including dolphins and porpoises) (SMM, 2016). Mysticetes are distinguished by their large body size and specialized baleen feeding structures, which are keratinous plates that replace teeth and are used to filter zooplankton (e.g., krill) and small fishes from seawater. In contrast, odontocetes have teeth for feeding and exhibit greater foraging diversity. Both cetacean groups are capable of emitting sound, but only odontocetes emit sound signals, called echolocation, used for locating prey and objects as well as navigating.

Hearing and sound production is highly developed in all studied cetacean species. Cetaceans rely heavily on sound and hearing for communication and sensing their environment (Frankel, 2009; Norris, 1969; Watkins and Wartzok, 1985). Of all mammals, cetaceans have the broadest acoustic range and the only fully specialized ears adapted for underwater hearing. Little information, however, is available for individual hearing capabilities in most cetacean species (Ketten, 1994; Ketten, 2000).

Sound production in cetaceans varies throughout a wide range of frequencies, sound types, and sound levels. The seasonal and geographic variation among cetacean species may also factor into the diversity of cetacean vocalizations. While all functions of sound production are not completely understood, vocalizations are likely used for echolocation, communication, navigation, sensing of the environment, prey location, and orientation in some species (Clark and Ellison, 2004; Ellison et al., 1987; Frankel, 2009; George et al., 1989; Tyack, 2000).

Mysticetes (Baleen Whales)

All mysticete species potentially occur in waters in which SURTASS LFA sonar may be operated and consequently could be affected by exposure LFA sonar (Table 3-4). The status of many mysticete species is considered to be imperiled throughout their worldwide ranges. All mysticetes produce LF 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 on such large animals (Clark, 1990; Edds-Walton, 1997; Evans and Raga, 2001; Richardson et al., 1995; Tyack, 2000). A few species' vocalizations are known to be communication signals, and while the function of other mysticete LF sounds are not fully understood, they likely are used for 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. Baleen whales are generally believed to have frequencies of best hearing where their calls have the greatest energy—below 5,000 Hz (Ketten, 2000). Information about the Mysticete species considered in this SEIS/SOEIS is presented in the taxonomic order, per the Society of Marine Mammalogy (2016), with each species in alphabetical order within each family (Table 3-4).

Balaenidae

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 (Allen and Angliss, 2010; Heide-Jørgensen et al., 2006). 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, only 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 (Mitchell, 1977) estimate of about 6,500 bowheads is the most commonly used estimate. The best available abundance estimate for bowhead whales in the Sea of Okhotsk, which is considered mature but small, is 247 bowhead whales (Ivashchenko and Clapham, 2010; Maclean, 2002). 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[17], 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 it is not clear if any predictable seasonal movements occur in this stock (Braham, 1984; Ivashchenko and Clapham, 2010). Currently, 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; Ivashchenko and Clapham, 2010; Rice, 1998; Rogachev et al., 2008). Bowheads have been observed in the northern sea in January and February; winter sightings so far north have lead to

17 Polynya=a Russian word that means ice clearing and refers to an area of open water that is surrounded by sea or landfast ice.

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., 2012). 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 (Heide-Jørgensen et al., 2003; Krutzikowsky and Mate, 2000; Thomas 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). Dive depth while foraging changes seasonally, in response to changes in copepod distribution (Heide-Jørgensen et al., 2013). Early in the season, bowheads in Disko Bay feed near the seafloor at depths of 328 to 1,312 ft (100 to 400 m). Later in the season, they fed on a copepod layer near 98 ft (30 m). The majority of bowhead dives appear to be shallow and short dives, at depths ≤53 ft (≤16 m) for a mean duration of 6.9 to 14.1 min (Krutzikowsky and Mate, 2000). Heide-Jorgensen et al. (2003) reported that fewer than 15 percent of all recorded bowhead dives were to depths greater than 499 ft (152 m) and only 5 percent of the dives lasted more than 24 min. Averaging about 0.6 to 3 kt (1.1 to 5.8 kph), bowhead whales are fairly slow swimmers (Mate et al., 2000). They can, however, travel vast distances, with one tagged bowhead whale having traveled 1,828 nmi (3,386 km) in 33 days at an overall swim speed of 2.7 kt (5 kph) (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 typically 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 a mean source level of bowhead moans 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). Calls made during migration have been shown to be moderately directional, with received levels 4-5 dB higher ‘in front’ of the animals than behind them (Blackwell et al., 2012). Calling rates during the summer feeding season varied spatially and temporally, with the highest rates found on the outer continental shelf, vice inner shelf and slope areas

(Charif et al., 2013). Bowhead whales are also capable of producing two different sounds at the same time (Tervo et al., 2011; Würsig and Clark, 1993).

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 (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. Johnson et al. (2014) reported 12 song types recorded during one migration season. 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; Johnson et al., 2014).

Several purposes for bowhead vocalizations have been suggested including communication and group cohesion. Song is widely considered to serve a reproductive signaling function (e.g., Stafford et al., 2012). 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).

<u>North Atlantic Right Whale (*Eubalaena glacialis*)</u>

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 2014 as 476 individual individuals (Waring et al., 2016). 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). In 2016, critical habitat for the North Atlantic right whale was expanded to include a total of 29,763 nmi^2 (102,084 km^2) of habitat in the Gulf of Maine and Georges Bank area as well as off the southeast U.S. Atlantic coast. The southern critical habitat area was expanded by 341 nmi^2 (1,170 km^2) and includes nearshore and offshore waters from Cape Fear, NC south to ~27 nmi (50 km) south of Cape Canaveral, FL (NOAA, 2016d).

North Atlantic right whales are found in temperate to subpolar waters of the North Atlantic Ocean (Jefferson et al., 2015). 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 (Foley et al., 2011), 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 between the northeast coast of Florida and southeastern Georgia and forage in the Bay of Fundy (IFAW, 2001; Vanderlaan et al., 2003). Right whales are found off New Jersey in all seasons of the year (Whitt et al., 2013). The Gulf of Maine has been proposed as a mating ground (Cole et al., 2013). Whales are detected acoustically throughout the winter in this region (Bort et al., 2015). These recent data suggest that the seasonal movements of right whales are more complex than originally thought.

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 1.9 kt (3.5 kph), while those that remained in the Bay of Fundy had a swim speed average of 0.6 kt (1.1 kph). The three whales that did not leave the Bay of Fundy still traveled more than 1,080 nmi (2,000 km) 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 398 ft (121 m), with a maximum depth of 571 ft (174 m). Whales foraging in Cape Cod Bay spent most of their time within 8.2 ft (2.5 m) of the surface, a behavior that increases their vulnerability to ship strike (Parks et al., 2011). However, the maximum dive depth recorded by North Atlantic right whales was 1,004 ft (306 m) (Mate et al., 1992). Whales in the Florida winter ground had an average speed of 0.7 kt (1.3 kph), with a range of 0.03 to 2.9 kt (0.05 to 5.37 kph) (Hain et al., 2013).

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 sounds” (Clark, 1982; Matthews et al., 2001). These gunshot sounds are produced only by males, and are thought to be a reproductive signal, possibly attracting females (Parks et al., 2005). 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 31 to 656 ft (40 and 200 m), with an average distance of 289 ft (88 m). The SLs for the sounds ranged from 137 to 162 dB for tonal calls and 174 to 192 dB for broadband gunshot sounds.

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. The population of the Eastern North Pacific right whale stock is estimated as 31 individuals (Muto et al., 2016), while the population of the Western North Pacific right whale stock is much larger, estimated as 922 individuals (Best et al., 2001).

The North Pacific right whale is not a very well known species because there are so few left. This whale population is primarily sighted in the Sea of Okhotsk and the eastern Bering Sea (Jefferson et al., 2015). They have also been seen southeast of the Kamchatka peninsula (Sekiguchi et al., 2014). Passive acoustics and satellite tracking led to the observation of 17 individuals in the eastern Bering Sea in 2004 (Wade et al., 2006). Passive Acoustic monitoring detected North Pacific right whales in deep oceanic waters in the Gulf of Alaska (Širović et al., 2015), suggesting that their current range may be larger than previously thought. Breeding grounds for this species are unknown. The historical range has been predicted based on whaling records and available climate information (Gregr, 2011). 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). There is no swim speed or dive information available for the North Pacific right whale except that they are known to be slow swimmers.

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 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) .The source level of North Pacific Right whale upcalls averaged 176 to 178 dB re 1μPa @ 1 m, with a frequency range of 90 to 170 Hz (Munger et al., 2011).

<u>Southern Right Whale (*Eubalaena australis*)</u>

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. The population size is estimated to be around 8,000 whales with an annual growth rate of 7 to 8 percent (Jefferson, et al., 2015).

Southern right whales have a circumpolar distribution in the Southern Hemisphere, predominately found off Argentina, South Africa, and Australia (Kenney, 2009). Major breeding areas include southern Australia, South America along the Argentine coast, and along the southern coast of South Africa (Croll et al., 1999). There is evidence that southern right whales are expanding their range as the population recovers (Carroll et al., 2014; Groch et al., 2005). No swimming or diving information is available for the southern right whale, but like other right whales, they are known to be slow swimmers.

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 (Cummings et al., 1972; Payne and Payne, 1971). "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 5.3 nmi (10 km) (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).

Neobalaenidae

Pygmy Right Whale (*Caperea marginata*)

The pygmy right whale is protected under CITES and classified as least concern (lower risk) under IUCN. No data are available on the abundance of this species. Very little is known about the pygmy right whale, as less than 25 sightings of this species have been recorded (Kemper, 2009).

The pygmy right whale is found in 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. Pygmy right whales occur in Tasmania throughout the year and during the southern winter off South Africa, particularly between False Bay and Algoa Bay (Evans, 1987; Leatherwood and Reeves, 1983). There is some evidence for an inshore movement in spring and summer, but no long-distance migration has been documented. There is no available literature on locations of breeding areas or mating and calving seasons (Baker, 1985; Lockyer, 1984; Ross et al., 1975). Records show this species swims at a speed of 2.9 to 5.1 kt (5.4 to 9.4 kph) 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 re 1 μPa @ 1 m (Frankel, 2009).

Eschrichtiidae

Gray Whale (*Eschrichtius robustus*)

The gray whale population is divided into two different stocks and DPSs. The Eastern North Pacific stock and DPS of gray whales was listed as endangered under the ESA, but was de-listed in 1994. The Western North Pacific stock and DPS is extremely small and remains listed as endangered under the ESA. Eastern North Pacific gray whales are protected under CITES and classified as a least concern (lower risk) species under the IUCN, while the Western North Pacific population is considered critically endangered under the IUCN. The Western North Pacific stock/DPS was thought to be extinct, but a small group of gray whales still remain. There are 165 individuals in the Western North Pacific gray whale photo-identification catalog (Tyurneva et al., 2010) but the current population is estimated as 140 individuals (Carretta et al., 2015). The Eastern North Pacific stock of gray whales is estimated to contain 20,990 individuals (Carretta et al., 2015). Western gray whales have been re-sighted off North America (Weller et al., 2012) and have been satellite tracked from Russia to America (Mate et al., 2015). These results suggest that there may be genetic interchange between the two populations.

Gray whales are confined to the shallow coastal waters of the North Pacific Ocean and adjacent seas. They are found as far south as the Baja of California in the eastern North Pacific, and to southern China in the western North Pacific (Jefferson et al., 2015). A foraging region for western gray whales has been identified along the Chukotka peninsula (Heide-Jørgensen et al., 2012). This is in close proximity to some of the eastern gray whale foraging areas along the Alaskan coasts. Every year most of the population makes a large north-south migration from high latitude feeding grounds to low latitude breeding grounds. Most gray whales in the eastern Pacific breed or calve during the winter in lagoons of Baja California (Jones and Swartz, 2009). There is no available information on breeding and calving areas of the western North Pacific gray whale, although Hainan Island has been suggested as a possible location (Brownell and Chun, 1977).

Swim speeds during migration average 2.4 to 4.9 kt (4.5 to 9 kph) and when pursued may reach about 8.64 kt (16 kph) (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 557 ft (170 m) (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 1.1 nmi (2 km) from shore. However, this response extinguished when the source was moved out of their migration path even though the received levels remained similar to the earlier condition (Clark et al., 1999). Gray whales detected and responded to 21 kHz sonar signals, indicating that their hearing range extends at least that high in frequency (Frankel, 2005).

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). A combination of clicks and grunts has 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).

Balaenopteridae

Antarctic Minke Whale (*Balaenoptera bonaerensis*)

The Antarctic minke whale is listed by the IUCN as data deficient. There are no recent population estimates, but this population still continues to be the target of Japanese “scientific whaling”. Jefferson et al. (2015) suggest that the population is less than Ruegg et al.’s (2009) estimate of 670,000 whales. An earlier paper provided estimates of 608,000, 766,000, and 268,000 for three different cruises covering the areas south of 60° S (Branch and Butterworth, 2001). The population of Antarctic minke whales occurring off Western Australia has been estimated as 90,000 whales (Bannister et al., 1996).

Diving behavior has been recorded from foraging individuals. Three dive types were identified: short and shallow, under ice, and long and deep. The mean depth for short, shallow dives was 33 ft (10 m), 98 ft (30 m) for under ice dives, and 187 ft (57 m) for long, deep dives (Friedlaender et al., 2014). Dive times ranged from 1 to 6 min (Friedlaender et al., 2014).

There is no direct measurement of the hearing sensitivity of Antarctic minke whales (Ketten, 2000; Thewissen, 2002). However, models of minke whale middle ears predict their best hearing overlaps with their vocalization frequency range (Tubelli et al., 2012). Few descriptions of the Antarctic minke whales have been published. Schevill and Watkins (1972) reported intense downsweeps from ~ 130 to 60 Hz for whales in the Antarctic. However, they were not able to discern if these were common or Antarctic minke whales. Antarctic minke whales are known to produce "bio-duck" sounds; short downsweeps between 250 and 100 Hz that are produced in patterns (Risch et al., 2014).

<u>Blue Whale (*Balaenoptera musculus*) and Pygmy Blue Whale (*Balaenoptera musculus brevicauda)*</u>

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 pygmy blue whale (*Balaenoptera musculus brevicauda)* is a subspecies of blue whale that occurs in the Southern Hemisphere, especially in the Indian Ocean. The global population of blue whales is estimated between 10,000 to 25,000 individuals (Jefferson et al., 2015), while 81 blue whales are estimated to occur in the Central North Pacific; 1,647 in the Eastern North Pacific (Carretta et al., 2015); 9,250 whales are estimated in the Western North Pacific (Stafford et al., 2001; Tillman, 1977); 9,250 blue whales are estimated to occur in the Western South Pacific (Stafford et al., 2001; Tillman, 1977); and 1,700 blue whales are estimated for the Southern Ocean (Branch et al., 2007). Although there is no best population estimate for the North Atlantic Ocean, 440 blue whales are estimated in the Western North Atlantic stock (Waring et al., 2014), while 979 blue whales are estimated for the Eastern North Atlantic (Pike et al., 2009). In the Northern Indian Ocean, 3,432 blue whales have been estimated to occur (IWC, 2016), with 424 blue whales estimated for the Madagascar Plateau of the western Indian Ocean region in the austral summer (Best et al., 2003), and 1,657 blue whales in the Southern Indian Ocean (Jenner et al., 2008; McCauley and Jenner, 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., 2015; 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., 2015). 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., 2015; Sears and Perrin, 2009). Blue whales appear to be concentrated near Cape Mendocino, the Gulf of the Farallones and the Channel Islands (Irvine et al., 2014). Blue whales are also commonly found in the Southern Ocean (Jefferson et al., 2015). Blue whales in the southeast Pacific Ocean appear to migrate between low latitude Eastern Tropical Pacific and high latitude regions off Chile (Buchan et al., 2015). At least some blue whales near Sri Lanka in the Indian Ocean remain at low-latitudes throughout the year, presumably because oceanographic upwelling supports sufficient productivity (de Vos et al., 2014). Pygmy blue whales off the west coast of Australia moved between ~42°S to the Molucca Sea, near the equator (Double et al., 2014). Blue whales have recently been spotted off Angola, part of the population that migrates between Gabon and South Africa (Figueiredo and Weir, 2014). They have also been recorded and visually identified off New Zealand (Miller et al., 2014).

The swimming and diving behavior of blue whales has been relatively well characterized. The average surface speed for a blue whale is 2.4 kt (4.5 kph) but can reach a maximum speed of 18.9 kt (45 kph) (Mate et al., 1999; Sears and Perrin, 2009). General dive times range from 4 to 15 min with average depths of 460 ft (140 m) (Croll, Acevedo-Gutierrez, et al., 2001; Sears and Perrin, 2009). The longest dive recorded was 36 min (Sears and Perrin, 2009). The mean surface interval has been measured at 145 seconds (de Vos et al., 2013).

There is no direct measurement of the hearing sensitivity of blue whales (Ketten, 2000; Nummela, 2009). 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, Clark, et al. (2001) 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. Control Exposure Experiments, presenting simulated mid-frequency (MF) sonar signals, did produce brief changes in deep-feeding and non-feeding whales, while surface-feeding whales were not affected (Goldbogen et al., 2013). Their vocalization rate appears to decrease in response of MF sonar, and increase in the presence of vessel noise (Melcón et al., 2012).

Blue whales produce a variety of LF vocalizations ranging from 10 to 200 Hz (Clark and Fristrup, 1997; Edds, 1982; Rivers, 1997; Stafford et al., 1998; Stafford et al., 1999a, 1999b, 2001; Thompson and Friedl, 1982) Alling and Payne, 1990). 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 (Mellinger and Clark, 2003; Moore et al., 1999). 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 (Aroyan et al., 2000; Cummings and Thompson, 1971). However, calls produced during foraging have been measured at lower source levels, ranging from 158 to 169 dB re 1µPa @ 1 m (Akamatsu et al., 2014).

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).

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. Call rates during foraging may be very low. A recent study recorded four calls during ~22 hours (Akamatsu et al., 2014).

Non-song calls are now being described. Pygmy blue whale calls off Australia were produced in at least five types composed of amplitude and frequency modulated components with frequencies ranging from 20 to 750 Hz and durations between 0.9 and 4.4 seconds (Recalde-Salas et al., 2014). Calls produced by foraging blue whales off Iceland were frequency modulated downsweeps with a frequency range of 105 to 48 Hz and durations of 1-2 seconds (Akamatsu et al., 2014).

<u>Bryde's Whale (*Balaenoptera edeni*)</u>

The Bryde's whale is currently protected under CITES and classified as a data deficient species by the IUCN. There are no global estimates for Bryde's whale. In the Western North Pacific and Western South Pacific, the population of Bryde's whales is estimated by the International Whaling Commission (IWC) as 20,501 whales (IWC, 2009), while 13,000 whales are estimated in the Eastern North Pacific and Eastern Tropical Pacific (Jefferson et al., 2015; Wade and Gerrodette, 1993). In Hawaiian waters, 798 Bryde's whales have been estimated (Carretta et al., 2015), and in the waters of the Gulf of Mexico, only 33

Bryde's whales are estimated to occur (Waring et al., 2014). In the Northern Indian Ocean, 9,176 Bryde's whales have been estimated (IWC, 2016; Wade and Gerrodette, 1993) while 13,854 Bryde's whales have been estimated for the Southern Indian Ocean (IWC, 1981).

Bryde's whales occur roughly between 40°N and 40°S throughout tropical and warm temperate (>61.3°F [16.3°C]) waters of the Atlantic, Pacific, and Indian Oceans year round (Kato and Perrin, 2009; Omura, 1959) 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). Bryde's whales are known to breed off South Africa (Best, 1960, 1975). Recent sightings indicate that the range of Bryde's whales is expanding poleward (Kerosky et al., 2012). Foraging grounds are not well known for this species, although there is evidence that they feed on a wide range of food in both pelagic and nearshore areas (Niño-Torres et al., 2014).

Bryde's whales are relatively fast swimming whales. The maximum swim speed reached by a Bryde's whale was recorded at 10.8 to 13.5 kt (20 to 25 kph), with average swim speeds reported between 1.1 and 3.8 kt (2 and 7 kph) (Kato and Perrin, 2009). Bryde's whales can dive to a water depth of about 984 ft (300 m) (Kato and Perrin, 2009). The maximum dive time reported for two Bryde's whales was 9.4 min with mean durations of 0.4 to 6 min (Alves et al., 2010).

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 fundamental frequencies below 240 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. Additional call types have been recorded in the Gulf of Mexico (Širović et al., 2014). 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). Pulsive, frequency-modulated and amplitude modulated calls with a frequency range of 50 to 900 Hz and 0.4 to 4.5 second duration were recorded off Brazil (Figueiredo, 2014). Although the function of Bryde's whale vocalizations is not known, communication is the presumed purpose.

<u>Common Minke Whale (*Balaenoptera acutorostrata*)</u>

The minke whale is protected under CITES as well as the MMPA and is classified by the IUCN as a least concern (lower risk) species. Common minke whales in the Western North Pacific Ocean are divided into the "O" stock, which ranges from the Okhotsk Sea to the waters off eastern Japan, and the "J" stock, which is located in waters around the Korean peninsula and in the Sea of Japan (Pastene et al., 1998).

The IWC reports a 1992 to 2004 population estimate for the Southern Hemisphere as 515,000 (IWC, 2016). Populations are estimated at least 180,000 in the Northern Hemisphere (Jefferson et al., 2015). U.S. regional stock assessments report 20,741 animals off the Canadian East Coast, which includes the U.S. Atlantic (Waring et al., 2014); 478 animals off the coasts of California, Oregon, and Washington (Carretta et al., 2014); and 1,233 minke whales in the Alaska stock (Allen and Angliss, 2015). The population of the Western North Pacific "O", Western South Pacific, and Hawaii stocks of common minke whales have been estimated as 25,049 individuals (Buckland et al., 1992) while the Western North Pacific "J" stock is estimated to include 893 common minke whales (Pastene and Goto, 1998).

Common minke whales in the Northeast Atlantic stock are estimated to include 78,572 individuals (IWC, 2010). A single stock is identified for the Indian Ocean with an estimated population of 257,500 whales (IWC, 2016), though minke whales are considered rare in the northern Indian Ocean (Salm et al., 1993; Sathasivam, 2002).

Minke whales are generally found over continental shelf waters; and in the far north, they are believed to be migratory, and 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 (Víkingsson and Heide-Jørgensen, 2015).

The mean speed value for minke whales in Monterey Bay was 4.5 (+/- 3.45) kt (8.3 +/- 6.4 kph) with a mean dive time was 4.43 (+/- 2.7) min (Stern, 1992). Minke whales in the St. Lawrence River performed both ‘short’ and ‘long’ dives. Short dives lasted between 2 and 3 min, while long dives ranged from 4 to 6 min (Christiansen et al., 2015).

There is no direct measurement of the hearing sensitivity of minke whales (Ketten, 2000; Thewissen, 2002). However, models of minke whale middle ears predict their best hearing overlaps with their vocalization frequency range (Tubelli et al., 2012). Minke whales produce a variety of sounds, primarily moans, clicks, downsweeps, ratchets, thump trains, and grunts in the 80 Hz to 20 kHz range (Edds-Walton, 2000; Frankel, 2009; Mellinger et al., 2000; Thompson et al., 1979; Winn and Perkins, 1976). 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 (Rankin and Barlow, 2005; Risch, Gales, et al., 2014). Boings begin with a brief pulse and then a longer amplitude modulated and frequency (AM and FM) signal lasting 2 to 10 seconds with frequency ranges from 1 to 5 kHz.

Minke whales alter their behavior in response to mid-frequency (SQS-53C) sonars. The observed vocalization rate decreases significantly. It is not known if this represents movement away from the area or if the animals simply vocalize less (Martin et al., 2015).

Both geographical and seasonal differences have been found among the sounds recorded from minke whales (Risch et al., 2013). 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. Similar sounds with a frequency range from 396 to 42 Hz have been recorded in the Saint Lawrence Estuary (Edds-Walton, 2000). Rankin and Barlow (2005) identified two distinct types of boings, which are found in the central and eastern North Pacific. Central-type boings have also been recorded in the Chukchi Sea (Delarue et al., 2013). Individuals within a population also use calls in different proportions (Risch, Van Parijs, et al., 2014) and had source levels of 164 to 168 dB re 1μPa @ 1 m (Risch, Van Parijs, et al., 2014). 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). The pattern of usage of calls while animals are within acoustic range of other minke whales reinforces the hypothesis that calls can serve to mediate social interactions (Risch, Van Parijs, et al., 2014).

Fin Whale (*Balaenoptera physalus*)

The fin whale is listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and as endangered by the IUCN. The global population estimate is roughly 140,000 whales (Jefferson et al., 2015). In the U.S. western North Atlantic, 1,618 fin whales have been estimated (Waring et al., 2015); 1,352 fin whales are estimated for the Canadian East Coast stock (Lawson and Gosselin, 2009); while the population estimated for the central and eastern North Atlantic is 30,000 individuals (IWC, 2009); with 9,019 whales of the number estimated for the Eastern North Atlantic (Hammond et al., 2013); and further north, the North-West Norway population is estimated to include 6,409 fin whales (Øien, 2009). The IWC (2009) estimates that 3,200 fin whales exist in West Greenland. Forcarda et al. (1996) estimated that 3,583 fin whales occur in the Mediterranean Sea. The California/Oregon/ Washington population includes an estimated 3,051 whales; in the Eastern North Pacific, fin whales are estimated to number 832 individuals (Ferguson and Barlow, 2003); the population in Hawai'i is estimated as 58 fin whales (Carretta et al., 2014); and the Western North and Western South Pacific stocks have been estimated as 9,250 individuals (Mizroch et al., 2009; Mizroch et al., 2015; Tillman, 1977). The Indian Ocean population of fin whales has been estimated to include 1,716 individuals (IWC, 2016), while the Southern Indian Ocean stock off western Australia is estimated as 38,185 fin whales (Branch and Butterworth, 2001; Mori and Butterworth, 2006).

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., 2015). 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 et al., 1998; Thompson et al., 1992).

Swimming speeds average between 5 to 8 kt (9.2 and 14.8 kph) (Aguilar, 2009). Fin whales dive for a mean duration of 4.2 min at depths averaging 197 ft (60 m) (Croll et al., 2001a; Panigada et al., 2004). Maximum dive depths have been recorded deeper than 1,181 ft (360 m) (Charif et al., 2002). Fin whales forage at dive depths between 328 to 656 ft (100 and 200 m), 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 (Edds, 1988; Watkins, 1981; Watkins, Tyack, and Moore, 1987). Short sequences of rapid FM calls from 20 to 70 Hz are associated with animals in social groups (Edds, 1988; McDonald et al., 1995; Watkins, 1981). 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 (Clark et al., 2002; Patterson and Hamilton, 1964; Watkins, Tyack, and Moore, 1987). The pulse patterns of the 20-Hz signal vary geographically and with seasons (Clark et al., 2002; Croll et al., 2002; Morano et al., 2012). 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 (Charif et al., 2002; Clark et al., 2002; Croll et al., 2002; Patterson and Hamilton, 1964; Thompson et al., 1992; Watkins, Tyack, and Moore, 1987; Weirathmueller et al., 2013). 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. Fin whales also produce 40 Hz downsweeps (Širović et al., 2012; Watkins, 1981).

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). A comparison of fin whales in the Mediterranean Sea and the Northeast Atlantic Ocean found that fin whale calls shrank in duration and decreased in frequency in response to vessel and airgun noise. Additionally the whales appeared to move away from the airgun array source (Castellote et al., 2012).

<u>Humpback Whale (*Megaptera novaeangliae*)</u>

The humpback whale is currently listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and as a least concern (lower risk) species by the IUCN. After the 2015 status review of the globally occurring humpback whale, NMFS proposed revising and relisting the humpback whale's global status under the ESA. Since this status change is expected to become finalized before this SEIS/SOEIS becomes final in 2017, the status of the humpback whale presented herein cites the existing endangered status, but also documents the proposed revised ESA status of the humpback whale DPSs throughout its global range. In the proposed changes to the humpback whale's global status, 14 DPSs for the humpback are recognized (Figure 3-10), of which only two would be listed as endangered and two listed as threatened (NOAA, 2015b). The Arabian Sea and Cape Verde/Northwest Africa DPSs are proposed for listing as endangered while the Western North Pacific (WNP) and Central America DPSs are proposed for listing as threatened. NMFS has determined that the remaining 10 global DPSs do not currently warrant listing under the ESA. No critical habitat has been established for the humpback whale.

The most current estimate of the humpback whale's global population is based on summing regional abundances, for an estimated total of 136,582 humpback whales worldwide (IWC, 2016). Pike et al, 2010) estimated the population as 11,572 humpbacks in the northeastern Atlantic and Norwegian Basin, which includes humpback whales in the Iceland stock with representatives from both the Cape Verdes-West Africa and West Indies DPSs. The West Indies DPS, including humpback whales from the Gulf of Maine and Newfoundland-Labrador stocks, is estimated as 12,312 individuals (Bettridge et al., 2015). Calambokidis et al. (2008) estimated the population of humpback whales in the entire North Pacific as 18,302 individuals. In the North Pacific Ocean, Carretta et al. (2015) estimated the population of the California/Oregon/Washington stock and Mexico DPS as 1,918 humpback whales; in the Central Pacific stock and Hawaii DPS, 10,103 humpback whales have been estimated to occur (Allen and Angliss, 2015; Calambokidis et al., 2008), with the same number estimated to occur in Gulf of Alaska waters where representative humpbacks from the Western and Central Pacific stocks and Hawaii, Mexico, and WNP DPSs coincide; while the Western North Pacific stock and DPS are estimated to include 1,328 humpback whales (Bettridge et al., 2015). The Southeast Pacific stock/Central America DPS of humpback whales is predicted to include 6,000 individuals (Félix et al., 2011; Johnston et al., 2011) and the population in the IWC Breeding stock E1, or East Australia DPS, is estimated as 14,500 humpback whales (Noad et al., 2011). The Western Australia stock and DPS of humpback whales is calculated to include 13,640

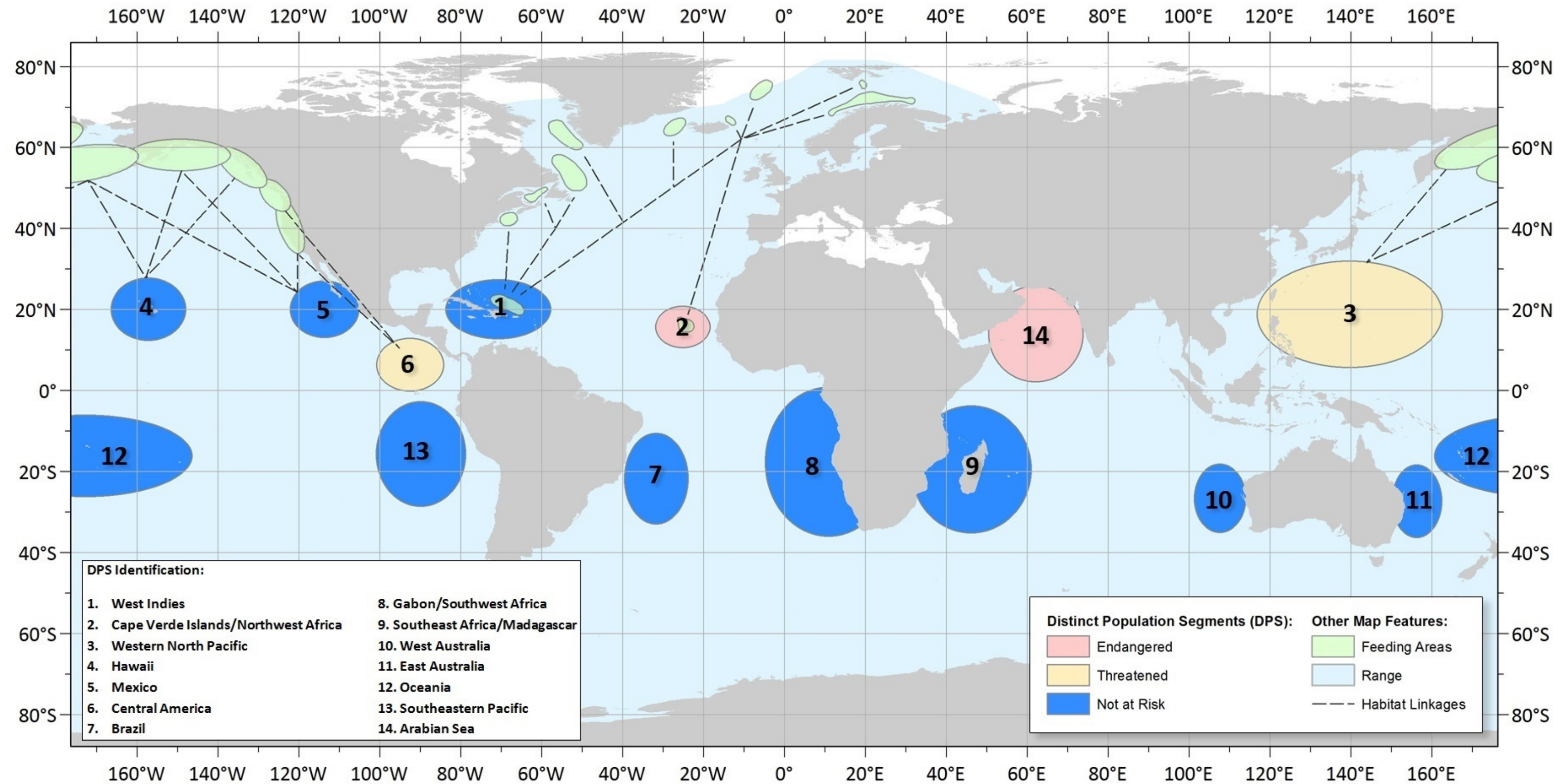


Figure 3-10. The Distinct Population Segments (DPSs) Proposed for Relisting of the Humpback Whale Globally Under the ESA (NOAA, 2015b). These Revisions Would Include Only Two Endangered DPSs, the Arabian Sea and Cape Verde/Northwest Africa, and Two Threatened DPSs, the Western North Pacific and Central America, With all Other DPSs not Proposed for Listing. Image Courtesy of NMFS/NOAA (2015b).

individuals (Bannister and Hedley, 2001), while the Arabian Sea stock and DPS are comprised of 200 humpback whales (Minton et al., 2008; Minton et al., 2011; Rosenbaum et al., 2009).

Humpback whales are distributed throughout the world's oceans, and are only absent from high Arctic and some parts of the equatorial region. They are a highly migratory species that can travel over 4,345 nmi (8,047 km) one way, which is the longest known migration of any mammal (Jefferson et al., 2008). The whales travel to high latitudes in the spring for feeding and to the tropics in the winter for calving and breeding. Humpback whales are found in coastal shelf waters when feeding and close to islands and reefs when breeding (Clapham, 2009). Data indicate that not all animals 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; Murray et al., 2013; Straley, 1999). There is also a small non-migratory population in the Arabian Sea (Pomilla et al., 2014). Barco et al. (2002) reported on humpback whale population site fidelity in the waters off the U.S. Mid-Atlantic States. Individual whales have shown a strong fidelity to specific feeding grounds, including the Gulf of Maine, Newfoundland/Labrador, the Gulf of Saint Lawrence, Greenland, Iceland, and Norway. Site fidelity has also been observed in the southern hemisphere feeding grounds (Acevedo et al., 2014). (Barco et al., 2002; Straley, 1999).

Humpback whales have well-defined breeding areas in tropical waters that are usually located near isolated islands. In the North Atlantic, there are breeding areas near the West Indies and Trinidad in the west, and the Cape Verde Islands and off northwest Africa in the east. 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). Humpbacks in the southern hemisphere are grouped into six management areas based on their summering locations near Antarctica (Donovan, 1991). The relationship between these management areas and actual humpback stocks is still being refined. Summering waters are found throughout the south Pacific, Atlantic and Indian Oceans.

Humpback whales travel long distances, with mean migratory swim speeds between 2.1 to 2.5 kt (3.8 and 4.7 kph) (Gabriele et al., 1996; Horton et al., 2011). 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). Dive times on the wintering grounds can be much longer. Singers typically dive between 10 and 25 min. Observations of 20 singers in the Caribbean found dive times between five and 20 min in duration (Chu, 1988). The deepest recorded humpback dive was 790 ft (240 m), with most dives ranging between 197 to 394 ft (60 and 120 m) (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). The presence of seismic survey activity can reduce the number of singing whales (Cerchio et al., 2014).

Humpbacks produce a great variety of sounds that fall into three main groups: 1) sounds associated with feeding; 2) Social sounds; and 3) Songs associated with reproduction. These vocalizations range in frequency from 20 to 10,000 Hz. Feeding groups produce stereotyped feeding calls ranging from 20 to 2,000 Hz, with dominant frequencies near 500 Hz (Frankel, 2009; Thompson et al., 1986). These sounds are attractive and appear to rally animals to the feeding activity (D'Vincent et al., 1985; Sharpe and Dill, 1997). Feeding calls were found to have SLs in excess of 175 dB re 1 μPa @ 1 m (Thompson, et al., 1986; Richardson et al., 1995). Humpback whales in the Northwest Atlantic ocean produce 'Megapclicks', which are click trains and buzzes with most of their energy below 2 kHz (Stimpert et al., 2007). These have a relative low source level of 143 to 154 dB re 1 μPa @ 1 m (peak-peak). While these calls are produced by feeding whales, their function remains unknown.

"Whup" calls are the most common call made by humpback whales in Glacier Bay, AK (Wild and Gabriele, 2014). These calls are composed of a short AM growl followed by a rapid upsweep from 56 to 187 Hz. These calls are thought to serve a communicative function. Additional social sounds have been described from Frederick Sound, AK, ranging from 70 to 3500 Hz and having mean durations from 0.8 to 16.7 seconds (Fournet et al., 2015). Social sounds produced in the Gulf of Marine had similar characteristics (Stimpert et al., 2011).

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 (Silber, 1986). 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 7.5 km (4.0 nmi) away (Tyack and Whitehead, 1983). Calves produce short, low-frequency sounds (Zoidis et al., 2008).

Migrating humpback whales also produced social sounds. (Dunlop et al., 2007) reported 34 types of calls ranging from 30 to 2400 Hz and between 0.2 and 2.5 seconds in duration. Twenty one of these call types were also included in the song. The median source level of social sounds is 158 dB re 1 μPa (range = 12-183) (Dunlop et al., 2013). Migrating humpbacks producing social sounds demonstrated the Lombard effect, which is an increase in the source level in response to increased ambient noise (Dunlop et al., 2014).

During the breeding season, males sing long complex songs with frequencies between 25 and 5,000 Hz. Mean SLs are ~165 dB re 1 μPa at 1 m (broadband), with a range of 144 to 174 dB (Au et al., 2006; Frankel et al., 1995; Payne and McVay, 1971). The songs vary geographically among humpback populations and appear to have an effective range of approximately 5.4 to 10.8 nmi (10 to 20 km) (Au et al., 2000). Singing males are typically solitary and maintain spacing of 2.7 to 3.2 nmi (5 to 6 km) from one another (Frankel et al., 1995; Tyack, 1981). Songs have been recorded on the wintering ground, along migration routes, and less often on feeding grounds (Clapham and Mattila, 1990; Clark and Clapham, 2004; Gabriele and Frankel, 2002; Magnúsdóttir et al., 2014; Stanistreet et al., 2013; Van Opzeeland et al., 2013; Vu et al., 2012).

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 Hawaiʻi 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.

Omura's Whale (*Balaenoptera omurai*)

Omura's whales have only recently been described and were previously known as a small form of Bryde's whale (Wada et al., 2003). The Omura's whale is not listed as threatened or endangered under the ESA nor is it categorized as depleted under the MMPA. The IWC recognizes the Omura's whale but has not yet defined stocks or estimated its population, and no global abundance of Omura's whales exists. The only abundance estimate that relates to the Omura's whale is that derived by Ohsumi (1980) for what he characterized at the time as unusually small Bryde's whales in the Solomon Islands. At least part of the whales Ohsumi (1980) identified as small Bryde's whales in the Solomon Islands have now been shown through genetic analysis to have been Omura's whales (Sasaki et al., 2006; Wada et al., 2003). Thus, while not ideal, given the paucity of data currently available for this species, Ohsumi's (1980) estimate of 1,800 individuals is the only available estimate for Omura's whales in the Western North and South Pacific stocks. The stock of Omura's whales that occurs in the Andaman Sea area of the northeast Indian Ocean has been estimated to include 9,176 individuals (IWC, 2016; Wade and Gerrodette, 1993) while the population of the Indian Ocean stock numbers 13,854 individuals (IWC, 1981).

Omura's whales are found in the Sea of Japan, the Solomon Sea, and the northeastern Indian Ocean (Wada et al., 2003) as well as in the Philippines (Aragones et al., 2010), China, and Australia, although the geographic range is not well established since so few specimens and sightings have been confirmed. The putative range of the Omura's whale is in tropical and subtropical waters of the Indian Ocean, including Madagascar (Cerchio et al., 2015) and the western Pacific Ocean from the Sea of Japan south to Southern Australian and New Caledonia from about 90° to 160°E, including the Solomon Sea, Java Sea, Andaman Sea, Gulf of Thailand, South China Sea, East China Sea, Sea of Japan, and parts of the Philippine Sea (Yamada, 2009). This whale occurs from inshore to oceanic waters (Cerchio et al., 2015; Reilly et al., 2008). Omura's whales are known from sightings, when they have been observed alone or in pairs, and single strandings. Cerchio et al. (2015) reported that there were never more than two individuals in a traditionally defined group but reported that there were often loose aggregations (within a few to several hundred meters apart), which may actually be social units. Cerchio et al. (2015) reported observations of small calves with bent dorsal fins, indicating that they were neonates.

Swim speeds and dive behavior characteristics have not yet been documented for the Omura's whale. Hearing has not been measured in the Omura's whale, but these whales produce long (mean duration = 9.2 sec), broadband, amplitude-modulated calls with energy concentrated in the 15 to 50 Hz band, with a rhythmic sequence with 2-3 minute intervals between utterances (Cerchio et al., 2015). Like other mysticetes, Omura's whales are classified as LF hearing specialists, presumably capable of hearing sound within the range of 7 Hz to 22 kHz (Southall et al., 2007).

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 at least 80,000 whales (Jefferson et al., 2015). The population estimate in Nova Scotian waters is 357 whales (Waring et al., 2014), while the population of the central North Atlantic is estimated as 10,000 whales (Horwood, 2009). Sei whales in the Iceland-Denmark Strait stock number 10, 300 individuals

(Cattanach et al., 1993; Donovan, 1991), and the population of the Labrador Sea stock includes 965 sei whales (Mitchell and Chapman, 1977). In the eastern North Pacific, an estimated 126 whales occur and 178 sei whales are estimated to occur in Hawaiian waters (Bradford et al., 2013; Carretta et al., 2014). The North Pacific and Western South Pacific stocks of sei whales are estimated to include 7,000 whales (Mizroch et al., 2009; Mizroch et al., 2015; Tillman, 1977). The Indian Ocean stock of sei whales is estimated as 13,854 whales (IWC, 1981).

Sei whales are primarily found in temperate zones of the world's oceans. Like other members of the family Balaenopteridae, sei whales are assumed to migrate to subpolar higher latitudes where they feed during the late spring through early fall, followed by movements to lower latitudes where they breed and calve during the fall through winter (Jefferson et al., 2015). 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). A migratory corridor between the Labrador Sea and the Azores has been established (Prieto et al., 2014). These data confirm cross-basin migratory paths in sei whales. 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. Specific breeding grounds are not known for this species, although the waters off NW Africa have been suggested for the North Atlantic sei whales (Prieto et al., 2014).

Sei whales are fast swimmers, surpassed only by blue whales (Sears and Perrin, 2009). Swim speeds have been recorded at 2.5 kt (4.6 kph), with a maximum speed of 13.5 kt (25 kph) (Jefferson et al., 2008). Prieto et al. (2014) reported mean speeds during migration of 3.3 to 4 kt (6.2 to 7.4 kph) "off migration". 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 65 to 100 ft (20 to 30 m), 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; Thewissen, 2002). Sei whale vocalizations are the least studied of all the rorquals. Rankin and Barlow (2007) recorded sei whale vocalizations in Hawaiʻi 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. A series of sei whales FM calls have been recorded south of New Zealand (Calderan et al., 2014). These calls have a frequency range from 87 to 34 Hz and a duration of 0.4 to 1.7 sec.

Odontocetes (Toothed Whales)

The odontocetes evaluated for this SEIS/SOEIS include six families containing 60 species (Table 3-4). Odontocetes can be distinguished from mysticetes by the presence of functional teeth and a single blowhole. Odontocetes have a broad acoustic range, with 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). Information about the Odontocete species considered in this SEIS/SOEIS is presented in the taxonomic order, per the Society of Marine Mammalogy (2016), with each species in alphabetical order within each family (Table 3-4).

Physeteridae

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 Jefferson et al. (2015) reports an estimate of 360,000 individuals. Sperm whale stocks in the Pacific Ocean have been estimated as 22,700 whales for the eastern tropical Pacific (ETP) (Wade and Gerrodette, 1993); 102,112 individuals in the North and Western South Pacific (Kato and Miyashita, 1998); 3,354 whales in Hawaii (Bradford et al., 2013; Carretta et al., 2014); and 2,106 individuals in California/Oregon/Washington (Carretta et al., 2015). Moore and Barlow (2014) examined abundance trends in sperm whale populations from 1991 to 2008 in the Northeast Pacific and were unable to precisely estimate overall trends but reported a high probability that the numbers of small groups was increasing. In the Atlantic Ocean, sperm whale stocks are estimated to include 763 in the U.S. Gulf of Mexico (Waring et al., 2016); 2,288 in the Western North Atlantic (Waring et al., 2014); and 7,785 in the Eastern North Atlantic (Christensen et al., 1992; Gunnlaugsson and Sigurjonsson, 1990; Whitehead, 2002). Indian Ocean sperm whale stocks have been reported as 24,446 individuals in the Northern and Southern Indian Ocean (IWC, 2016; Perry et al., 1999; Wade and Gerrodette, 1993). The Mediterranean Sea population is estimated by Rendell et al. (2014) to consist of 396 sperm whales.

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), but are commonly found near the equator and in the North Pacific (Whitehead, 2009). The distribution of sperm whales is not uniform, but clumped in relation to oceanographic features (summarized in Wong and Whitehead, 2014). The migration patterns of sperm whales are not well understood, as some whales show seasonal north-south migrations, and some whales show no clear seasonal migration, especially in the equatorial areas (Whitehead, 2009). 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 2.2 kt (2.6 to 4 kph) (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 4,921 ft (1,500 m) (Davis et al., 2007), but stomach content evidence suggests that sperm whales may dive as deep as 10,498 ft (3,200 m) (Clarke, 1976). Foraging dives typically last about 30 to 40 min and descend to depths from 984 to 4,085 ft (300 to 1,245 m) (Papastavrou et al., 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 (Goold and Jones, 1995; Madsen, Payne, et al., 2002; Møhl et al., 2000; Thode et al., 2002; Watkins and Schevill, 1977; Weilgart and Whitehead, 1997). Regular click trains and creaks have been recorded from foraging sperm whales and may be produced as a function of echolocation (Jaquet et al., 2001; Madsen, Wahlberg, et al., 2002; Whitehead and Weilgart, 1991). A series of short clicks, termed “codas,” have been associated with social interactions and are thought to play a role in communication (Pavan et al., 2000; Watkins and

Schevill, 1977; Weilgart and Whitehead, 1993). 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 (Madsen and Møhl, 2000; Muhl et al., 2000; Muhl et al., 2003; Thode et al., 2002). Muhl 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. Møhl 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 (Møhl, 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 1,640 ft (500 m). 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.

<u>Kogiidae</u>

<u>Pygmy Sperm Whale *(Kogia breviceps)* and Dwarf Sperm Whale *(Kogia sima)*</u>

Both the pygmy sperm whale and dwarf sperm whale are listed as data deficient under the IUCN. Abundance estimates of the global population sizes for these species are unknown but sometimes population information is combined for both species due to the difficulty in distinguishing between the species. Jefferson et al. (2015) reported that an estimated 11,200 dwarf sperm whales occur in the ETP (Wade and Gerrodette, 1993), while 579 pygmy sperm whales are estimated to occur in the California/Oregon/Washington stock, and 17,519 dwarf sperm and 7,138 pygmy sperm whales occur in the Hawaii stocks (Barlow, 2006; Carretta et al., 2014). The population of both species has been estimated as 350,553 whales in the Western North Pacific (Ferguson and Barlow, 2001 and 2003). An estimated 579 pygmy sperm whales are found off the U.S. Pacific coast (Carretta et al., 2014). In the Western and Eastern North Atlantic, an estimated 3,785 *Kogia* spp. occur while 186 are estimated occurring in the Gulf of Mexico (Waring et al., 2014). The stocks of pygmy and dwarf sperm whales in the Indian Ocean are estimated to number 10,541 individuals (Wade and Gerrodette, 1993)

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 5.9 kt (11 kph) (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 (Carder et al., 1995; Ridgway and Carder, 2001; Santoro et al., 1989). Echolocation pulses were documented with peak frequencies at 125 to 130 kHz (Ridgway and Carder, 2001). Thomas, Moore, Nachtigall, 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.

<u>Ziphiidae</u>

<u>Arnoux's Beaked Whale (*Berardius arnuxii*) and Baird's Beaked Whale (*Berardius bairdii*)</u>

Both the Baird's and Arnoux's beaked whales are currently classified as data deficient under the IUCN. 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, 2009b). Baird's beaked whale population numbers are estimated at 1,100 in the eastern North Pacific, including 847 Baird's beaked whales in the waters of Washington, Oregon, and California (Jefferson et al., 2008; Caretta et al., 2014), 847 whales in Alaska (Allen and Angliss, 2015; Carretta et al., 2015), and 8,000 whales in the Western North Pacific (Kasuya, 1986).

Baird's beaked whales occur in the North Pacific, including the Bering and Okhotsk seas (Kasuya, 1986; Kasuya, 2009a) and off California (Yack et al., 2013). 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, 2009b). 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 5,830 ft (1,777 m). It was also found that one deep dive (>3,280 ft [>1,000 m]) was followed by several intermediate dives (328 to 3,280 ft [100 to 1,000 m]) (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 and Brown, 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.

Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is currently classified as a least concern (lower risk) species by the IUCN. Global population estimates for this species are unknown. Abundances of Cuvier's beaked whales are estimated for the ETP as 20,000 individuals (Wade and Gerrodette, 1993); for the eastern North Pacific as 90,000 whales (Barlow, 1995); and as 90,725 whales in the Western North and Western South Pacific (Ferguson and Barlow, 2001 and 2003). The California/Oregon/Washington and Alaska stocks of Cuvier's beaked whales have been estimated most recent as 6,590 individuals, while 1,941 individuals are estimated for Hawaiian EEZ waters (Bradford et al., 2013; Caretta et al., 2014). The best abundance estimate for pooled beaked whales in the western North Atlantic is 6,532 whales (Waring et al., 2014). In the Alboran Sea stock of the Mediterranean, 429 Cuvier's beaked whales are estimated (Cañadas and Vázquez, 2014). The northern Indian Ocean stock of Cuvier's beaked whales is estimated to include 27,222 individuals (Wade and Gerrodette, 1993) while the stock off Western Australia in the Southern Indian Ocean is estimated to include 76,500 individuals (Dalebout et al., 2005).

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 (Jefferson et al., 2008; Omura et al., 1955). The Cuvier's beaked whale is the most cosmopolitan of all beaked whale species. The Cuvier's apparently prefers waters over the continental slope. No data on breeding and calving grounds are available.

Swim speeds of Cuvier's beaked whale have been recorded between 2.7 and 3.3 kt (5 and 6 kph) (Houston, 1991). Dive durations range between 20 and 87 min with an average dive time near 30 min (Baird et al., 2004; Heyning, 1989; Jefferson, 1993). This species is a deep diving species and can reach depths of 6,194 ft (1,888 m) (Heyning and Mead, 2009). Schorr et al. (2014) reported a maximum dive depth of 9,816 ft (2,992 m) that lasted 137.5 min.

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). 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) also found that Cuvier's beaked whales do not vocalize when within 656 ft (200 m) of the surface and only started clicking at an average depth of 1,558 ft (475 m) and stopped clicking on the ascent at an average depth of 2,789 ft (850 m) with click intervals of approximately 0.4 sec. Zimmer, Johnson, et al. (2005) 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.

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. Global abundance estimates of this species are not available but 4,571 Longman's beaked whales are estimated to occur in the Western and Central (Hawaii) North Pacific and Western South Pacific stocks (Bradford et al., 2013), 25,300 whales are estimated in the ETP (Wade and Gerrodette, 1993) and 16,867 whales are estimated to occur in the Indian Ocean (Wade and Gerrodette, 1993).

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, 2009a; Pitman et al., 1998). Strandings have occurred in Hawaiʻi and Japan (West et al., 2012; 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). Longman's beaked whales produce burst-pulses and echolocation clicks and pulses. Echolocation clicks are made at 15 and 25 kHz, along with a 25 kHz FM upsweep pulse. Burst-pulses are long sequence of clicks lasting ~ 0.5 seconds (Rankin et al., 2011).

Mesoplodon Beaked Whales

In this SEIS/SOEIS, 15 species in the *Mesoplodon* genus of beaked whales may occur in the waters in which SURTASS LFA sonar may operate. These species include: Andrew's, Blainville's, Deraniyagala's, Gervais', ginkgo-toothed, Gray's, Hector's, Hubb's, Perrin's, pygmy, Sowerby's, spade-toothed, Stejneger's, strap-toothed, and True's beaked whales (Table 3-4). The *Mesoplodon* species are very poorly known, difficult to identify to the species level at sea, and so little about their behavior has been documented that much of the available characterization for beaked whales is to genus level only; for this reason, information on the *Mesoplodon* beaked whale species is presented together.

Species in the genus *Mesoplodon* are currently classified with a data deficient status by IUCN. The worldwide population sizes for all species of *Mesoplodon* spp. are unknown. However, an estimated 694 *Mesoplodon* whales in the California/Oregon/Washington stocks (Carretta et al., 2015; Moore and Barlow, 2013) have been documented. In addition, the population of Blainville's beaked whales in the western North Atlantic was estimated as 149 whales (Waring et al., 2015), while 8,032 Blainville's were estimated to occur in the Western North and Western South Pacific (Ferguson and Barlow, 2001 and 2003), 2,338 whales were reported in Hawaii (Bradford et al., 2013; Carretta et al., 2014), and 25,300 Blainville's beaked whales were estimated for the ETP (Wade and Gerrodette, 1993). In the Indian Ocean, 16,687 Blainville's beaked whales are estimated. Other species of Mesoplodon beaked whales have been estimated at populations of 22,799 individuals in the Western North Pacific Ocean (Ferguson and Barlow, 2001 and 2003), while Stejneger's beaked whales were estimated including 8,000 individuals in the Western North Pacific (Kasuya, 1986).

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. 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)

Few swim speed data are available for any beaked whale species. Schorr et al. (2009) reported a horizontal swim speed of 0.4 to 0.8 kt (0.8 to 1.5 kph) for a Blainville's beaked whales in Hawai'i with a maximum rate of 4.4 kt (8.1 kph). 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 Hawai'i, a Blainville's beaked whale had a maximum dive depth of 4,619 ft (1,408 m), 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). A stranded Blainville's beaked whale's hearing was tested between 5.6 and 160 kHz. The best hearing response was between 40 and 50 kHz, with AEP thresholds less than 50 dB re 1 μPa (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)..

Recordings of Sowerby's beaked whales found echolocation clicks with center frequencies of 33, 25, 51, or 67 kHz (Cholewiak et al., 2013). Most clicks did not have any frequency modulation, although a few showed a slight sweep from 30 to 36 kHz. Burst-pulse signals were also detected, however the occurred much less often than clicks (7 v. 2969).

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). The Scotian Shelf population of northern bottlenose whales was listed as endangered under Canada's Species at Risk Act (SARA). Both species are also protected under CITES. Abundance estimates of the global populations are unknown. An estimated 40,000 northern bottlenose whales occur in the North Atlantic Ocean, with over 5,000 northern bottlenose whales estimated to occur in the Faroe Islands (Whitehead et al., 1997). The Davis Strait stock of northern bottlenose whales off eastern Canada is estimated to include 50 whales (DFO, 2011; Whitehead and Hooker, 2012) while the Eastern North Atlantic stock is estimated as 19538 whales (Cañadas et al., 2011). 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). In the Indian Ocean, an estimated 599,300 southern bottlenose whales occur (Kasamatsu and Joyce, 1995).

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 non-migratory, unlike other northern bottlenose whale populations. 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.

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 2.7 kt (5 kph) (Kastelein and Gerrits, 1991). Hooker and Baird (1999) documented northern bottlenose whales with regular dives from 394 ft (120 m) to over 2,625 ft (800 m), with a maximum recorded dive depth to 4,770 ft (1,453 m). Martin Lopez et al. (2015) reported a mean dive depth of 5,158 ft (1,572 m) and a mean dive duration of 49 min. 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. Additional measurements report that the whales produce FM sweeps from 20 to 55 kHz, with RMS source levels between 175 and 202 dB re 1µPa @ 1 m (Wahlberg, Beedholm, et al., 2011). 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.

Shepherd's Beaked Whale (*Tasmacetus shepherdi*)

The Shepherd's beaked whale is currently classified as a data deficient species by IUCN. 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). 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.

Monodontidae

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., 2015; NMFS, 2008). Worldwide abundance is estimated near 150,000; with 39,258 in the Beaufort Sea; 3,710 in the eastern Chukchi Sea; 19,186 in the eastern Bering Sea; 18,142 in Norton Sound; 2,877 in Bristol Bay; 312 in Cook Inlet; 28,000 in Baffin Bay; 25,000 in western Hudson Bay; and 10,000 in eastern Canada (Allen and Angliss, 2015; Jefferson et al., 2015). In the Sea of Okhotsk, 12,226 belugas have been estimated to occur (Shpak and Glazov, 2013).

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). One of the Alaska stocks of beluga whales, the Cook Inlet stock, resides there year-round and is geographically isolated from all other stocks (Hansen and Hubbard, 1999; Rugh et al., 2000) .Little is known about the distribution of beluga whales in the winter, but it is believed that the whales migrate in the direction of the advancing ice front and overwinter near "polynyas" (O'Corry-Crowe, 2009).

The beluga is not a fast swimmer, with maximum swim speeds estimated between 8.6 and 11.9 kt (16 and 22 kph) and a steady swim rate in the range of 1.3 to 1.8 kt (2.5 to 3.3 kph) (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 2,123 ft (647 m) 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 984 and 1,968 ft (300 and 600 m). In deep waters beyond the continental shelf, belugas may dive in excess of 3,281 ft (1,000 m), remaining submerged for up to 25 min (O'Corry-Crowe, 2009). Wild belugas were tagged with time-depth recorders (Citta et al., 2013). They found that dives could be categorized into three types. Shallow dives were typically less than 164 ft (50 m). Intermediate dives ranged to 820 (250 m), while deep dives extended to 1,312 ft (400 m). Dive duration typically ranged from 1 to 18 min. They also found regional differences; belugas in the eastern Beaufort Sea dove deeper than those in the western Beaufort or Chukchi seas.

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 (Au, 1993; Awbrey et al., 1988; Johnson et al., 1989; 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). Hearing was tested in seven wild belugas using AEP methodology (Castellote et al., 2014). There was substantial variability in sensitivity between individuals (>30 dB). The lowest hearing thresholds of 35-45 dB were found in the 45 to 80 kHz range. All animals could hear up to 128 kHz, and two were able to hear 150 kHz.

Signals produced by belugas have been described as a graded continuum (Sjare and Smith, 1986), meaning that call types grade continuously into other call types. 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 24 kHz range (Chmelnitsky and Ferguson, 2012). Echolocation clicks extend to 120 kHz (O'Corry-Crowe, 2009; Schevill and Lawrence, 1949; Sjare and Smith, 1986). There are at least 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). Belugas can also produce vocalizations that incorporate both tonal and pulsed components (Miralles et al., 2012). There is supportive evidence of geographical variation from distinctive calls used for individual recognition among beluga whales (Bel'kovich and Sh'ekotov, 1993).

Delphinidae

Atlantic Spotted Dolphin *(Stenella frontalis)*

The Atlantic spotted dolphin is classified as a data deficient species by the IUCN. 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 44,715 (Waring et al., 2015), while the number estimated in the northern Gulf of Mexico is 3,200 Atlantic spotted dolphins (Jefferson et al., 2015).

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 656 ft (200 m) depth contour, but they occasionally swim closer to shore in order to feed.

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

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 a frequency range of 1-23 kHz and with a duration less than one second (Azevedo et al., 2010; Lammers et al., 2003). 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 and Herzing, 2003).

<u>Atlantic White-sided Dolphin *(Lagenorhynchus acutus)*</u>

The Atlantic white-sided dolphin 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 48,819 Atlantic white-sided dolphins (Waring et al., 2015), and the Eastern North Atlantic stock includes an estimated 3,904 dolphins (Hammond et al., 2002). Off the western coast of Scotland, an estimated 96,000 Atlantic white-sided dolphins occur (Jefferson et al., 2015), while in the Labrador Sea stock, 24,422 Atlantic white-sided dolphins have been estimated (Lawson and Gosselin, 2009 and 2011; Waring et al., 2015).

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., 2015). 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., 2015). Calving occurs during the summer months with peaks in June and July (Croll et al., 1999; Jefferson et al., 2015).

Atlantic white-sided dolphins are probably not deep divers. A tagged dolphin dove for an average of 38.8 sec with 76 percent of the dives lasting less than 1 minute; this dolphin also swam at an average speed of 3.1 kt (5.7 kph) (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).

<u>Clymene Dolphin (*Stenella clymene*)</u>

Clymene dolphins are one of the more poorly known dolphin species and are classified as data deficient by the IUCN. Global population estimates are unknown, but there are an estimated 129 in the northern Gulf of Mexico (Waring et al., 2015).

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., 2015). 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 (Jefferson, 2015).

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).

Commerson's Dolphin (*Cephalorhynchus commersonii*), Chilean Dolphin (*Cephalorhynchus eutropia*), Heaviside's Dolphin (*Cephalorhynchus heavisidii*), and Hector's Dolphin (*Cephalorhynchus hectori*).

Commerson's and Heaviside's dolphins are classified as data deficient species. Heaviside's dolphin is listed as Near Threatened while the South Island population Hector's dolphin is classified as endangered and the North Island population is critically endangered under the IUCN. 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., 2015; 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 (Dawson, 2009; Slooten et al., 2002). Only one population estimate of 6,345 animals exists for Heaviside's dolphins in the Cape Town, South Africa region (Elwen et al., 2009).

Cephalorhynchus dolphins are found only in the temperate shallow (<656 ft [<200 m]), coastal waters of the Southern Hemisphere (Dawson, 2009; Goodall, 1994a, 1994b; Goodall et al., 1988; Sekiguchi et al., 1998). 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 (Dawson, 2009; Goodall, 1994b). 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. 2015; 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 4.3 nmi (8 km) from shore or in waters greater than 246 ft (75 m) deep (Jefferson et al., 2015). 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 328 ft (100 m) (Jefferson et al., 2015; Dawson, 2009). There is no evidence of large-scale seasonal movement for Heaviside's dolphins (Dawson, 2009).

Commerson's dolphins have been observed swimming at speeds of at least 16 kt (30 kph) (Gewalt, 1990), while Heaviside's dolphins swim much more slowly at a typical speed of 0.9 kt (1.6 kph) and a maximum speed of 2.1 kt (3.8 kph) (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 66 ft (20 m), although they are capable of diving to 341 ft (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 De Bufrenil, 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). Commerson's dolphin produce narrow bandwidth high frequency clicks with a peak frequency of >110 kHz and frequencies ranging from about 110 to ~200 kHz (Kyhn et al., 2010; Yoshida et al., 2014). Hector's dolphin emit sounds that are short (140 msec) 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 signals that are <2 to 5 kHz with a dominant frequency of 800 Hz (Watkins et al., 1977). Echolocation clicks have a center frequency of 125 kHz, a mean duration of 74 µs and a peak-to-peak source level of 173 dB (Morisaka et al., 2011).

<u>Common Bottlenose Dolphin *(Tursiops truncatus)*</u>

Overall, the common bottlenose dolphin is classified as least concern (lower risk) by the IUCN. However, the Fiorldland, NZ population is considered critically endangered and the Mediterranean population is considered vulnerable by the IUCN. The global population for the bottlenose dolphin is unknown. Estimates of 335,834 dolphins have been documented in the ETP (Gerrodette et al., 2008), and an estimated 168,791 bottlenose dolphins occur in the Western North and Western South Pacific stocks (Miyashita, 1993). The Inshore Archipelago stock that occurs in the Asian continental seas includes 105,138 dolphins (Miyashita, 1986 and 1993). Off the Pacific coast of the U.S., 323 coastal and 1,006 offshore bottlenose dolphins were estimated (Carretta et al., 2015). The pelagic Hawaiian population of common bottlenose dolphins includes 5,950 individuals, while the nearshore Hawaiian stocks include 184 dolphins in the Kaua'i/Ni'ihau stock, 743 off O'ahu, 191 in the 4-Island stock, and 128 in the Hawai'i Island stock (Baird et al., 2009; Bradford et al., 2013; Carretta et al., 2015). The Western Mediterranean stock of common bottlenose dolphins is estimated to include 1,676 individuals (Lauriano et al., 2014), 785,585 dolphins are estimated in the Indian Ocean population (Wade and Gerrodette, 1993), and 3,000 bottlenose dolphins may occur off Western Australia (Preen et al., 1997). The Eastern North Atlantic stock of common bottlenose dolphins has been estimated as 35780 individuals (Hammond et al., 2009 and 2013). Population estimates have been derived for each of the stocks of common bottlenose dolphins that occur in the U.S. western North Atlantic and Gulf of Mexico waters (Waring et al., (2015) (Table 3-5).

Table 3-5. Details of the Population Estimates for the U.S. Western North Atlantic and Gulf of Mexico Stocks of Common Bottlenose Dolphins (Waring et al., 2015).

Stock Name	***Population Estimate***
Western North Atlantic, Offshore	77,532
Western North Atlantic, Northern migratory, coastal	11,548
Western North Atlantic, Southern migratory, coastal	9,173
Western North Atlantic, S. Carolina/Georgia coastal	4,377
Western North Atlantic, Northern Florida coastal	1,219
Western North Atlantic, Central coastal Florida	4,895
Gulf of Mexico Continental shelf	51,192
Gulf of Mexico, Eastern coastal	12,388
Gulf of Mexico, Northern coastal	7,185
Gulf of Mexico, Western coastal	20,161
Gulf of Mexico Oceanic	5,806

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 Mahakunayanakul, 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.

Sustained swim speeds for bottlenose dolphins range between 2.2 and 10.8 kt (4 and 20 kph) and may reach speeds as high as 16.1 kt (29.9 kph) (Croll et al., 1999). Dive times range from 38 sec 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 322 ft (98 m) (Mate et al., 1995). The deepest dive recorded for a bottlenose dolphin is 1,755 ft (535 m) 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 to 110 kHz, where the threshold level range is 42 to 52 dB RL (Au, 1993). The range of highest sensitivity occurs between 25 and 70 kHz, with peaks in sensitivity at 25 and 50 kHz (Nachtigall et al., 2000). 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 are able to voluntarily reduce their hearing sensitivity to loud sounds (Nachtigall and Supin, 2015).

Bottlenose dolphins produce sounds as low as 50 Hz 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 (Croll et al., 1999; dos Santos et al., 1990; Johnson, 1967; McCowan and Reiss, 1995; Oswald et al., 2003; Popper, 1980c; Schultz et al., 1995). The maximum

SL reported is 228 dB (Croll et al., 1999). Bottlenose dolphins produce a variety of whistles, echolocation clicks, low-frequency narrow, 'bray' 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 msec duration with peak frequencies ranging from 30 to 100 kHz and fractional bandwidths between 10 and 90 percent 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. Inter-Click intervals (ICIs) vary to form different types of click patterns such as 1) low-frequency clicks that have no regular repeating interval; 2) train clicks (ICI = 35-143 msec); 3) Packed clicks (ICI = 2-6 msec); and 4) Burst, with an ICI of 1.7 to 4.9 msec, with more clicks than a packed click train (Buscaino et al., 2015). Burst-pulse sounds are typically used during escalations of aggression (Croll et al., 1999). Whistles range in frequency from 1.5 to 23 kHz and have durations up to 4 seconds (Díaz López, 2011; Gridley et al., 2015).

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 used for recognition, but may have other social contexts (Janik et al., 2013; Jones and Sayigh, 2002; Kuczaj et al., 2015). 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 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 Intracoastal Waterway site, which whistled more than the dolphins at the Sarasota site. Echolocation production was higher at the Intracoastal Waterway 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).

Dusky Dolphin (*Lagenorhynchus obscurus*)

The dusky dolphin is listed as data deficient species under the IUCN. 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., 2015; 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. Calving takes place from November to February (Croll et al., 1999).

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 2.4 and 6.6 kt (4.5 and 12.2 kph) (Cipriano, 1992; Würsig and Würsig, 1980). During feeding they can burst at speeds up to 19 kt (36 kph) (Bernasconi et al., 2011).

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 (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. Whistles were also recorded, but only at a rate of 0.01 whistle per minute. Those whistles ranged from 7 to 16 kHz with durations less than once second (Yin, 1999).

False Killer Whale (*Pseudorca crassidens*)

False killer whales are classified as least concern (lower risk) by the IUCN. The Main Hawaiian Island Insular DPS of 151 false killer whales is listed as endangered under the ESA (NOAA, 2012b). The global population for this species is unknown. Estimates of 39,800 whales have been documented in the ETP (Wade and Gerrodette, 1993), while 16,668 whales have been documented in the northwestern and southwestern Pacific (Miyashita, 1993), and 9,777 whales have been estimated in the Inshore Archipelago stock of the Asian continental seas (Miyashita, 1986). In Hawaiian waters, false killer whales have been estimated as 1,540 whales in the Hawaii pelagic population, as 617 whales in the Northwestern Hawaiian Islands DPS, and 1,329 whales off Palmyra (Bradford et al., 2014 and 2015; Carretta et al., 2016). In the western north Atlantic, there are an estimated 442 false killer whales and an unknown number in the Gulf of Mexico (Waring et al., 2015). The population of false killer whales in the Indian Ocean has been estimated as 144,188 whales (Wade and Gerrodette, 1993).

False killer whales are found in tropical to warm temperate zones in deep, offshore waters (Baird, 2009a; Odell and McClune, 1999; Stacey et al., 1994). 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., 2015). These whales do not have specific feeding grounds but feed opportunistically (Jefferson et al., 2015). False killer whales have an approximate swim speed of 3 kph (1.6 kt), although a maximum swim speed has been documented at 28.8 kph (11.9 kt) (Brown et al., 1966; Rohr et al., 2002).

False killer whales tagged in the western North Pacific performed both shallow and deep dives. Shallow dives had a mean duration of 103 sec and a mean maximum depth of 56 ft (17 m). Deep Dives had a mean duration of 269 sec (SD = 189) with a mean maximum depth of 424 ft (129 m) (SD = 185) (Minamikawa et al., 2013). The longest dives lasted 15 min and the deepest went to 2,133 ft (650 m). Dives were deeper during the day, suggesting that the whales are feeding on the deep scattering layer during the day (Minamikawa et al., 2013).

False killer whales hear underwater sounds in the range of less than 1 to 115 kHz (Au, 1993; Johnson, 1967). 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 show 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 ± 1.2 dB for the 75-Hz pure tone and 139.0 dB RL ±1.1 dB for the ATOC signal. False killer whales have the ability to reduce their hearing sensitivity in response to loud sounds (Nachtigall and Supin, 2013).

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; Murray et al., 1998; Thomas and Turl, 1990). 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. Echolocation clicks of false killer whales are highly directional and range between 20 and 60 kHz and 100 and 130 kHz (Kamminga and van Velden, 1987; Madsen et al., 2004b; Thomas and Turl, 1990). There are no available data regarding seasonal or geographical variation in the sound production of false killer whales. Estimated peak-to-peak SL of captive animal clicks is near 228 dB re 1 μPa @ 1 m (Madsen et al., 2004b; Thomas and Turl, 1990).

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphin is classified as a data deficient species by the IUCN. 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 Western North and South Pacific stocks, 220,789 Fraser's dolphins are estimated; while in the Central North Pacific stock, including Hawaii, 16,992 dolphins occur (Bradford et al., 2013; Carretta et al., 2015); in the ETP, the Fraser's abundance has been estimated as 289,000 Fraser's dolphins (Wade and Gerrodette, 1993); and in the eastern Sulu Sea the abundance is estimated as 13,518 dolphins (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., 2015). The Indian Ocean population is estimated to include 151,554 dolphins (Wade and Gerrodette, 1993).

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 (4,921 to 6,562 ft [1,500 to 2,000 m]) usually 8.1 to 11 nmi (15 to 20 km) 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., 2015). 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). Swim speeds of Fraser's dolphin have been recorded between 2.2 and 3.8 kt (4 and 7 kph) with swim speeds up to 15 kt (28 kph) 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 820 ft (250 m) and the deepest is no less than 1,640 ft (500 m). In the Sulu Sea, they appear to feed near the surface to at least 1,968 ft (600 m). 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 sec 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.

Hourglass Dolphin (*Lagenorhynchus cruciger*)

Hourglass dolphins are listed as least concern 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 (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. The apparent peak-to-peak source level is 190 to 2003 dB (Kyhn et al., 2009).

Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*)

Only recently 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. 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). The population off Natal numbers 900, while more than 600 dolphins occur in Shark Bay, Australia, 700 to 1,000 at Point Lookout, Australia, 334 in Moreton Bay, Australia, more than 24 off Taiwan, and 44 in the northeast Philippines (Jefferson et al., 2015). In the Indian Ocean, the population has been numbered at 7,850 dolphins (Wade and Gerrodette, 1993).

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., 2015). 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 (Cribb et al., 2013; Jefferson et al., 2015). However, movements across deep, oceanic waters have been reported (Wang and Yang, 2009).

Swimming speeds range from 0.8 to 2.2 kt (1.5 to 4.1 kph) but bursts of higher speeds can reach 8.6 to 10.3 kt (16 to 19 kph) (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 656 ft (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 4 to 12 kHz (Gridley et al., 2012; Morisaka et al., 2005a). 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., 2005b). Variability in whistle structure has been documented between both nearby and distant groups, although a few whistle types were shared, suggesting that their repertoire is driven by social functions such as group identity (Hawkins, 2010). Preliminary analyses suggest that Info-Pacific bottlenose dolphins use signature whistles like the common bottlenose dolphin (Gridley et al., 2014). Indo-Pacific bottlenose dolphin echolocation clicks have peak-to-peak source levels that range between 177-219 dB, with a duration of 8-48 μs, and peak frequencies that range from 45 to 141 kHz (de Freitas et al., 2015; Wahlberg, Jensen, et al., 2011).

Indo-Pacific Common Dolphin (*Delphinus delphis tropicalis*), Long-beaked Common Dolphin (*Delphinus delphis bairdii*), and Short-beaked Common Dolphin (*Delphinus delphis delphis*)

Genetic research has recently assisted in resolving the taxonomy of common dolphins. In this SEIS/SOEIS, we include three species of common dolphins: the Indo-Pacific, the long-beaked, and short-beaked common dolphins. The Indo-Pacific common dolphin is essentially the long-beaked common dolphin of the Indian Ocean (SMM, 2016). However, the characterizations that define the three species are difficult to assess at sea, and until recently, at-sea observations only reported "common" dolphins generically. Since little information is known to the species level, the three common dolphin species are presented together herein and long-beaked common dolphin references generally pertain to both species of long-beaked common dolphins.

The short-beaked 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. The global population for all common dolphin species is unknown. There are little data available on abundance estimates of long-beaked common dolphins. Short-beaked common dolphins are the most abundant species in the ETP at an estimated 3,127,203 dolphins (Gerrodette et al., 2008). In the California/Oregon/ Washington stocks 107,016 long-beaked common dolphins occur, an estimated 411,211 short-beaked common dolphins occur (Barlow, 2010; Carretta et al., 2011; Carretta et al., 2015). In the Western North and Western South Pacific stocks, 3,286,163 short-beaked common dolphins are estimated (Ferguson and Barlow, 2001 and 2003), while 279,182 long-beaked common dolphins are estimated for the Western North Pacific stock (Carretta et al., 2011). Estimates for the western North Atlantic stock of short-beaked common dolphins include 173,486 individuals (Waring et al., 2015), with 172,930 short-beaked common dolphins found in the Eastern North Atlantic (Hammond et al., 2009 and 2013). Cañadas and Hammond (2008) estimated that 19428 short-beaked common dolphins occurred in the Western Mediterranean. Jefferson et al (2015) estimates 15,000 to 20,000 long-beaked dolphins are estimated to occur in South African waters. As many as 1,819,882 long-beaked or Indo-Pacific common dolphins are estimated to occur in the Indian Ocean (Wade and Gerrodette, 1993).

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. 2015; Perrin, 2009). They seem to be most common in the coastal waters of the Pacific Ocean, usually beyond the 656-ft (200-m) isobath and north of 50°N in the Atlantic Ocean (Croll et al., 1999). Long-beaked dolphins, however, seem to prefer shallower, warmer waters that are closer to the coast (Perrin, 2009b). They are often found within 97.2 nmi (180 km) of the coast (Jefferson et al., 2015). 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.

Swim speeds for *Delphinus* spp. have been measured at 3.1 kt (5.8 kph) with maximum speeds of 8.7 kt (16.2 kph); but in other studies, common dolphins have been recorded at swimming up to 20 kt (37.1 kph) (Croll et al., 1999; Hui, 1987). Dive depths range between 30 and 656 ft (9 and 200 m), with a majority of dives 30 to 164 ft (9 to 50 m) (Evans, 1994). The deepest dive recorded for these species was 850 ft (260 m) (Evans, 1971). The maximum dive duration has been documented at 5 min (Heyning and Perrin, 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 (Au, 1993; Moore and Ridgway, 1995; Popper, 1980c; Watkins, 1967). Signal types consist of clicks, squeals, whistles, and creaks (Evans, 1994). Whistles of short-beaked common dolphins range between 3.5 and 23.5 kHz (Ansmann et al., 2007), 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 (Croll et al., 1999). There are no available data regarding seasonal or geographical variation in the sound production of common dolphins.

<u>Killer Whale (*Orcinus orca*)</u>

The killer whale is classified as a data deficient species under the IUCN. In 2005, the NMFS published a final determination to list the Southern Resident killer whales (*Orcinus orca*) DPS as endangered under the ESA (NOAA, 2005). Both the Southern Resident and AT1 Transient stocks of killer whales are listed as depleted under the MMPA. Critical habitat has been 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).

Generally, three major ecotypes of killer whales have been identified: the coastal (fish-eating) residents, the coastal (mammal-eating) transients, and the offshore types of killer whales. The basic social unit for all of these ecotypes is the matrilineal group (Ford, 2009). In resident killer whales, pods are formed from multiple matrilines and related pods form clans. 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).

Although no current global population estimates are available, Jefferson et al. (2015) estimated the killer whale worldwide abundance near 50,000 individuals. An abundance of 8,500 killer whales was estimated for the waters of the ETP (Wade and Gerrodette, 1993), with 101 killer whales currently estimated in the Hawaii stock (Bradford et al., 2013; Carretta et al., 2014), 240 killer whales are estimated in the Eastern Pacific Offshore stock (Carretta et al., 2015), and 12,256 whales in the Western North and Western South Pacific stocks (Ferguson and Barlow, 2001 and 2003). Additionally in the eastern North Pacific stock, 2,347 Alaska Resident, 587 Gulf of Alaska/Aleutian Islands/Bering Sea transient, 82 Southern Resident, 261 Northern Resident, 7 AT1 Transient, and 243 West Coast Transient killer whales have been estimated in these sub-stocks (Allen and Angliss, 2015; Carretta et al., 2015). Killer whales in the Sea of Okhotsk, members of the Okhotsk-Kamchatka-Western Aleutians Transient stock, number 12,256 killer whales (Ferguson and Barlow, 2001 and 2003; Carretta et al., 2016). In U.S. Atlantic waters, 28 killer whales are estimated to occur in the northern Gulf of Mexico (Waring et al., 2015), while 76 whales have been estimated to occur in the Western North Atlantic U.S. (Lawson and Stevens, 2014), and the Northern Norway stock of killer whales includes 731 whales (Kuningas et al., 2014). In the Indian Ocean, killer whales number 12,593 individuals (Wade and Gerrodette, 1993).

Nearly 80,000 killer whales are estimated south of the Antarctic Convergence Zone (Jefferson et al., 2008).

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 (Ford, 2009; Leatherwood and Dalheim, 1978). However, they appear to be more common within 430 nmi (800 km) of major continents in cold-temperate to subpolar waters (Mitchell, 1975). Individual populations are known to migrate between high and low latitude waters (Dahlheim et al., 2008; Durban and Pitman, 2012; Matthews et al., 2011).

Swimming speeds usually range between 3.2 to 5.4 kt (6 to 10 kph), but they can achieve speeds up to 20 kt (37 kph) in short bursts (Lang, 1966; LeDuc, 2009). The diving behavior of killer whales differs between fish-eating and mammal-eating types. Baird et al. (2005) reported that southern resident (fish-eating) killer whales in Washington State had a mean maximum dive depth of 463 ft (141 m [SD = 62 m]), with a maximum depth of 807 ft (246 m). Males dove more often and remained submerged longer than females. They also reported more dives during the day than at night. Fish-eating killer whales in Antarctica had shallow dives that ranged to about 656 ft (200 m), while deep dives approached 2,625 ft (800 m) (Reisinger et al., 2015). These animals also dove significantly deeper during the day than the night. Miller et al. (2010) reported on the diving behavior of transient (mammal-eating) killer whales in Alaska. Dives were categorized and short and shallow, and long and deep. Short dives lasted less than one minute and had dive depths of less than five meters. Deep dives ranged between 39 to 164 ft (12 and 50 m) in depth and lasted from 4 to 6 min. The mammal-easting killer whales dove much less deeply than the fish-eating whales, reflecting the distribution of their prey.

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 (Awbrey, 1982; Diercks et al., 1973; Diercks et al., 1971; Evans, 1973; Ford, 1989; Ford and Fisher, 1982; Miller and Bain, 2000; Schevill and Watkins, 1966). An average of 12 different call types (range 7 to 17)—mostly repetitive discrete calls—exist for each pod (Ford, 2009). Pulsed 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 range in frequency up to at least 75 kHz (Filatova et al., 2012; Samarra et al., 2015; Simonis et al., 2012). 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). Offshore killer whales tracked in the Southern California bight had source levels for echolocation clicks of 170-205 dB re 1µPa @ 1 m (peak-peak) (Gassmann et al., 2013). Whistle source levels ranged between 185 and 193 dB re 1 µPa @ 1 m. Pulse call source levels ranged between 146-158 dB re 1µPa @ 1 m. While the basic structure of killer whale vocalizations are similar within all populations, geographic variation between populations does exist (Samarra et al., 2015).

All pods within a clan have similar dialects of pulsed calls and whistles. Whales engaged in different activities produce different proportion of calls, suggesting that high-frequency and biphonic calls are used for long range communication, and low-frequency monophonic calls are used for intra-pod signaling (Filatova et al., 2013). Intense low-frequency pulsed calls (683 Hz, 169-192 dB re 1 µPa @ 1 m (peak-peak) appear to be used to manipulate herring prey, increasing foraging efficiency (Simon et al., 2006).

Long-finned Pilot Whale (*Globicephala melas*)

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., 2015). An estimate of 26,535 long-finned pilot whales was reported for the western North Atlantic (Waring et al., 2015); 6,134 whales were estimated in the Canadian East Coast stock (Lawson and Gosselin, 2009 and 2011); and 128,093 whales in the eastern North Atlantic (North Atlantic Marine Mammal Commission [NAMMCO], 2016).

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 (Nelson and Lien, 1996; Sergeant, 1962).

Pilot whales generally have swim speeds ranging between 1.1 to 6.5 kt (2 to 12 kph) (Shane, 1995b). Long-finned pilot whales have an average speed of 1.8 kt (3.3 kph) (Nelson and Lien, 1996) and are considered deep divers (Croll et al., 1999). Dive depths of long-finned pilot whales range from 52 ft (16 m) during the day to 2,126 ft (648 m) 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 vocalize with other school members (Olson, 2009). Pilot whales were able to mimic LF and MF sonar signals, indicating an ability to hear as low as 1 kHz (Alves et al., 2014). 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 (Busnel and Dzeidzic, 1966; Mcleod, 1986; Rendell et al., 1999; Schevill, 1964; Steiner, 1981; Taruski, 1979). Sound production of long-finned pilot whales is correlated with behavioral state and environmental context (Frankel, 2009; Taruski, 1979; Weilgart and Whitehead, 1990). 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. Echolocation clicks have a centroid frequency of 55 kHz and a peak-to-peak source level of 196 dB re 1 µPa @ 1 m (Eskesen et al., 2011). Pulsed calls have a complex and variable structure, with a measured frequency range of 140 to 20,000 Hz and durations that range between 0.2 and 2.2 sec (Nemiroff and Whitehead, 2009). It should be noted that the 20 kHz upper limit of these values may be an artifact of the recording equipment, which only recorded between 10 Hz and 20 kHz.

Melon-headed Whale (*Peponocephala electra*)

Melon-headed whales are classified as a lower risk (least concern) species by the IUCN. The global population for this species is unknown. Estimates of 45,400 melon-headed whales have been reported for the ETP (Wade and Gerrodette, 1993), while 36,770 whales have been estimated for the Western North and Western South Pacific Ocean (Ferguson and Barlow, 2001 and 2003). In the Northern Mariana

Islands, 2,455 melon-headed whales were estimated (Fulling et al., 2011). Two populations have been documented in Hawaiian waters: the pelagic stock with 5,794 whales and the Kohala resident population with an estimated 447 whales (Aschettino, 2010; Carretta et al., 2014; Oleson et al., 2013). An estimate of 2,235 melon-headed whales was reported for the northern Gulf of Mexico (Waring et al., 2015). In the Indian Ocean, the melon-headed whale population has been estimated as 64,600 whales (Wade and Gerrodette, 1993).

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 mesopelagic squid found down to 4,920 ft (1,500 m) deep, so they appear to feed deep in the water column (Jefferson and Barros, 1997). General swim speeds for this species are not available. Few data are available on diving or swim speed for the melon-headed whale. Mooney et al. (2012) reported in preliminary research findings that a tagged melon-headed whale in Hawaiian waters dove deeply to near the seafloor, >984 ft (300 m), at night but stayed near the sea surface during the day, with no dives >67 ft (20 m).

There is no direct measurement of hearing sensitivity for melon-headed whales (Ketten, 2000; Thewissen, 2002). The first (confirmed) description of melon-headed whale vocalizations was reported by (Frankel and Yin, 2010). The earlier report by Watkins et al. (1997) had an error in species identification (Baird, pers. comm.). Melon-headed whale's clicks have frequency emphases beginning at 13 kHz and extending to at least 100 kHz (Baumann-Pickering, Roch, et al., 2015; Frankel and Yin, 2010). Dominant frequencies of whistles are 1 to 24 kHz, with both upsweeps and downsweeps in frequency modulation. Burst-pulse sounds had a mean duration of 586 msec. No available data exist regarding seasonal or geographical variation in the sound production of this species. Changes in vocalization activity patterns suggest that melon-headed whales may forage at night and rest during the day (Baumann-Pickering, Roch, et al., 2015).

Northern Right Whale Dolphin *(Lissodelphis borealis)*

The northern right whale dolphin is classified as a least concern (lower risk) species by the IUCN. The global population in the North Pacific Ocean of the northern right whale dolphin is estimated as 68,000 animals (Jefferson et al., 2015). In the U.S. waters of California, Oregon, and Washington, northern right whale dolphins have been estimated as 21,332 dolphins and 8,334 dolphins, respectively, depending upon oceanographic conditions that factored into their distributional extent (Forney et al., 1995; Carretta et al., 2015).

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., 2015; 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 46.4 to 66.2°F (8 and 19°C) (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 (Lipsky, 2009).

Swim speeds for northern right whale dolphins can reach 18.3 to 21.6 kt (34 to 40 kph) (Leatherwood and Reeves, 1983; Leatherwood and Walker, 1979). The maximum recorded dive duration is 6.25 min with a maximum dive depth of 656 ft (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). Echolocation clicks have peak frequencies that range from 23 to 41 kHz (Rankin et al., 2007). The maximum known peak-to-peak SL of northern right whale dolphins is 170 dB (Fish and Turl, 1976). Northern right whale dolphins also produce burst-pulse sounds that are lower in frequency and shorter in duration than echolocation click sequences. The peak frequencies of burst-pulses signals range from 6 to 37 kHz with durations from 1 to 178 msec (Rankin et al., 2007). Northern right whale dolphins do not produce whistles (Oswald et al., 2008).

Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

Pacific white-sided dolphins are listed as least concern under the IUCN. In the North Pacific Ocean, an abundance of 931,000 Pacific white-sided dolphins has been estimated (Buckland et al., 1993; Jefferson et al., 2015). There are an estimated 26,930 Pacific white-sided dolphins in the waters of the U.S. west coast (California/Oregon/Washington stock) and an estimated 26,880 in the Gulf of Alaska (Allen and Angliss, 2015; Carretta et al., 2015). 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 (Black, 2009; Jefferson et al., 2015). 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 393.7 to 656 ft (120 to 200 m), with most of their foraging dives lasting a mean of 27 sec (Black, 1994). Captive Pacific white-sided dolphins were recorded swimming as fast as 15.0 kt (27.7 kph) for 2 sec intervals (Fish and Hui, 1991) with a mean travel speed of 4.1 kt (7.6 kph) (Black, 1994).

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). These clicks have spectral peaks at 22.2, 26.6, 33.7, and 37.3 kHz with spectral notches at 19.0, 24.5, and 29.7 kHz. These spectral characteristics can be used to identify the species from recordings (Soldevilla et al., 2008). There are no available data regarding seasonal or geographical variation in the sound production of *Lagenorhynchus* dolphins.

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. In the ETP, 640,000 Northeastern Pacific Offshore pantropical spotted dolphins have been estimated (Gerrodette and Forcada, 2005); 228,000 in the ETP coastal stock, and 800,000 in the ETP western/southern stock (Jefferson et al., 2015). The Western North and Western South Pacific populations of pantropical spotted dolphins is estimated to included 438,064 individuals, while the portion of the Western North Pacific stock occurring in the South and East China seas is estimated to include fewer members, estimated as 219,032 individuals

((Miyashita, 1993). In the central North Pacific surrounding the Hawaiian Islands, four stocks of pantropical spotted dolphins have been documented: the pelagic stock, estimated as 15,917 dolphins (Bradford et al., 2013; Carretta et al., 2014), as well as the Hawaii Island, Oahu, and 4-Islands stocks, which have each been estimated to include 220 individuals (Courbis et al., 2014). An estimated 3,333 occur in the western North Atlantic and 50,880 dolphins are estimated in the northern Gulf of Mexico (Perrin, 2009c; Waring et al., 2015). As many as 736,575 pantropical spotted dolphins have been estimated to occur in the Indian Ocean (Wade and Gerrodette, 1993).

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, 2009c). 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., 2015). Pantropical spotted dolphins also occur in the Persian Gulf and Red Sea.

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

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.

<u>Peale's Dolphin (*Lagenorhynchus australis*)</u>

Peale's dolphins are classified at data deficient under the IUCN. 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., 2015). 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. 2015). The dive sequences Peale's dolphins are usually three short dives followed by one longer dive with dive durations from 3 to 157 sec, averaging 28 sec (Goodall, 2009b).

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, 1980c; Schevill and Watkins, 1971). 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 estimated levels of 80 dB re 1 µPa @ 1 m with a frequency of 1 to 5 kHz and were mostly inaudible at more than 65.6 ft (20 m) away (Schevill and Watkins, 1971).

<u>Pygmy Killer Whale (*Feresa attenuata*)</u>

Pygmy killer whales are one of the least known cetacean species. They are classified as data deficient by the IUCN. The global population for this species is unknown. Estimates of 38,900 of pygmy killer whales have been documented in the ETP (Wade and Gerrodette, 1993), while 3,433 whales in the Hawaiian population (Bradford et al., 2013; Carretta et al., 2014) and 30,214 whales in the Western North and

South Pacific populations have been estimated (Ferguson and Barlow, 2001 and 2003). An estimated 152 pygmy killer whales were reported in the Gulf of Mexico (Waring et al., 2015) and another 22,029 pygmy killer whales have been estimated in the Indian Ocean (Wade and Gerrodette, 1993).

Pygmy killer whales have been recorded in oceanic tropical and subtropical waters (Caldwell, 1971; Donahue and Perryman, 2009). It is sighted relatively frequently in the ETP, the Hawaiian archipelago, and off Japan (Donahue and Perryman, 2009; Leatherwood et al., 1988). The population in Hawaiian waters shows high site fidelity and is considered to represent a resident population (McSweeney et al., 2009). It has been seen in the Indian Ocean (De Boer, 2000), the Philippines (Dolar et al., 2006) and stranded off Brazil (de Moura et al., 2010). No data are available to confirm seasonal migration patterns for pygmy killer whales. No data on breeding and calving grounds are available. No dive data are available. Baird et al. (2011) reported that tagged pygmy killer whales in Hawaiian waters swam at speeds from 1.5 to 1.7 kt (2.7 to 3.1 kph).

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 at 100 kHz) (Montie et al., 2011). The peak frequencies of wild pygmy killer whale clicks ranged from 45 to 117 kHz, with peak-to-peak source levels that ranged from 197 to 223 dB (Madsen et al., 2004b). One document describes pygmy killer whales producing LF "growl" sounds (Pryor et al., 1965).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphins are classified as a least concern (lower risk) species by the IUCN. Although no global population abundance exists for the Risso's dolphin, in the waters of the ETP, the Philippines, and off Sri Lanka abundances have been estimated at 110,457 (Gerrodette et al., 2008); 1,500; and 5,550 to 13,000 dolphins, respectively (Jefferson et al., 2015). The Western North and South Pacific as well as Inshore Archipelago populations have been estimated to include 83,289 dolphins (Miyashita, 1993). In the U.S. Pacific Ocean waters, an estimated 6,272 Risso's dolphins occur in the California/Oregon/Washington stock (Barlow, 2010; Carretta et al., 2015; Forney, 2007), while 7,256 dolphins occur in the Hawaiian stock (Bradford et al., 2013; Carretta et al., 2014). An abundance of 18,250 Risso's dolphins has been estimated for the Western and Eastern North Atlantic stocks and 2,442 Risso's dolphins in the northern Gulf of Mexico stock (Waring et al., 2015). Population levels for the UK are estimated at 2,800 (Jefferson et al., 2015) and for the Western Mediterranean Sea at 5,320 (Airoldi et al., 2005; Gomez de Segura et al., 2006). The population of Risso's dolphins in the Indian Ocean is estimated to include 452,125 individuals (Wade and Gerrodette, 1993).

Risso's dolphin inhabits deep oceanic and continental slope waters from the tropics through the temperate regions (Baird, 2009b; Jefferson, 1993; Leatherwood et al., 1980). 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., 2015).

Typical Risso's dolphin swimming speeds are 3.2 to 3.8 kt (6 to 7 kph) (Kruse et al., 1999). Risso's dolphins studied in the Ligurian Sea also swam at speeds from 3.2 to 3.8 kt (6 to 7 kph), remained at the surface for about 7 to 15 sec between dives that lasted 5 to 7 min and occasionally longer (Bearzi et al., 2011). Swim speeds from Risso's dolphins were recorded at 1.1 to 6.5 kt (2 to 12 kph) off Santa Catalina Island (Shane, 1995a). Tag data from a rehabilitated and released Risso's dolphin in the Gulf of Mexico indicate that the Risso's dolphin swam on average at 3.9 kt (7.19 kph) and the majority (95 percent) of the dives were within 50 m of the sea surface, with the deepest to 1,312 to 1,640 ft (400 to 500 m) (Wells et al., 2009). 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. 2015; Philips et al., 2003).

Audiograms for Risso's dolphins indicate that their hearing RLs equal to or less than approximately 125 dB in frequencies ranging from 1.6 to 110 kHz (Nachtigall et al., 1995). Philips 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 (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). Another individual had best hearing at 11 kHz, and between 40 and 80 kHz, a response threshold of about 60 dB re 1µPa (Mooney et al., 2015). These values are comparable to those previously reported by (Nachtigall et al., 1995; Nachtigall et al., 2005). Risso's dolphins are able to reduce their hearing sensitivity while echolocating (Nachtigall and Supin, 2008).

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 (Au, 1993; Corkeron and Van Parijs, 2001; Croll et al., 1999; Watkins, 1967). Risso's dolphins produce tonal whistles, burst-pulse sounds, echolocation clicks and a hybrid burst-pulse tonal signal (Corkeron and Van Parijs, 2001).Echolocation clicks have peak frequencies around 50 kHz, centroid frequencies of 60-90 kHz with peak-to-peak source levels of 202-222 dB re 1 µPa at 1 m (Madsen et al., 2004a). In one experiment conducted by Phillips et al. (2003), clicks were found to have a peak frequency of 65 kHz, with 3 dB bandwidths of 72 kHz and durations ranging from 40 to 100 msec. In a second experiment, Phillips et al. (2003) recorded clicks with peak frequencies up to 50 kHz, with a 3 dB bandwidth of 35 kHz. Click durations ranging from 35 to 75 msec. 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 from 400 to 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.

Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is classified as least concern by the IUCN. Globally, few population estimates are available for the rough-toothed dolphin except in the ETP, where the stock was estimated at 107,633 individuals (Gerrodette et al., 2008); in the U.S. Atlantic and Gulf of Mexico, where the stocks were estimated as 271 and 624 dolphins, respectively (Waring et al., 2015); and in Hawaiian waters, where the stock was estimated at 6,288 individuals (Carretta et al., 2015). The populations of rough-toothed dolphins in the Western North and South Pacific were estimated to include 145,729 dolphins (Ferguson and Barlow, 2001 and 2003). In the Indian Ocean, the population of rough-toothed dolphins was estimated at 156,690 individuals (Wade and Gerrodette, 1993).

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, 2009b). 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, 2009b). 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, 2009b). 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., 2015). Seasonal movements and breeding areas for this species have not been confirmed.

Rough-toothed dolphins are not known to be fast swimmers. They are known to skim the surface at a moderate speed (Jefferson, 2009b). Swim speeds of this species vary from 3.0 to 8.6 kt (5.6 to 16 kph) (Ritter, 2002; Watkins et al., 1987). Rough-toothed dolphins can dive to 98 to 230 ft (30 to 70 m) with dive durations ranging from 0.5 to 3.5 min (Ritter, 2002; Watkins et al., 1987). 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 (Miyazaki and Perrin, 1994; Popper, 1980b; Thomson and Richardson, 1995). Clicks have peak energy at 25 kHz, while whistles have a maximum energy between 2 to 14 kHz (Lima et al., 2012; Norris, 1969; Norris and Evans, 1967; Oswald et al., 2007; Popper, 1980b). There are no available data regarding seasonal or geographical variation in the sound production of this species.

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is classified as data deficient by the IUCN. A global population estimate for short-finned pilot whales is unknown. Off the U.S. west coast, the abundance of the California/Oregon/Washington stock has been estimated as 760 individuals (Barlow, 2010; Barlow and Forney, 2007; Carretta et al., 2015; Forney, 2007). Wade and Gerrodette (1993) estimated the population of short-finned pilot whales in the ETP as 160,200, while 53,608 short-finned pilot whales are estimated for the Western North Pacific stock (Miyashita, 1993). Estimates of 2,415 short-finned pilot whales were reported for the Gulf of Mexico with 21,515 whales reported for the Western North

Atlantic (Waring et al., 2015). The population in the Indian Ocean has been estimated at 268,751 individuals (Wade and Gerrodette, 1993).

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.

Pilot whales generally have swim speeds ranging between 1.1 to 6.5 kt (2 to 12 kph) (Shane, 1995). Short-finned pilot whales have swim speeds ranging between (3.8 and 4.6 kt (7 and 9 kph) (Norris and Prescott, 1961). Short-finned pilot whale perform underwater ‘sprints’, with velocities ranging up to 17.5 kt (32.4 kph) that are associated with foraging attempts (Aguilar Soto et al., 2008). Both long- and short-finned pilot whales are considered deep divers, feeding primarily on fish and squid (Croll et al., 1999). Short-finned pilot whales off Tenerife showed a bimodal dive behavior with a large number of dives to 984 ft (300 m), very few between 984 to 1,640 ft (300 and 500 m), many dives with a maximum depth between 1,640 to 3,343 ft (500 and 1,019 m) (Aguilar Soto et al., 2008). Generally, dive times increased with dive depth, to a maximum duration of 21 min. (Ridgway, 1986). Data from Madeira Island show that dives can last as long as 20 min to as deep as 3,281 ft (1,000 m) (Alves et al., 2013), although the majority of recorded dives were much shorter and shallower, and almost all of these were recorded during the daytime. Short-finned pilot whales off Kauai produced the majority of their foraging echolocation clicks at night (Au et al., 2013). Two whales that had stranded were equipped with satellite tags and were tracked for 16 and 67 days; 93 percent of their dives were to less than 328 ft (100 m) (Wells, 2013).

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. Another four stranded short-finned pilot whales were tested with AEP. Their greatest sensitivity was around 20-40 kHz for all whales, with thresholds between 70 and 80 dB re 1µPa. Thresholds at 80 kHz were 25-61 dB higher in the adults than the juveniles (Greenhow et al., 2014).

Pilot whales echolocate with a precision similar to bottlenose dolphins and 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). The frequency content of tonal calls extends to at least 30 kHz (Sayigh et al., 2013). 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). The center frequency of their clicks is 25 kHz, with a mean 10 dB bandwidth of 10 kHz (Baumann-Pickering, Simonis, et al., 2015). Mean click duration was 545 msec. 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) and specific call types can be repeated (Sayigh et al., 2013).

Southern Right Whale Dolphin *(Lissodelphis peronii)*

The southern right whale dolphin 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., 2015). Southern right whale dolphins can swim up to 22 kph (12 kt) 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). Southern right whale dolphins do not produce whistles (Oswald et al., 2008).

Spinner Dolphin (*Stenella longirostris*)

Spinner dolphins are classified overall as a data deficient species by the IUCN, although the eastern population in the ETP is considered vulnerable. Spinner dolphins are one of the most abundant dolphin species in the world. In the ETP, 450,000 Eastern stock spinner dolphins have been estimated (Gerrodette and Forcada, 2005). In the Western North and South Pacific, 1,015,059 spinner dolphins have been estimated (Ferguson and Barlow, 2001 and 2003). In Hawaiian waters, the Hawaii pelagic stock includes 3,351 dolphins (Barlow, 2006), and the island associated populations include the Kauaʻi and Niʻihau stock with 601 individuals, the Hawaiʻi Island stock that number 631 dolphins, the Oahu/4-Islands stock with 355 spinner dolphins, the Kure/Midway Atoll stock of 260 dolphins, and the Pearl and Hermes Reef stock of 300 spinner dolphins (Andrews et al., 2006’ Carretta et al., 2014; Hoos, 2013). In the northern Gulf of Mexico, there are an estimated 11,441 individuals in the stock number and 262 spinner dolphins in the Western North Atlantic (Waring et al., 2013). The spinner dolphin population in the Indian Ocean is estimated as 634,108 individuals (Wade and Gerrodette, 1993).

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. 2015). 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 (Perrin, 2009d). 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., 2015).

Hawaiian spinner dolphins have swim speeds ranging from 1.4 to 3.2 kt (2.6 to 6 kph) (Norris et al., 1994). Based on where their prey is located in the water column, spinner dolphins likely dive as deep as 1,969 ft (600 m) (Perrin, 2009d). 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 9 ft (3 m) 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 (Bazua-Duran and Au, 2002; Norris et al., 1994). 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. The whistle contours of near shore spinner dolphins in Hawaiʻi show geographic variation between groups (Bazua-Duran and Au, 2004), correlating with the Island associated populations. Additionally, the burst pulse signals are predominantly ultrasonic, often with little or no energy below 20 kHz (Lammers et al., 2003). Echolocation clicks show the typical delphinid broadband character, with center frequencies ranging from 34 to 58 kHz, peak frequencies from 27 to 41 kHz, and durations of 140 to 620 μs (Baumann-Pickering et al., 2010).

<u>Striped Dolphin (*Stenella coeruleoalba*)</u>

Striped dolphins are a lower risk (least concern) species classified by the IUCN. Striped dolphins are known to be the most abundant marine mammal species in the Mediterranean Sea, with an estimated 117,880 individuals in the Western Mediterranean Sea (Forcada and Hammond, 1998). In the ETP, an estimated 964,362 striped dolphins occur (Gerrodette et al., 2008), and 570,038 individuals are estimated for the Western North and Western South Pacific and Inshore Archipelago stocks (Miyashita, 1993). Off the Pacific coast of the U.S., an estimated 10,908 spinner dolphins are estimated in the California/Oregon/Washington stock while and the Hawaiian EEZ, 20,650 striped dolphins are estimated (Bradford et al., 2013; Carretta et al., 2015). In the western North Atlantic, an estimated 54,807 spinner dolphins are estimated while in the northern Gulf of Mexico, an estimated 1,849 dolphins occur (Waring et al., 2015). Striped dolphins in the Eastern North Atlantic number 67,414 individuals (Hammond et al., 2009). The Indian Ocean striped dolphin population is estimated to include 674,578 individuals (Wade and Gerrodette, 1993).

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 and the Arabian Gulf (Braulik et al., 2010). 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 but most often between 18° and 22°C. In the Ligurian Sea, striped dolphins are commonly found along the Ligurian Sea Front, which has water depths of 6,562 to 8,202 ft (2,000 to 2,500 m). 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).

Average swim speeds of 5.9 kt (11 kph) 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 656 to 2,297 ft (200 to 700 m) to feed (Archer, 2009). Dive times are unknown for this species.

The behavioral audiogram developed by Kastelein et al. (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 lasting up to three seconds, with frequencies ranging from 1.5 to >24 kHz, with peak frequencies ranging from 8 to 12.5 kHz (Azzolin et al., 2013; Thomson and Richardson, 1995). An examination of whistle structure within the Mediterranean Sea found geographic variation between different sub-populations (Azzolin et al., 2013).

White-beaked Dolphin (*Lagenorhynchus albirostris*)

The white-beaked dolphin is classified as a least concern (lower risk) species under the IUCN. 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., 2015). White-beaked dolphins in the Eastern North Atlantic number 16,536 dolphins (Hammond et al., 2013).

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; Kinze, 2009; Reeves and Leatherwood, 1994). Reports of white-beaked dolphins in the Mediterranean Sea are questionable (Jefferson et al., 2015; 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 (Kinze, 2009).

Very little is known about the diving or swimming behavior of white-beaked dolphins. Tagged white-beaked dolphins in Icelandic waters were reported diving to the maximum depth, 148 ft (45 m), which was near the seafloor; exhibited U- and V-shaped dives; dove for durations of 2 to 78 sec; and swam at speeds of 1.9 to 2.7 kt (3.5 to 5 kph) (Rasmussen et al., 2013).

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. 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 msec 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). Whistles had source levels of 118 to 167 dB (Rasmussen et al., 2006). The fundamental frequency of these whistles ranged from 7 to 13 kHz, and harmonics up to 50 kHz were observed. Burst-pulse sounds have also been described. The peak frequency of these sounds ranged from 1.5 to 46.5 kHz with durations less than 0.6 second (Simard et al., 2008). The maximum recorded source level was 159 dB.

Phocoenidae

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoises are separated taxonomically into two major ecotypes or subspecies: the *truei*-type and the *dalli*-type. Dall's porpoise is considered least concern under the IUCN. The total population of Dall's porpoise is estimated at 1.2 million (Jefferson et al., 2015). In the North Pacific Ocean, there are an estimated 42,000 Dall's porpoises in the California/Oregon/Washington stock (Carretta et al., 2015), and 173,638 porpoises estimated in the Sea of Japan, Western North Pacific, and Alaska stocks (Allen and Angliss, 2015; IWC, 2008). In the Sea of Okhotsk, 111,402 *dalli*-type and 101,173 *truei*-type Dall's porpoises in the Western North Pacific stock are estimated (Kanaji et al., 2015).

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., 2015). 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., 2015). Distribution in most areas is very poorly defined (Jefferson, 2009a).

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 1.3 and 11.7 kt (2.4 and 21.6 kph) and are dependent on the type of swimming behavior (slow rolling, fast rolling, or rooster-tailing) (Croll et al., 1999), but Dall's porpoises may reach speeds of 29.7 kt (55 kph) for quick bursts (Leatherwood and Reeves, 1983). They are relatively deep divers, diving to 900 ft (275 m) for as long as 8 min (Hanson et al., 1998; Ridgway, 1986).

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 (Awbrey et al., 1979; Evans and Awbrey, 1984; Evans and Maderson, 1973; Hatakeyama et al., 1994; Hatakeyama and Soeda, 1990; Ridgway, 1966) and can emit LF clicks in the range of 40 Hz to 12 kHz (Awbrey et al., 1979; Evans, 1973). Narrow band high frequency clicks are also produced with energy concentrated around 120 to 141 kHz with a duration of 35 to 251 μsec (Au, 1993; Kyhn et al., 2013). Their maximum peak-to-peak SL is 175 dB (Evans, 1973; Evans and Awbrey, 1984). Dall's porpoise do not whistle very often.

<u>Harbor Porpoise (*Phocoena phocoena*)</u>

Harbor porpoises are classified overall as least concern under IUCN. The global population for the harbor porpoise estimated to be at least 675,000 (Jefferson et al., 2015). Three major residential isolated populations exist: 1) the North Pacific; 2) North Atlantic; and 3) the Black Sea (Jefferson et al., 2008; Bjorge 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 (Allen and Angliss, 2015; Caretta et al., 2015; Waring et al., 2015).

In the Gulf of Maine and Bay of Fundy, there are an estimated 79,833 harbor porpoises (Waring et al., 2015) while 3326 individuals are estimated in the Newfoundland stock (Lawson and Gosselin, 2009 and 2011; LGL, 2015; Waring et al., 2015). Harbor porpoise populations have been estimated as 27,000 in the Gulf of Saint Lawrence, 28,000 in Iceland waters, 36,000 in Kattegat, 268,000 in the North Sea, and 36,000 in the waters around Ireland and the western United Kingdom (Jefferson et al., 2015). The Eastern North Atlantic stock is estimated as 375,358 porpoises (Hammond et al., 2013). In Alaska, there are 11,146 porpoises in the southeastern Alaska population, 31,046 individuals in the Gulf of Alaska, and 48,215 harbor porpoises in the Bering Sea (Allen and Angliss, 2015). The Western North Pacific population consists of an estimated 31046 individuals (Allen and Angliss, 2014; Hobbs and Waite, 2010). There are seven populations described off the west coast of the U.S.: the Morrow Bay population with 2,917 individuals; Monterey Bay estimated as 3,715 porpoises; San Francisco to the Russian River includes 9,886 individuals; northern California and southern Oregon there are 35,769 porpoises, while 10,662 individuals are estimated in the Washington inland waters (Carretta et al., 2015).

Harbor porpoises are found in cold temperate and sub-arctic coastal waters of the northern hemisphere (Bjørge and Tolley, 2009; Gaskin, 1992; Jefferson, 1993). They are typically found in waters of about 41 to 61° F (5 to 16° C) with only a small percentage appearing in arctic waters 32° to 39° F (0° to 4° C)

(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).

Harbor porpoises show seasonal movement in northwestern Europe that may be related to oceanographic changes throughout certain times of the year (Gaskin, 1992; Heimlich-Boarn et al., 1998; Read and Westgate, 1997). 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).

Maximum swim speeds for harbor porpoises range from 9.0 to 12.0 kt (16.6 and 22.2 kph) (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 65.6 to 426.5 ft (20 to 130 m), although maximum dive depths have reached 741.5 ft (226 m) (Westgate et al., 1995). Three tagged porpoises in shallow Danish waters had an average dive rate of 45 dives per hour, with maximum dive depth of 82 ft (25 m) (Linnenschmidt et al., 2013).

Harbor porpoises can hear frequencies in the range of 100 Hz to 140 kHz (Kastelein et al., 2002; Kastelein et al., 2015; 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). In a series of experiments designed to investigate harbor porpoise hearing with respect to naval sonar, the hearing threshold for 1-2 kHz FM signals was 75 dB, without the presence of harmonics. When harmonics were present, the threshold dropped to 59 dB (Kastelein et al., 2011). The thresholds for LF sonars were higher than for MF sonars; the measured threshold for 6-7 kHz signals was 67 dB.

Harbor porpoises produce click and whistle vocalizations that cover a wide frequency range, from 40 Hz to at least 150 kHz (Verboom and Kastelein, 1995). 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). 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.

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. There is no information about the abundance of this species (Goodall, 2009c). There are also no data on diving, swim speeds, hearing, or vocalizations.

Spectacled porpoises are circumpolar in occurrence and are found only in the cool temperate, sub-Antarctic, and Antarctic waters of the southern hemisphere (Goodall, 2009c). 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 Kergulan in the southern Indian Ocean (Goodall, 2009c).

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, 2009c).

3.3.4.3 Occurrence and Population Estimates of Marine Mammals in 26 Potential Mission Areas

To estimate the risk to marine mammals from exposure to SURTASS LFA sonar in each of the 26 representative mission areas and seasons, a list of marine mammals likely to be encountered in each area was developed (Table 3-6). In addition, stocks were identified for each species in each mission area as well as abundance and density estimates derived for each species' stock at each representative mission area for a selected season. This list of marine mammal species for each mission area was verified with distributional information and data from published literature; government reports, including NMFS's stock assessment reports (SARs) for U.S. waters; and the International Union for the Conservation of Nature's Red List of Threatened Species.

Marine Mammal Density and Abundance Estimates

The distribution of many marine mammal species is irregular and highly dependent upon geography, oceanography, and seasonality. Density and abundance estimates are critical components needed to analytically estimate risk to marine mammal populations from activities occurring in the marine environment. The process for developing density and abundance estimates for every species/stock at the 26 potential mission areas in representative seasons was a multi-step procedure that utilized data with the highest degree of fidelity first. Abundance estimates are typically more available than are density estimates, which require more sophisticated sampling and analysis and are not always available for each species/stocks in all mission areas. In the rare cases where no abundance estimates were available for the stock of a species, an abundance derived for another stock of the same species or for a similar species in the same oceanographic area might be used as a surrogate abundance. These population data were derived using the best available information and data (Table 3-6), including the most current NMFS final Stock Assessment Reports (SARs) for U.S. Alaska, North Pacific, and Atlantic waters (Allen and Angliss, 2015; Carretta et al., 2015, and Waring et al., 2015), respectively, or the SAR that was relevant for a species' or stock's information.

When deriving density estimates, direct estimates from line-transect surveys that occurred in or near each of the 26 mission areas and model sites were utilized first (e.g., Barlow, 2006). However, density estimates require more sophisticated sampling and analysis and were not always available for each species at all sites. When density estimates were not available from a survey in the operation area, then density estimates from a region with similar oceanographic characteristics were extrapolated to the operation 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). Densities for some mission areas/model sites were also derived from the Navy's Marine Species Density Database (DoN, 2016). Last, density estimates are usually not available for very rare marine mammal species or for those that have been newly defined (e.g., the Deraniyagala's beaked whale). For such species, the lowest density estimate of 0.0001 animals per square kilometer (animals/km^2) was used in the risk analysis for SURTASS LFA sonar to reflect the very low probability of occurrence in a specific SURTASS LFA sonar mission area for data sparse species, such as the North Pacific right whale. 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

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km²)[19]*	*Density References*
Mission Area 1: Sea of Japan; Summer Season					
Blue whale	WNP	9,250	1, 2, 3		1, 10, 11, 12
Bryde's whale	WNP	20,501	4	0.0006	13
Common minke whale	WNP "O"	25,049	5	0.0022	5
Fin whale	WNP	9,250	1, 6	0.0002	1
Humpback whale	WNP stock and DPS[20]	1,328	7	0.00036	12, 14
North Pacific right whale	WNP	922	8		
Sei whale	NP	7,000	1, 9	0.0006	1, 15
Baird's beaked whale	WNP	8,000	16	0.0029	16
Common bottlenose dolphin	WNP	168,791	17	0.0171	17
Cuvier's beaked whale	WNP	90,725	10, 11	0.0031	10, 11
False killer whale	WNP	16,668	17	0.0036	17
Ginkgo-toothed beaked whale	NP	22,799	10, 11	0.0005	10, 11
Harbor porpoise	WNP	31,046	18, 19	0.0190	18
Hubbs' beaked whale	NP	22,799	10, 11	0.0005	10, 11
Killer whale	WNP	12,256	10, 11	0.0001	23
Kogia spp.	WNP	350,553	10, 11	0.0031	10, 11
Pacific white-sided dolphin	NP	931,000	20	0.0082	10, 11
Pantropical spotted dolphin	WNP	438,064	17	0.0259	17
Pygmy killer whale	WNP	30,214	10, 11	0.0021	10, 11
Risso's dolphin	WNP	83,289	17	0.0097	17
Rough-toothed dolphin	WNP	145,729	10, 11	0.0059	10, 11
Short-beaked common dolphin	WNP	3,286,163	10, 11	0.0761	10, 11

18 NP=North Pacific; EP=Eastern Pacific; WNP=Western North Pacific; CNP=Central North Pacific; ENP=Eastern North Pacific; WSP=Western South Pacific; ETP=Eastern Tropical Pacific; C/O/W=California/Oregon/Washington; AK=Alaska; ECS=East China Sea; SOJ=Sea of Japan; IA=Inshore Archipelago; NMI=Northern Mariana Islands; IND=Indian; NIND=Northern Indian; SIND=Southern Indian; WAU=Western Australia; AS=Arabian Sea; WNA=Western North Atlantic; ENA=Eastern North Atlantic; WM=Western Mediterranean; ANT=Antarctica

19 No density in a season means that the marine mammal is not expected to occur in that mission area during that season.

20 DPS=distinct population segment, which is a discrete, vertebrate population or group of populations of a species that is significant to the entire species. Populations are identified as stocks under the MMPA and as DPSs under the ESA. Thus, the humpback whale is listed by stock and DPS (DPS/stock) where relevant.

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Short-finned pilot whale	WNP	53,608	17	0.0128	17
Sperm whale	NP	102,112	21, 22	0.00123	24
Spinner dolphin	WNP	1,015,059	10, 11	0.00083	25
Stejneger's beaked whale	WNP	8,000	16	0.0005	10, 11
Striped dolphin	WNP	570,038	17	0.0111	17
Mission Area 2: North Philippine Sea; Fall Season					
Blue whale	WNP	9,250	1, 2, 3	0.00001	1, 10, 11, 12
Bryde's whale	WNP	20,501	4	0.0006	13
Common minke whale	WNP "O"	25,049	5	0.0044	5
Fin whale	WNP	9,250	1, 6		1
Humpback whale	WNP stock and DPS	1,328	7	0.00089	12, 14
North Pacific right whale	WNP	922	8		
Omura's whale	WNP	1,800	26	0.00006	27
Blainville's beaked whale	WNP	8,032	10, 11	0.0005	10, 11
Common bottlenose dolphin	WNP	168,791	17	0.0146	17
Cuvier's beaked whale	WNP	90,725	10, 11	0.0054	10, 11
False killer whale	WNP	16,668	17	0.0029	17
Fraser's dolphin	WNP	220,789	10, 11	0.0069	29
Ginkgo-toothed beaked whale	NP	22,799	10, 11	0.0005	10, 11
Killer whale	WNP	12,256	10, 11	0.00009	23
Kogia spp.	WNP	350,553	10, 11	0.0031	10, 11
Long-beaked common dolphin	WNP	279,182	28	0.1158	28
Longman's beaked whale	WNP	4,571	29	0.00025	23
Melon-headed whale	WNP	36,770	10, 11	0.00428	24
Pacific white-sided dolphin	NP	931,000	20		10, 11
Pantropical spotted dolphin	WNP	438,064	17	0.0137	17
Pygmy killer whale	WNP	30,214	10, 11	0.0021	10, 11
Risso's dolphin	WNP	83,289	17	0.0106	17
Rough-toothed dolphin	WNP	145,729	10, 11	0.0059	10, 11
Short-beaked common dolphin	WNP	3,286,163	10, 11	0.0562	10, 11
Short-finned pilot whale	WNP	53,608	17	0.0153	17

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km²)[19]*	*Density References*
Sperm whale	NP	102,112	21, 22	0.00123	24
Spinner dolphin	WNP	1,015,059	10, 11	0.00083	25
Striped dolphin	WNP	570,038	17	0.0329	17
Mission Area 3: West Philippine Sea; Fall Season					
Blue whale	WNP	9,250	1, 2, 3	0.00001	1, 10, 11, 12
Bryde’s whale	WNP	20,501	4	0.0006	13
Common minke whale	WNP “O”	25,049	5	0.0033	5
Fin whale	WNP	9,250	1, 6		1
Humpback whale	WNP stock and DPS	1,328	7	0.00089	12, 30
Omura’s whale	WNP	1,800	26	0.00006	27
Blainville’s beaked whale	WNP	8,032	10, 11	0.0005	10, 11
Common bottlenose dolphin	WNP	168,791	17	0.0146	17
Cuvier’s beaked whale	WNP	90,725	10, 11	0.0003	10, 11
Deraniyagala’s beaked whale	NP	22,799	10, 11, 31	0.0005	10, 11
False killer whale	WNP	16,668	17	0.0029	17
Fraser’s dolphin	WNP	220,789	10, 11	0.0069	29
Ginkgo-toothed beaked whale	NP	22,799	10, 11	0.0005	10, 11
Killer whale	WNP	12,256	10, 11	0.00009	23
Kogia spp.	WNP	350,553	10, 11	0.0017	10, 11
Long-beaked common dolphin	WNP	279,182	10, 11	0.1158	28
Longman’s beaked whale	WNP	4,571	29	0.00025	23
Melon-headed whale	WNP	36,770	10, 11	0.00428	24
Pantropical spotted dolphin	WNP	438,064	17	0.0137	17
Pygmy killer whale	WNP	30,214	10, 11	0.0021	10, 11
Risso’s dolphin	WNP	83,289	17	0.0106	17
Rough-toothed dolphin	WNP	145,729	10, 11	0.0059	10, 11
Short-finned pilot whale	WNP	53,608	17	0.0076	17
Sperm whale	NP	102,112	21, 22	0.00123	24
Spinner dolphin	WNP	1,015,059	10, 11	0.00083	25
Striped dolphin	WNP	570,038	17	0.0164	17

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km²)[19]*	*Density References*
Mission Area 4: Offshore Guam; Summer Season					
Blue whale	WNP	9,250	1, 2, 3		1, 10, 11, 12, 24
Bryde's whale	WNP	20,501	4	0.0004	24
Common minke whale	WNP "O"	25,049	5		10, 11
Fin whale	WNP	9,250	1, 6		10, 11
Humpback whale	WNP stock and DPS	1,328	7		12, 30
Omura's whale	WNP	1,800	26, 27	0.00004	27
Sei whale	NP	7,000	1, 9		24
Blainville's beaked whale	WNP	8,032	10, 11	0.001	29
Common bottlenose dolphin	WNP	168,791	17	0.00245	29
Cuvier's beaked whale	WNP	90,725	10, 11	0.00079	29
Deraniyagala's beaked whale	NP	22,799	10, 11, 32	0.00093	10, 11
Dwarf sperm whale	WNP	350,553	10, 11	0.00714	25
False killer whale	WNP	16,668	17	0.00111	24
Fraser's dolphin	CNP	16,992	29	0.0069	29
Ginkgo-toothed beaked whale	NP	22,799	10, 11	0.00093	10, 11
Killer whale	WNP	12,256	10, 11	0.00014	29
Longman's beaked whale	WNP	4,571	29	0.0019	29
Melon-headed whale	NMI	2,455	24	0.00428	24
Pantropical spotted dolphin	WNP	438,064	17	0.0226	24
Pygmy killer whale	WNP	30,214	10, 11	0.00014	24
Pygmy sperm whale	WNP	350,553	10, 11	0.00291	25
Risso's dolphin	WNP	83,289	17	0.003	29
Rough-toothed dolphin	WNP	145,729	10, 11	0.0026	29
Short-finned pilot whale	WNP	53,608	17	0.0051	29
Sperm whale	NP	102,112	21, 22	0.00123	24
Spinner dolphin	WNP	1,015,059	10, 11	0.00083	25
Striped dolphin	WNP	570,038	17	0.00616	24
Mission Area 5: Sea of Japan; Fall Season					
Bryde's whale	WNP	20,501	4	0.0001	10, 11

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Common minke whale	WNP "O"	25,049	5	0.0004	10, 11
Common minke whale	WNP "J"	893	33	0.00016	10, 11
Fin whale	WNP	9,250	1, 6	0.0009	10, 11
North Pacific right whale	WNP	922	8		
Omura's whale	WNP	1,800	26, 27	0.00001	27
Western North Pacific gray whale	WNP stock/Western DPS	140	2	0.0000121	
Baird's beaked whale	WNP	8,000	16	0.0003	16
Common bottlenose dolphin	IA	105,138	17, 34	0.00077	23
Cuvier's beaked whale	WNP	90,725	10, 11	0.0031	10, 11
Dall's porpoise	SOJ	173,638	35	0.0520	10, 11
False killer whale	IA	9,777	17, 34	0.0027	10, 11
Harbor porpoise	WNP	31,046	18, 19	0.0190	18
Killer whale	WNP	12,256	10, 11	0.00009	23
Kogia spp.	WNP	350,553	10, 11	0.0017	10, 11
Long-beaked common dolphin	WNP	279,182	28	0.1158	28
Pacific white-sided dolphin	NP	931,000	17, 20		10, 11
Risso's dolphin	IA	83,289	17	0.0073	17
Rough-toothed dolphin	WNP	145,729	10, 11	0.0026	29
Short-beaked common dolphin	WNP	3,286,163	10, 11	0.0860	10, 11
Short-finned pilot whale	WNP	53,608	17	0.0014	17
Sperm whale	NP	102,112	21, 22	0.00123	24
Spinner dolphin	WNP	1,015,059	10, 11	0.00083	25
Stejneger's beaked whale	WNP	8,000	16	0.0005	10, 11
Striped dolphin	IA	570,038	17	0.00584	23
Spotted seal	Southern stock and DPS	3,500	36, 37, 38	0.00001	
Mission Area 6: East China Sea; Summer Season					
Bryde's whale	ECS	137	39	0.0003	29

21 A density value of 0.00001 with no reference citation indicates that no density was available for this species; because a density was necessary to compute takes, the lowest value possible was assigned to the data-sparse species for the purpose of impact estimation.

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Common minke whale	WNP "O"	25,049	5	0.0044	5
Common minke whale	WNP "J"	893	33	0.0018	5
Fin whale	ECS	500	1, 6, 40	0.0002	1
North Pacific right whale	WNP	922	8		
Omura's whale	WNP	1,800	26, 27	0.00003	27
Western North Pacific gray whale	WNP stock/Western DPS	140	2		
Blainville's beaked whale	WNP	8,032	10, 11	0.0005	10, 11
Common bottlenose dolphin	IA	105,138	17, 34	0.00077	23
Cuvier's beaked whale	WNP	90,725	10, 11	0.0003	10, 11
False killer whale	IA	9,777	17, 34	0.00111	24
Fraser's dolphin	WNP	220,789	10, 11	0.00694	29
Ginkgo-toothed beaked whale	NP	22,799	10, 11	0.0005	10, 11
Killer whale	WNP	12,256	10, 11	0.00009	23
Kogia spp.	WNP	350,553	10, 11	0.0017	10, 11
Long-beaked common dolphin	WNP	279,182	28	0.1158	28
Longman's beaked whale	WNP	4,571	29	0.00025	23
Melon-headed whale	WNP	36,770	10, 11	0.00428	24
Pacific white-sided dolphin	NP	931,000	17, 20		10, 11
Pantropical spotted dolphin	WNP	219,032	17	0.01374	17
Pygmy killer whale	WNP	30,214	10, 11	0.00014	24
Risso's dolphin	IA	83,289	17	0.0106	17
Rough-toothed dolphin	WNP	145,729	10, 11	0.0026	29
Short-beaked common dolphin	WNP	3,286,163	10, 11	0.0461	10, 11
Short-finned pilot whale	WNP	53,608	17	0.0016	24
Sperm whale	NP	102,112	21, 22	0.00123	24
Spinner dolphin	WNP	1,015,059	10, 11	0.00083	25
Striped dolphin	IA	570,038	17	0.00584	23
Spotted seal	Southern stock and DPS	1,000	41	0.00001	
Mission Area 7: South China Sea; Fall Season					
Bryde's whale	WNP	20,501	4	0.0006	13
Common minke whale	WNP "O"	25,049	5	0.0033	5

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Common minke whale	WNP "J"	893	33	0.0018	5
Fin whale	WNP	9,250	1, 6	0.0002	1
Humpback whale	WNP stock and DPS	1,328	7	0.00036	12, 30
North Pacific right whale	WNP	922	8		
Omura's whale	WNP	1,800	26, 27	0.00006	27
Western North Pacific gray whale	WNP stock/Western DPS	140	2	0.00001	
Blainville's beaked whale	WNP	8,032	10, 11	0.0005	10, 11
Common bottlenose dolphin	IA	105,138	34	0.00077	23
Cuvier's beaked whale	WNP	90,725	10, 11	0.0003	10, 11
Deraniyagala's beaked whale	NP	22,799	10, 11, 32	0.0005	10, 11
False killer whale	IA	9,777	34	0.00111	24
Fraser's dolphin	WNP	220,789	10, 11	0.00694	29
Ginkgo-toothed beaked whale	NP	22,799	10, 11	0.0005	10, 11
Killer whale	WNP	12,256	10, 11	0.00009	23
Kogia spp.	WNP	350,553	10, 11	0.0017	10, 11
Long-beaked common dolphin (Indo-Pacific common dolphin)	WNP	279,182	28	0.1158	28
Longman's beaked whale	WNP	4,571	29	0.00025	23
Melon-headed whale	WNP	36,770	10, 11	0.00428	24
Pantropical spotted dolphin	WNP	219,032	17	0.01374	17
Pygmy killer whale	WNP	30,214	10, 11	0.00014	24
Risso's dolphin	IA	83,289	17	0.0106	17
Rough-toothed dolphin	WNP	145,729	10, 11	0.0026	29
Short-finned pilot whale	WNP	53,608	17	0.00159	24
Sperm whale	NP	102,112	21, 22	0.0012	24
Spinner dolphin	WNP	1,015,059	10, 11	0.00083	25
Striped dolphin	IA	570,038	17	0.00584	23
Mission Area 8: Offshore Japan 25° to 40°N; Summer Season					
Blue whale	WNP	9,250	1, 2, 3		1, 10,1 1, 12
Bryde's whale	WNP	20,501	4	0.00041	24
Common minke whale	WNP "O"	25,049	5	0.0003	5

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Fin whale	WNP	9,250	1, 6	0.0001	1
Humpback whale	WNP stock and DPS	1,328	7	0.00036	12, 14
Sei whale	NP	7,000	1, 9	0.00029	24
Baird's beaked whale	WNP	8,000	16	0.0001	16
Blainville's beaked whale	WNP	8,032	23, 28	0.0007	23
Common bottlenose dolphin	WNP	168,791	17	0.00077	23
Cuvier's beaked whale	WNP	90,725	10, 11	0.00374	23
Dwarf sperm whale	WNP	350,553	10, 11, 28	0.0043	23
False killer whale	WNP	16,668	17	0.0036	17
Hubbs' beaked whale	NP	22,799	10, 11	0.0005	10, 11
Killer whale	WNP	12,256	10, 11	0.00009	23
Longman's beaked whale	WNP	4,571	29	0.0003	23
Melon-headed whale	WNP	36,770	10, 11	0.0027	23
Mesoplodon spp.	WNP	22,799	10, 11, 28	0.0005	10, 11
Northern right whale dolphin	NP	68,000	20		
Pacific white-sided dolphin	NP	931,000	20	0.0048	10, 11
Pantropical spotted dolphin	WNP	438,064	17	0.0113	23
Pygmy killer whale	WNP	30,214	10, 11	0.0001	23
Pygmy sperm whale	WNP	350,553	10, 11, 28	0.0018	23
Risso's dolphin	WNP	83,289	17	0.0005	23
Rough-toothed dolphin	WNP	145,729	10, 11	0.0019	23
Short-beaked common dolphin	WNP	3,286,163	10, 11	0.0863	10, 11
Short-finned pilot whale	WNP	53,608	17	0.0021	23
Sperm whale	NP	102,112	21, 22	0.0022	23
Spinner dolphin	WNP	1,015,059	10, 11	0.0019	23
Stejneger's beaked whale	WNP	8,000	16	0.0005	10, 11
Striped dolphin	WNP	570,038	17	0.0058	23
Hawaiian monk seal	Hawaii	1,112	153	0.0001	
Northern fur seal	Western Pacific	503,609	42, 43		20
Mission Area 9: Offshore Japan 10° to 25°N; Winter Season					
Blue whale	WNP	9,250	1, 2, 3	0.00001	1, 10, 11, 12

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Bryde's whale	WNP	20,501	4	0.0003	23
Fin whale	WNP	9,250	1, 6	0.00001	
Humpback whale	WNP stock and DPS	1,328	7	0.00036	12, 30
Omura's whale	WNP	1,800	26, 27	0.00003	27
Sei whale	NP	7,000	1, 6	0.0029	24
Blainville's beaked whale	WNP	8,032	23, 28	0.0007	23
Common bottlenose dolphin	WNP	168,791	17	0.00077	23
Cuvier's beaked whale	WNP	90,725	10, 11	0.00374	23
Deraniyagala's beaked whale	NP	22,799	10, 11, 32	0.00093	11,
Dwarf sperm whale	WNP	350,553	10, 11	0.0043	23
False killer whale	WNP	16,668	17	0.00057	23
Fraser's dolphin	CNP	16,992	29	0.00251	23
Ginkgo-toothed beaked whale	NP	22,799	10, 11	0.00093	11
Killer whale	WNP	12,256	10, 11	0.00009	23
Longman's beaked whale	WNP	4,571	29	0.00025	23
Melon-headed whale	WNP	36,770	10, 11	0.00267	23
Pantropical spotted dolphin	WNP	438,064	17	0.01132	23
Pygmy killer whale	WNP	30,214	10, 11	0.00006	23
Pygmy sperm whale	WNP	350,553	10, 11	0.00176	23
Risso's dolphin	WNP	83,289	17	0.00046	23
Rough-toothed dolphin	WNP	145,729	10, 11	0.00185	23
Short-finned pilot whale	WNP	53,608	17	0.00211	23
Sperm whale	NP	102,112	21, 22	0.00222	23
Spinner dolphin	WNP	1,015,059	10, 11	0.00187	23
Striped dolphin	WNP	570,038	17	0.00584	23
Mission Area 10: Hawaii North; Summer Season					
Blue whale	CNP	81	29, 44		29
Bryde's whale	Hawaii	798	29, 44	0.0003	29
Common minke whale	Hawaii	25,049	5		10, 11
Fin whale	Hawaii	58	29, 44		29
Humpback whale	Central Pacific stock/Hawaii	10,103	14, 22		12, 30

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km²)[19]*	*Density References*
	DPS				
Sei whale	Hawaii	178	29, 44		29
Blainville's beaked whale	Hawaii	2,338	29, 44	0.001	29
Common bottlenose dolphin	Hawaii Pelagic	5,950	29, 44	0.0025	29
	Kauai/Niihau	184	44, 45	0.0001	29, 46
	4-Islands	191	44, 45	0.0001	29, 46
	Oahu	743	44, 45	0.0003	29, 46
	Hawaii Island	128	44, 45	0.0001	29, 46
Cuvier's beaked whale	Hawaii	1,941	29, 44	0.0008	29
Dwarf sperm whale	Hawaii	17,519	25, 44	0.00714	25
False killer whale	Hawaii Pelagic	1,540	153, 154, 155	0.0006	47
	Main Hawaiian Islands Insular stock and DPS	151	2, 48	0.0012	48
	Northwestern Hawaiian Islands	617	153, 154, 155	0.0013	47
Fraser's dolphin	Hawaii	16,992	29, 44	0.0069	29
Killer whale	Hawaii	101	29, 44	0.00004	29
Longman's beaked whale	Hawaii	4,571	29, 44	0.0019	29
Melon-headed whale	Hawaiian Islands	5,794	44, 49, 50	0.0012	29
	Kohala Resident	447	44, 49, 50	0.03725	44
Pantropical spotted dolphin	Hawaiian Pelagic	15,917	29, 44	0.0067	29
	Hawaii Island	220	51	0.0067	29
	Oahu	220	51	0.0067	29
	4-Islands	220	51	0.0067	29
Pygmy killer whale	Hawaii	3,433	29, 44	0.0014	29
Pygmy sperm whale	Hawaii	7,138	25, 44	0.0029	25
Risso's dolphin	Hawaii	7,256	29, 44	0.003	29
Rough-toothed dolphin	Hawaii	6,288	29, 44	0.0026	29
Short-finned pilot whale	Hawaii	12,422	29, 44	0.0051	29
Sperm whale	Hawaii	3,354	29, 44	0.0014	29
Spinner dolphin	Hawaii Pelagic	3,351	25	0.0008	25

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Spinner dolphin (continued)	Kauai/Niihau	601	44	0.007	25
	Hawaii Island	631	44	0.007	25
	Oahu/4-Islands	355	44	0.007	25
	Kure/Midway Atoll	260	44	0.007	25
	Pearl and Hermes Reef	300	52, 53	0.007	25
Striped dolphin	Hawaii	20,650	29, 44	0.0084	29
Hawaiian monk seal	Hawaii	1,112	153	0.0001	
Mission Area 11: Hawaii South; Fall Season					
Blue whale	CNP	81	29, 44	0.00003	29
Bryde's whale	Hawaii	798	29, 44	0.0003	29
Common minke whale	Hawaii	25,049	5	0.0002	10, 11
Fin whale	Hawaii	58	29, 44	0.00002	29
Humpback whale	Central Pacific stock/Hawaii DPS	10,103	14, 22	0.00089	12, 30
Sei whale	Hawaii	178	29, 44	0.0001	29
Blainville's beaked whale	Hawaii	2,338	29, 44	0.001	29
Common bottlenose dolphin	Hawaii Pelagic	5,950	29, 44	0.00245	29
	Kauai/Niihau	184	44, 45	0.0001	29, 46
	4-Islands	191	44, 45	0.0001	29, 46
	Oahu	743	44, 45	0.0003	29, 46
	Hawaii Island	128	44, 45	0.0001	29, 46
Cuvier's beaked whale	Hawaii	1,941	29, 44	0.0008	29
Deraniyagala beaked whale	NP	22,799	10, 11, 32	0.00093	10, 11
Dwarf sperm whale	Hawaii	17,519	25, 44	0.00714	25
False killer whale	Hawaii Pelagic	1,540	153, 154, 155	0.0006	47
	Main Hawaiian Islands Insular stock and DPS	151	2, 48	0.0012	48
Fraser's dolphin	Hawaii	16,992	29, 44	0.0069	29
Killer whale	Hawaii	101	29, 44	0.00004	29
Longman's beaked whale	Hawaii	4,571	29, 44	0.0019	29
Melon-headed whale	Hawaiian Islands	5,794	44, 49, 50	0.0012	29

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Melon-headed whale	Kohala Resident	447	44, 49, 50	0.03725	44
Pantropical spotted dolphin	Hawaiian Pelagic	15,917	29, 44	0.0067	29
	Hawaii Island	220	51	0.0067	29
	Oahu	220	51	0.0067	29
	4-Islands	220	51	0.0067	29
Pygmy killer whale	Hawaii	3,433	29, 44	0.0014	29
Pygmy sperm whale	Hawaii	7,138	25, 44	0.0029	25
Risso's dolphin	Hawaii	7,256	29, 44	0.003	29
Rough-toothed dolphin	Hawaii	6,288	29, 44	0.0026	29
Short-finned pilot whale	Hawaii	12,422	29, 44	0.0051	29
Sperm whale	Hawaii	3,354	29, 44	0.0014	29
Spinner dolphin	Hawaii Pelagic	3,351	25	0.0008	25
	Kauai/Niihau	601	44	0.007	25
	Hawaii Island	631	44	0.007	25
	Oahu/4-Islands	355	44	0.007	25
Striped dolphin	Hawaii	20,650	29, 44	0.0084	29
Hawaiian monk seal	Hawaii	1,112	153	0.0001	
Mission Area 12: Offshore Southern California; Spring Season					
Blue whale	ENP	1,647	2, 54	0.00011	55
Bryde's whale	ENP	13,000	56	0.00001	55
Common minke whale	C/O/W	478	2, 57, 58, 59	0.00026	55
Eastern North Pacific gray whale	ENP	20,990	2, 60	0.03090	55
Fin whale	C/O/W	3,051	2, 61	0.00022	55
Humpback whale	C/O/W stock/Mexico DPS	1,918	2	0.00121	55
Sei whale	ENP	126	2, 57, 58, 59	0.00009	55
Western North Pacific gray whale	WNP	140	2, 62	0.00001	
Baird's beaked whale	C/O/W	847	2, 58, 59	0.00046	55
Blainville's beaked whale	C/O/W	694	2, 63	0.00101	55
Common bottlenose dolphin	C/O/WOffshore	1,006	2, 58, 59	0.01230	55
Cuvier's beaked whale	C/O/W	6,590	2, 63	0.00358	55
Dall's porpoise	C/O/W	42,000	2	0.02184	55

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Ginkgo-toothed beaked whale	C/O/W	694	2, 63	0.00020	55
Hubb's beaked whale	C/O/W	694	2, 63	0.00086	55
Killer whale	Eastern Pacific Offshore	240	2	0.00030	55
Long-beaked common dolphin	California	107,016	2, 28, 59	0.08591	55
Northern right whale dolphin	C/O/W	21,332	64	0.13352	55
Pacific white-sided dolphin	C/O/W (Northern and Southern)	26,930	2, 58, 59	0.21549	55
Perrin's beaked whale	C/O/W	694	2, 63	0.00088	55
Pygmy beaked whale	C/O/W	694	2, 63	0.00020	55
Pygmy sperm whale	C/O/W	579	2, 59	0.00108	55
Risso's dolphin	C/O/W	6,272	2, 58, 59	0.01000	55
Short-beaked common dolphin	C/O/W	411,211	2, 58, 59	0.95146	55
Short-finned pilot whale	C/O/W	760	2, 57, 58, 59	0.00031	55
Sperm whale	C/O/W	2,106	2, 65	0.00337	55
Stejneger's beaked whale	C/O/W	694	2, 63	0.00065	55
Striped dolphin	C/O/W	10,908	2, 58, 59	0.02592	55
California sea lion	U.S. (Pacific Temperate)	296,750	2	0.33596	55
Guadalupe fur seal	Mexico	7,408	66, 67	0.00387	55
Harbor seal	California	30,968	2	0.02033	55
Northern elephant seal	California Breeding	179,000	2, 68	0.03222	55
Northern fur seal	California	14,050	153	0.01775	55
Mission Area 13: Western North Atlantic (off Florida); Winter Season					
Common minke whale	Canadian East Coast	20,741	69	0.00230	70
Humpback whale	Gulf of Maine stock/West Indies DPS	12,312	7	0.00004	70
North Atlantic right whale	WNA	476	156	0.00002	70
Atlantic spotted dolphin	WNA	44,715	69	0.01143	70
Clymene dolphin	WNA	6,086	71	0.02522	70
Common bottlenose dolphin	Offshore WNA	77,532	69	0.04195	70
	Southern Migratory Coast	9,173	69	0.00155	70
	Northern Florida Coast	1,219	69	0.00155	70

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Common bottlenose dolphin (cont'd)	Central Florida Coast	4,895	69	0.00155	70
Cuvier's beaked whale	WNA	6,532	69	0.00166	70
False killer whale	WNA	442	69	0.00008	70
Killer whale	WNA	67	72	0.00001	70
Kogia spp.	WNA	3,785	69	0.00094	70
Mesoplodon spp.	WNA	7,092	69	0.00180	70
Pantropical spotted dolphin	WNA	3,333	69	0.00608	70
Risso's dolphin	WNA	18,250	69	0.00411	70
Rough-toothed dolphin	WNA	271	69	0.00069	70
Short-beaked common dolphin	WNA	173,486	69	0.00125	70
Short-finned pilot whale	WNA	21,515	69	0.00616	70
Sperm whale	WNA	2,288	69	0.00083	70
Spinner dolphin	WNA	262	70	0.00040	70
Striped dolphin	WNA	54,807	69	0.00298	70
Mission Area 14: Eastern North Atlantic; Summer Season					
Blue whale	ENA	979	73	0.00002	73
Common minke whale	Northeast Atlantic	78,572	74	0.00329	73
Fin whale	ENA	9,019	75	0.00100	75
Humpback whale	Iceland stock/Cape Verdes and West Africa DPS	11,572	76	0.00009	77
Sei whale	Iceland-Denmark Strait	10,300	78, 79	0.00040	75
Atlantic white-sided dolphin	ENA	3,904	80	0.00001	77
Blainville's beaked whale	ENA	6,992	75	0.00700	75
Common bottlenose dolphin	ENA	35,780	75, 81	0.00200	75
Cuvier's beaked whale	ENA	6,992	75	0.00700	75
Gervais' beaked whale	ENA	6,992	75	0.00700	75
Harbor porpoise	ENA	375,358	81	0.07400	81
Killer whale	Northern Norway	731	82	0.00001	
Kogia spp.	ENA	3,785	69	0.00079	70
Long-finned pilot whale	ENA	128,093	83	0.05400	75
Northern bottlenose whale	ENA	19,538	84	0.00260	85, 86

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Risso's dolphin	ENA	18,250	69	0.00200	75, 81
Short-beaked common dolphin	ENA	172,930	75, 81	0.01000	75
Sowerby's beaked whale	ENA	6,992	75	0.00700	75
Sperm whale	ENA	7,785	85, 87, 88	0.00077	85, 88
Striped dolphin	ENA	67,414	75	0.00150	75
True's beaked whale	ENA	6,992	75	0.00700	75
White-beaked dolphin	ENA	16,536	81	0.01400	81
Gray seal	Northwest Europe	116,800	89	0.00040	90
Harbor seal	Northwest Europe	40,414	89	0.04000	90
Mission Area 15: Mediterranean Sea; Summer Season					
Fin whale	Mediterranean	3,583	91	0.00168	92
Common bottlenose dolphin	WM	1,676	93	0.00058	93
Cuvier's beaked whale	Alboran Sea	429	94	0.000108	94
Long-finned pilot whale	ENA	21,515	69	0.0027	95
Risso's dolphin	WM	5,320	96, 97	0.0011	95
Short-beaked common dolphin	WM	19,428	98	0.00144	98
Sperm whale	WM	396	99	0.00052	95
Striped dolphin	WM	117,880	100	0.0436	92
Mission Area 16: Arabian Sea; Summer Season					
Blue whale	NIND	3,432	101	0.00004	55
Bryde's whale	NIND	9,176	56, 101	0.00040	55
Common minke whale	IND	257,500	101	0.00920	55
Fin whale	IND	1,716	101	0.00092	55
Humpback whale	AS stock and DPS	200	102, 103, 104	0.00005	55
Blainville's beaked whale	IND	16,867	56	0.00276	55
Common bottlenose dolphin	IND	785,585	56	0.05521	55
Cuvier's beaked whale	IND	27,272	56	0.00308	55
Deraniyagala beaked whale	IND	16,867	56	0.00278	55
Dwarf sperm whale	IND	10,541	56	0.00006	55
False killer whale	IND	144,188	56	0.00025	55

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Fraser's dolphin	IND	151,554	56	0.00194	55
Ginkgo-toothed beaked whale	IND	16,867	56	0.00278	55
Indo-Pacific bottlenose dolphin	IND	7,850	56	0.00055	55
Killer whale	IND	12,593	56	0.00737	55
Long-beaked common dolphin (Indo-Pacific common dolphin)	IND	1,819,882	56	0.00013	55
Longman's beaked whale	IND	16,867	56	0.01193	55
Melon-headed whale	IND	64,600	56	0.00931	55
Pantropical spotted dolphin	IND	736,575	56	0.00922	55
Pygmy killer whale	IND	22,029	56	0.00141	55
Pygmy sperm whale	IND	10,541	56	0.00002	55
Risso's dolphin	IND	452,125	56	0.08952	55
Rough-toothed dolphin	IND	156,690	56	0.00075	55
Short-finned pilot whale	IND	268,751	56	0.03474	55
Sperm whale	NIND	24,446	56, 105	0.00877	55
Spinner dolphin	IND	634,108	56	0.00718	55
Striped dolphin	IND	674,578	56	0.15196	55
Mission Area 17: Andaman Sea; Summer Season					
Blue whale	NIND	3,432	101	0.00003	55
Bryde's whale	NIND	9,176	56, 101	0.00037	55
Common minke whale	IND	257,500	101	0.00968	55
Fin whale	IND	1,716	101		55
Omura's whale	IND	9,176	56, 101	0.00037	55
Blainville's beaked whale	IND	16,867	56	0.00094	55
Common bottlenose dolphin	IND	785,585	56	0.07261	55
Cuvier's beaked whale	IND	27,272	56	0.00480	55
Deraniyagala beaked whale	IND	16,867	56	0.00097	55
Dwarf sperm whale	IND	10,541	56	0.00006	55
False killer whale	IND	144,188	56	0.00024	55
Fraser's dolphin	IND	151,554	56	0.00180	55
Ginkgo-toothed beaked whale	IND	16,867	56	0.00097	55

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Indo-Pacific bottlenose dolphin	IND	7,850	56	0.00073	55
Killer whale	IND	12,593	56	0.00730	55
Long-beaked common dolphin (Indo-Pacific common dolphin)	IND	1,819,882	56	0.00010	55
Longman's beaked whale	IND	16,867	56	0.00459	55
Melon-headed whale	IND	64,600	56	0.00878	55
Pantropical spotted dolphin	IND	736,575	56	0.00829	55
Pygmy killer whale	IND	22,029	56	0.00125	55
Pygmy sperm whale	IND	10,541	56	0.00001	55
Risso's dolphin	IND	452,125	56	0.09173	55
Rough-toothed dolphin	IND	156,690	56	0.00077	55
Short-finned pilot whale	IND	268,751	56	0.03543	55
Sperm whale	NIND	24,446	56, 101	0.00107	55
Spinner dolphin	IND	634,108	56	0.00701	55
Striped dolphin	IND	674,578	56	0.14123	55
Mission Area 18: Panama Canal; Winter Season					
Blue whale	ENP	1,647	2, 54	0.00008	106
Bryde's whale	ETP	13,000	56, 107	0.0003	106, 108
Common minke whale	ETP	478	2	0.00031	11
Fin whale	ENP	832	11		11
Humpback whale	Southeast Pacific stock/Central America DPS	6,000	109, 110	0.00001	
Blainville's beaked whale	ETP	25,300	56	0.00225	106
Common bottlenose dolphin	ETP	335,834	111	0.0375	106
Cuvier's beaked whale	ETP	20,000	56	0.00058	106
Deraniyagala's beaked whale	ETP	25,300	56	0.00225	106
False killer whale	ETP	39,800	56	0.0004	10, 11
Fraser's dolphin	ETP	289,300	56	0.001	10, 11
Ginkgo-toothed beaked whale	ETP	25,300	56	0.0016	10, 11
Killer whale	ETP	8,500	56	0.00015	112
Kogia spp.	ETP	11,200	56	0.014	10, 11, 106

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km²)[19]*	*Density References*
Longman's beaked whale	ETP	25,300	56	0.00225	106
Melon-headed whale	ETP	45,400	56	0.00313	106
Mesoplodon spp.	ETP	25,300	56	0.00225	106
Pantropical spotted dolphin	Northeastern Pacific Offshore	640,000	113	0.0375	106
Pygmy killer whale	ETP	38,900	56	0.0014	10, 11
Pygmy beaked whale	ETP	25,300	56	0.00225	106
Risso's dolphin	ETP	110,457	111	0.01781	106
Rough-toothed dolphin	ETP	107,633	111	0.00488	106
Short-beaked common dolphin	ETP	3,127,203	111	0.005	106
Short-finned pilot whale	ETP	160,200	56	0.01813	106
Sperm whale	ETP	22,700	56	0.0047	10, 11
Spinner dolphin	Eastern	450,000	113	0.01875	106
Striped dolphin	ETP	964,362	111	0.08125	106
Mission Area 19: Northeast Australia; Spring Season					
Blue whale	WSP	9,250	1, 2, 3	0.00001	1, 10, 11, 12
Bryde's whale	WSP	20,501	4	0.0006	13
Common minke whale	WSP	25,049	5	0.0044	5
Fin whale	WSP	9,250	1,9	0.0002	1
Humpback whale	IWC Breeding Stock E1/East Australia DPS	14,500	114	0.00089	12, 14
Omura's whale	WSP	1,800	26	0.00006	27
Sei whale	WSP	7,000	1, 9	0.0006	1, 15
Blainville's beaked whale	WSP	8,032	10, 11	0.0005	10, 11
Common bottlenose dolphin	WSP	168,791	17	0.0146	17
Cuvier's beaked whale	WSP	90,725	10, 11	0.0054	10, 11
False killer whale	WSP	16,668	17	0.0029	17
Fraser's dolphin	WSP	220,789	10, 11	0.0069	29
Gingko-toothed beaked whale	WSP	22,799	10, 11	0.0005	10, 11
Killer whale	WSP	12,256	10, 11	0.00009	23
Kogia spp.	WSP	350,553	10, 11	0.0031	10, 11

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Longman's beaked whale	WSP	4,571	29	0.00025	23
Melon-headed whale	WSP	36,770	10, 11	0.00428	24
Pantropical spotted dolphin	WSP	438,064	17	0.0137	17
Pilot whales	WSP	53,608	17	0.0153	17
Pygmy killer whale	WSP	30,214	10, 11	0.0021	10, 11
Risso’s dolphin	WSP	83,289	17	0.0106	17
Rough-toothed dolphin	WSP	145,729	10, 11	0.0059	10, 11
Short-beaked common dolphin	WSP	3,286,163	10, 11	0.0562	10, 11
Sperm whale	WSP	102,112	21, 22	0.00123	24
Spinner dolphin	WSP	1,015,059	10, 11	0.00083	25
Striped dolphin	WSP	570,038	17	0.0329	17
Mission Area 20: Northwest of Australia; Winter Season					
Antarctic minke whale	ANT	90,000	115		
Blue whale	SIND	1,657	116, 117		55
Bryde's whale	SIND	13,854	118	0.00032	55
Common minke whale	IND	257,500	101		55
Fin whale	SIND	38,185	119, 120	0.00001	55
Humpback whale	WAU stock and DPS	13,640	121		55
Omura's whale	IND	13,854	118	0.00032	55
Sei whale	IND	13,854	118	0.00001	55
Blainville's beaked whale	IND	16,867	56	0.00083	55
Common bottlenose dolphin	IND	3,000	122	0.03630	55
Cuvier's beaked whale	IND	76,500	123	0.00399	55
Dwarf sperm whale	IND	10,541	56	0.00004	55
False killer whale	IND	144,188	56	0.00020	55
Fraser's dolphin	IND	151,554	56	0.00145	55
Killer whale	IND	12,593	56	0.00585	55
Longman's beaked whale	IND	16,867	56	0.00393	55
Melon-headed whale	IND	64,600	56	0.00717	55
Pantropical spotted dolphin	IND	736,575	56	0.00727	55
Pygmy killer whale	IND	22,029	56	0.00100	55

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km²)[19]*	*Density References*
Risso's dolphin	IND	452,125	56	0.07152	55
Rough-toothed dolphin	IND	156,690	56	0.00059	55
Short-finned pilot whale	IND	268,751	56	0.02698	55
Southern bottlenose whale	IND	599,300	124	0.00083	55
Spade-toothed beaked whale	IND	16,867	56	0.00083	55
Sperm whale	SIND	24,446	56	0.00096	55
Spinner dolphin	IND	634,108	56	0.00561	55
Striped dolphin	IND	674,578	56	0.12018	55
Mission Area 21: Northeast of Japan; Summer Season					
Blue whale	WNP	9,250	1, 2, 3		1, 10, 11, 12
Common minke whale	WNP "O"	25,049	5	0.0022	5
Fin whale	WNP	9,250	1, 6	0.0002	1
Humpback whale	WNP stock and DPS	1,328	7	0.00050	55
North Pacific right whale	WNP	922	125	0.00001	
Sei whale	NP	7,000	1, 9	0.00029	24
Western North Pacific gray whale	WNP stock/Western DPS	140	2	0.00001	
Baird's beaked whale	WNP	8,000	16	0.0029	16
Cuvier's beaked whale	WNP	90,725	10, 11	0.0054	10, 11
Dall's porpoise	WNP	173,638	35	0.0650	10, 11
Killer whale	WNP	12,256	10, 11	0.0036	126
Pacific white-sided dolphin	NP	931,000	20	0.0048	10, 11
Short-beaked common dolphin	WNP	3,286,163	10, 11	0.0863	10, 11
Sperm whale	NP	102,112	21, 22	0.0022	23
Stejneger's beaked whale	WNP	8,000	16	0.0005	10, 11
Northern fur seal	Western Pacific	503,609	42, 43	0.01378	20
Ribbon seal	NP	61,100	22, 127	0.0452	128
Spotted seal	Alaska stock/Bering Sea DPS	460,268	22	0.2770	128
Steller sea lion	Western-Asian stock and Western DPS	62,218	157	0.00001	

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Mission Area 22: Southern Gulf of Alaska; Summer Season					
Blue whale	ENP	1,647	2	0.00051	55
Common minke whale	AK	1,233	22	0.0006	55
Eastern North Pacific gray whale	ENP	20,990	2, 59	0.00019	55
Fin whale	AK/Northeast Pacific	1,368	22	0.00049	55
Humpback whale	WNP and CNP stocks/Hawaii, Mexico, and WNP DPSs	10,103	22	0.00050	55
North Pacific right whale	ENP	31	22	0.00003	55
Sei whale	ENP	126	2	0.00007	55
Baird's beaked whale	AK	847	2, 22	0.0004	55
Cuvier's beaked whale	AK	6,590	2, 22	0.00245	55
Dall's porpoise	AK	173,638	22	0.07214	55
Killer whale	ENP AK Resident	2,347	22, 157	0.005	55
	ENP Gulf of Alaska, Aleutian Islands, and Bering Sea Transient	587	22, 157	0.00021	55
Pacific white-sided dolphin	NP	26,880	20, 22	0.0208	55
Sperm whale	NP	102,112	21, 22	0.00127	55
Stejneger's beaked whale	AK	694	2, 22	0.00084	55
Northern elephant seal	California Breeding	179,000	2	0.00380	55
Northern fur seal	EP	648,534	22	0.03211	55
Ribbon seal	AK	184,000	157, 158	0.00001	55
Steller sea lion	Eastern U.S. stock/Eastern DPS	60,131	22	0.01085	55
	Western U.S. stock/Western DPS	49,497	157	0.01085	55
Mission Area 23: Southern Norwegian Basin; Summer Season					
Blue whale	ENA	979	73	0.00001	77
Common minke whale	Northeast Atlantic	78,572	74	0.03206	129, 130
Fin whale	North-West Norway	6,409	77	0.00157	77
Humpback whale	Iceland stock/Cape Verdes-	11,572	76	0.00009	77

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km²)[19]*	*Density References*
	West Africa and West Indies DPSs				
Sei whale	Iceland-Denmark Strait	10,300	79, 105, 131	0.00001	77
Atlantic white-sided dolphin	ENA	3,904	80	0.00001	77
Cuvier's beaked whale	ENA	6,992	75	0.011	75
Harbor porpoise	ENA	375,358	81	0.074	81
Killer whale	Northern Norway	731	82	0.00001	
Long-finned pilot whale	ENA	128,093	83	0.054	75
Northern bottlenose whale	ENA	19,538	84	0.0026	85, 86
Sowerby's beaked whale	ENA	6,992	75	0.011	75
Sperm whale	ENA	7,785	85, 87, 88	0.0049	87, 88
White-beaked dolphin	ENA	16,536	81	0.011	81
Hooded seal	West Ice	84,020	132	0.00811	133
Mission Area 24: Western North Atlantic (off Virginia/Maryland); Summer Season					
Common minke whale	Canadian East Coast	20,741	69	0.00013	70
Fin whale	WNA	1,618	69	0.00075	70
Humpback whale	Gulf of Maine stock/West Indies DPS	12,312	7	0.00006	70
North Atlantic right whale	WNA	476	156	0.00000	70
Atlantic spotted dolphin	WNA	44,715	69	0.09630	70
Clymene dolphin	WNA	6,086	71	0.01424	70
Common bottlenose dolphin	Offshore WNA	77,532	69	0.04241	70
	Northern Migratory Coastal	11,548	69	0.00236	70
	Southern Migratory Coastal	9,173	69	0.00236	70
Cuvier's beaked whale	WNA	6,532	69	0.00878	70
False killer whale	WNA	442	69	0.00008	70
Killer whale	WNA	67	72	0.00001	70
Kogia spp.	WNA	3,785	69	0.00079	70
Mesoplodon spp.	WNA	7,092	69	0.00954	70
Pantropical spotted dolphin	WNA	3,333	69	0.00515	70
Risso's dolphin	WNA	18,250	69	0.02202	70

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Rough-toothed dolphin	WNA	271	69	0.00060	70
Short-beaked common dolphin	WNA	173,486	69	0.07284	70
Short-finned pilot whale	WNA	21,515	69	0.02215	70
Sperm whale	WNA	2,288	69	0.01274	70
Spinner dolphin	WNA	262	70	0.00034	70
Striped dolphin	WNA	54,807	69	0.13345	70
Mission Area 25: Labrador Sea; Winter Season					
Blue whale	WNA	440	134	0.00002	73
Common minke whale	Canadian East Coast	20,741	69	0.00013	70
Fin whale	Canadian East Coast	1,352	135	0.00005	135
Humpback whale	Newfoundland-Labrador stock/West Indies DPS	12,312	7	0.00019	135
North Atlantic right whale	WNA	476	156	0.00000	70
Sei whale	Labrador Sea	965	136	0.00002	137
Atlantic white-sided dolphin	Labrador Sea	24,422	69, 135, 138	0.00200	135
Harbor porpoise	Newfoundland	3,326	69, 135, 138, 139	0.00160	135
Killer whale	WNA	67	72	0.00001	70
Long-finned pilot whale	Canadian East Coast	6,134	135, 138	0.00370	135
Northern bottlenose whale	Davis Strait	50	140, 141	0.00001	
Short-beaked common dolphin	WNA	173,486	69, 135, 138, 139	0.00100	135
Sowerby's beaked whale	WNA	50	69	0.00001	
Sperm whale	WNA	2,288	69	0.00127	70
White-beaked dolphin	Canadian East Coast	15,625	135, 138, 139	0.00077	135
Arctic ringed seal	Arctic	787,000	143	0.07300	140
Harp seal	WNA	7,411,000	142	0.07043	133
Hooded seal	WNA	592,100	137	0.00811	133
Mission Area 26: Sea of Okhotsk; Spring Season					
Bowhead whale	Okhotsk Sea	247	144, 145	0.00001	145
Common minke whale	WNP “O”	25,049	5	0.01727	5
	WNP “J”	893	33	0.00062	5

Table 3-6. Marine Mammal Species, Stocks, Abundance Estimates, Density Estimates, as well as Associated References for 26 SURTASS Representative LFA Sonar Mission Areas and Season Modeled (References Found at End of Table).

Marine Mammal Species	*Stock[18] Name*	*Stock Abundance*	*Abundance References*	*Density Estimates (animals/km^2)[19]*	*Density References*
Fin whale	WNP	9,250	1, 6	0.0002	1
Humpback whale	WNP stock and DPS	1,328	7	0.00089	12, 14
North Pacific right whale	WNP	922	125		
Western North Pacific gray whale	WNP stock/Western DPS	140	2		
Baird's beaked whale	WNP	8,000	16	0.0015	16
Beluga whale	Okhotsk Sea	12,226	146	0.0071	147
Cuvier's beaked whale	WNP	90,725	10, 11	0.0054	10, 11
Dall's porpoise	WNP dalli-type	111,402	148	0.18031	148
	WNP truei-type	101,173	148	0.16375	148
Harbor porpoise	WNP	31,046	18, 19	0.0190	18
Killer whale	Okhotsk-Kamchatka-Western Aleutians Transient	12,256	10, 11, 153	0.0036	126
Pacific white-sided dolphin	NP	931,000	20	0.0048	10, 11
Sperm whale	NP	102,112	21, 22	0.0022	23
Northern fur seal	Western Pacific	503,609	42, 43	0.08031	147
Okhotsk ringed seal	Okhotsk	676,000	150, 152	0.23881	147
Pacific bearded seal	Okhotsk stock and DPS	200,000	150	0.01174	147
Ribbon seal	Sea of Okhotsk	124,000	151	0.0904	128
Spotted seal	Sea of Okhotsk stock and DPS	180,000	150	0.2770	128
Steller sea lion	Western stock and DPS	82,516	22	0.02189	147

TABLE 3-6 CITED LITERATURE REFERENCES

1. Tillman, 1977
2. Carretta et al., 2015
3. Stafford et al., 2001
4. IWC, 2009
5. Buckland et al., 1992
6. Mizroch et al., 2009
7. Bettridge et al., 2015
8. Best et al., 2001
9. Mizroch et al.,2015
10. Ferguson and Barlow, 2001
11. Ferguson and Barlow, 2003
12. LGL, 2008
13. Ohsumi, 1977
14. Calambokidis et al., 2008
15. Masaki, 1977
16. Kasuya, 1986
17. Miyashita, 1993
18. Hobbs and Waite, 2010
19. Allen and Angliss, 2014
20. Buckland et al., 1993
21. Kato and Miyashita, 1998
22. Allen and Angliss, 2015
23. LGL, 2011
24. Fulling et al., 2011
25. Barlow, 2006
26. Ohsumi, 1980
27. DoN, 2013
28. Carretta et al., 2011
29. Bradford et al., 2013
30. Acebes et al., 2007
31. Lacsamana et al., 2015
32. Dalebout et al., 2014
33. Pastene and Goto, 1998
34. Miyashita, 1986
35. IWC, 2008
36. Han et al., 2010
37. Nesterenko and Katin, 2008
38. Boveng et al., 2009
39. IWC, 1996
40. Evans, 1987
41. Han et al., 2010
42. Kuzin, 2014
43. Gelatt et al., 2015
44. Carretta et al., 2014
45. Baird et al., 2009
46. DoN, 2015
47. Bradford et al., 2012
48. Oleson et al., 2010
49. Oleson et al., 2013
50. Aschettino, 2010
51. Courbis et al., 2014
52. Hoos, 2013
53. Andrews et al., 2006
54. Calambokidis, 2013
55. DoN, 2016
56. Wade and Gerrodette, 1993
57. Barlow and Forney, 2007
58. Forney, 2007
59. Barlow, 2010
60. Durban et al., 2013
61. Moore and Barlow, 2011
62. Cooke et al., 2013
63. Moore and Barlow, 2013
64. Forney et al., 1995
65. Moore and Barlow, 2014
66. Gallo Reynosa, 1994
67. Barlow et al., 1997
68. Lowry et al., 2014
69. Waring et al., 2015
70. Roberts et al., 2016
71. Mullin and Fulling, 2003
72. Lawson and Stevens, 2014
73. Pike et al., 2009
74. IWC, 2010
75. Hammond et al., 2009
76. Pike et al., 2010 cited in Bettridge et al., 2015
77. Oien, 2009
78. Donovan, 1991
79. Cattanach et al., 1993
80. Hammond et al., 2002
81. Hammond et al., 2013
82. Kuningas et al., 2014
83. NAMMCO, 2016
84. Canadas et al., 2011
85. Gunnlaugsson and Sigurjonsson, 1990
86. Barlow et al., 2006
87. Christensen et al., 1992
88. Whitehead, 2002
89. SCOS, 2015
90. Jones et al., 2015
91. Forcada et al., 1996
92. Panigada et al., 2011
93. Lauriano et al., 2014
94. Cañadas and Vázquez, 2014
95. Laran et al., 2010

96. Gomez de Segura et al., 2006
97. Airoldi et al., 2005
98. Cañadas and Hammond, 2008
99. Rendell et al., 2014
100. Forcada and Hammond, 1998
101. IWC, 2016
102. Rosenbaum et al., 2009
103. Minton et al., 2008
104. Minton et al., 2011
105. Perry et al., 1999
106. Barlow et al., 2009
107. Jefferson et al., 2015
108. Palacois et al., 2012
109. Félix et al., 2011
110. Johnston et al., 2011
111. Gerrodette et al., 2008
112. Forney and Wade, 2006
113. Gerrodette and Forcada, 2005
114. Noad et al., 2011
115. Bannister et al., 1996
116. Jenner et al., 2008
117. McCauley and Jenner, 2010
118. IWC, 1981
119. Branch and Butterworth, 2001
120. Mori and Butterworth, 2006
121. Bannister and Hedley, 2001
122. Preen et al., 1997
123. Dalebout et al., 2005
124. Kasamatsu and Joyce, 1995
125. Miyashito and Kato, 1998
126. Springer et al., 2003
127. Ver Hoef et al., 2014
128. Moreland et al., 2012
129. Skaug et al., 2004
130. Bothun et al., 2008
131. Prieto et al., 2014
132. ICES, 2013
133. Haug et al., 2007
134. Waring et al., 2011
135. Lawson and Gosselin, 2009
136. Mitchell and Chapman, 1977
137. Waring et al., 2008
138. Lawson and Gosselin, 2011
139. LGL, 2015
140. DFO, 2011
141. Whitehead and Hooker, 2012
142. DFO, 2014
143. Finley et al., 1983
144. Maclean, 2002
145. Ivashchenko and Clapham, 2010
146. Shpak and Glazov, 2013
147. Kaschner, 2006
148. Kanaji et al., 2015
149. Parsons et al., 2013
150. Fedoseev, 2000
151. Boveng et al., 2013
152. Kelly et al., 2010
153. Carretta et al., 2016
154. Bradford et al., 2014
155. Bradford et al., 2015
156. Waring et al., 2016
157. Muto et al., 2016
158. Conn et al., 2014

dwarf sperm whales. Density estimates are available for these species groups rather than the individual species (Table 3-6). For this SEIS/SOEIS, one season was modeled for each of the 26 representative mission areas/model sites. Seasons as applied herein are defined according to the following monthly breakdown:

- Winter: December, January, and February
- Spring: March, April, and May
- Summer: June, July, and August
- Fall: September, October, and November.

3.3.5 Marine Protected 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. Three types of marine and aquatic habitats protected under U.S. legislation or Presidential EO, critical habitat, essential fish habitat, and marine protected areas, are described in this section.

3.3.5.1 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:

- 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
- 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).

Critical habitat is not designated in foreign countries or any other areas outside U.S. jurisdiction. Although not required, critical habitat may be established for 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.

One hundred thirty-nine marine and anadromous species have been listed as threatened or endangered under the ESA, including 49 foreign species (NMFS, 2016). Critical habitat has been designated for 49 of the marine and anadromous species, although some of the critical habitat for anadromous species is located in inland fresh water bodies (Table 3-7; NMFS, 2016). Although NMFS has jurisdiction over many marine and anadromous species listed under ESA and their designated critical habitat, the USFWS also has jurisdiction over marine/anadromous species, such as the manatee, polar bear, walrus, and sea

Table 3-7. ESA Designated Critical Habitat for ESA-listed Marine and Anadromous Species Considered in this SEIS/SOEIS.

Species	*Status Under ESA*	*Listed Distinct Population Segment (DPS)/Population/Evolutionarily Significant Unit (ESU)*	*Critical Habitat—Type of Habitat Designated*
Marine Mammals			
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, nearshor and >12 nmi
Hawaiian monk seal	Endangered		Marine, nearshore <12 nmi
Steller sea lion	Endangered	Western	Marine, nearshore <12 nmi
Sea Turtles			
Green turtle	Threatened	North Atlantic DPS	Marine, nearshore <12 nmi
Hawksbill turtle	Endangered		Marine, nearshore <12 nmi
Loggerhead turtle	Threatened	Northwest Atlantic Ocean DPS	Marine, nearshore <12 nmi
Leatherback turtle	Endangered		Marine, nearshore <12 nmi and oceanic
Marine/Anadromous Fishes			
Atlantic salmon	Endangered	Gulf of Maine	Inland, river
Chinook salmon	Threatened	California coastal	Inshore, estuarine
	Threatened	Central valley spring-run	Inland, river
	Threatened	Lower Columbia River	Inland, river
	Endangered	Upper Columbia River spring-run	Inland, river
	Threatened	Puget Sound	Inshore
	Endangered	Sacramento River winter-run	Inland, river
	Threatened	Snake River fall-run	Inland, river
	Threatened	Snake River spring/summer-run	Inland, river
	Threatened	Upper Willamette River	Inland, river
Chum salmon	Threatened	Columbia River	Inland, river
	Threatened	Hood Canal summer-run	Inshore
Coho salmon	Endangered	Central California coast	Inshore, estuarine

Table 3-7. ESA Designated Critical Habitat for ESA-listed Marine and Anadromous Species Considered in this SEIS/SOEIS.

Species	*Status Under ESA*	*Listed Distinct Population Segment (DPS)/Population/Evolutionarily Significant Unit (ESU)*	*Critical Habitat—Type of Habitat Designated*
	Threatened	Oregon coast	Inshore, estuarine
	Threatened	Southern Oregon and northern California coasts	Inshore, estuarine
Sockeye salmon	Threatened	Ozette Lake	Inland, lake
	Endangered	Snake River	Inland, river
Steelhead trout	Threatened	Central California coast	Inshore, estuarine
	Threatened	Snake River Basin	Inland, river
	Threatened	Upper Columbia River	Inland, river
	Endangered	Southern California	Inland, river
	Threatened	Middle Columbia River	Inland, river
	Threatened	Lower Columbia River	Inland, river
	Threatened	Upper Willamette River	Inland, river
	Threatened	Northern California	Inland, river
	Threatened	South-Central California coast	Inshore, estuarine
	Threatened	California Central Valley	Inland, river
Boccaccio	Endangered	Puget Sound/ Georgia Basin DPS	Inshore marine and estuarine
Canary rockfish	Threatened	Puget Sound/ Georgia Basin DPS	Inshore marine and estuarine
Eulachon	Threatened	Southern DPS	Inland, river
Green sturgeon	Threatened	Southern	Marine, nearshore >12 nmi
Gulf sturgeon	Threatened		Inshore and Marine <12 nmi
Yelloweye rockfish	Threatened	Puget Sound/ Georgia Basin DPS	Inshore marine and estuarine

otter; and shares jurisdiction with NMFS for some species, such as the Atlantic salmon, gulf sturgeon, and all sea turtles.

3.3.5.2 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 percent 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."

MPAs have been proven to be effective conservation tools to manage fisheries, preserve habitat and biodiversity, and enhance the aesthetic and recreational value of marine areas (NRC, 2000b). Although the objectives for establishing protection of marine areas vary widely, MPAs are typically used to achieve two broad objectives: 1) habitat protection, and 2) fisheries management and protection (Agardy, 2001). Many MPAs are multi-use areas while others only allow restricted uses within the designated MPA boundaries.

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, and in partnership with states, national estuarine research reserves, while the Department of Interior manages the national wildlife refuges and the national park system, which includes national parks, national seashores, and national monuments. 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 habitat, 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 National MPA System's classification 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 2009, the NMPAC, in collaboration with federal, state, and territory agencies, 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, twelve 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 12 nmi (22 km) from the coastline. While there are closure and management MPAs that lie within the potential operating areas of SURTASS LFA sonar, since these areas are relevant for fisheries, they are not included here. The MPAs that are located with in the ptoential operating areas for SURTASS LFA sonar include:

- Olympic Coast NMS
- Greater Farallones NMS
- Monterey Bay NMS
- Cordell Bank NMS
- Stellwagen Bank NMS
- Penguin Bank area of the Hawaiian Islands Humpback Whale NMS
- NMS of America Samoa
- *Monitor* NMS

- Gray's Reef NMS
- Flower Garden Banks NMS
- Florida Keys NMS
- Papahānaumokuākea Marine National Monument (NOAA, 2015.

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 (Table 3-8). 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).

3.3.5.3 National Marine Sanctuaries

Currently, 13 National Marine Sanctuaries (NMSs) are found in U.S. waters, creating a system that protects over 46,000 km^2 of ocean habitat and waters. Since one NMS is located in the waters of Lake Huron, only 12 NMS are located in the potential operating areas of SURTASS LFA sonar (Table 3-9). Each NMS was established to protect the aquatic habitats, marine and aquatic species, and historical artifacts encompassed within a sanctuary and has an established management plan that guides the activities and programs, sets priorities, and contains relevant regulations.

The National Marine Sanctuary Program (NMSP) divides the resources of NMSs into four categories: water, habitat, living, and maritime archaeological resources. Waters include the water column of the sanctuary; habitat includes pelagic, benthic, and coastal areas of importance within a sanctuary; living resources include the biota, including plants and animals, that occur year-round or seasonally in a sanctuary, and finally, a maritime heritage or archaeological resource is defined any type of historical, cultural, archaeological, or paleontological significance resource that is more than 50 years old.

Sanctuaries have established activities that are prohibited or regulated within the sanctuary boundary. However, Department of Defense (DoD) agencies are exempt from these prohibitions or regulations in many of the NMSs. Details of the military exemptions for each NMS may be found in CFR 15 §922. The focus of the each sanctuary's habitats descriptions in this section are on those habitats that occur in the waters in which SURTASS LFA sonar is most likely to be operated (i.e., not in intertidal, coastal habitats).

Table 3-8. Examples Of Larger-Scale International Mpas that are Located Within Potential SURTASS LFA Sonar Operating Areas (Protect Planet Ocean, 2009; UNESCO, 2009; WDPA, 2009).

Name	*Designating Country*	*Location*	*Ocean Area*
Pelagos Sanctuary for the Conservation of Marine Mammals in the Mediterranean	Italy, Monaco, Spain, and international waters	Mediterranean Sea roughly centered at 8.7796°N, 42.7124°E (Ligurian Sea)	87,492 km^2/ 8,749,200 hectares
Phoenix Island Protected Area	Republic of Kiribati	Pacific Ocean, roughly between Fiji and Hawaiian Islands, (just southeast of Howland Island)	41,500,000 hectares/415,000 km^2
Cocos Island National Park	Costa Rica	280 nmi off Pacific coast of Costa Rica	1,998 km^2/199,790 hectares
Malpelo Island Fauna and Flora Sanctuary	Columbia	~265 nmi off Pacific coast of Columbia; roughly centered at 3°51'07'' S and 81°35'4"E	8,575 km^2
Galapagos Marine Reserve	Ecuador	The reserve extends 40 nautical miles out to sea from the islands' baseline; centered at ~ 137°S, 90.629°W	13,000 km^2
Great Barrier Reef Marine Part	Australia	Pacific Ocean; World Heritage Site	344,000 km^2
Heard and Macdonald Islands MPA	Australia	Indian Ocean; 51.663°S, 74.935°E	65,000 km^2
Southeast Commonwealth Marine Reserve	Australia	Indian Ocean; >12 nmi from shore but in Australia EEZ	226,458 km^2
Seaflower Marine Protected Area	Columbia	Atlantic Ocean; 13°30'0"N, 81°0'0"W; World Heritage Site	65,000 km^2
Marine Mammal Sanctuary of the Dominican Republic	Dominican Republic	Atlantic Ocean (Caribbean Sea); 19°56'9"N, 69°19'31"W	25,000 km^2

Table 3-9. The National Marine Sanctuary's (NMSs) Located in SURTASS LFA Sonar's Global Operating Area.

NMS Name	*NMS Located Outside Coastal Standoff Range for SURTASS LFA sonar (>12 nautical miles from land)*	*NMS Designated as Marine Mammal OBIA for SURTASS LFA Sonar*
Olympic Coast	Part	Yes
Cordell Bank	Part	Yes
Greater Farallones	Part	Yes
Monterey Bay	Part	Yes
Channel Islands	No	No
Hawaii Humpback Whale	No, except Penguin Bank	Only Penguin Bank
America Samoa (formerly Fagatele Bay NMS, includes Rose Atoll NM)	Part	No
Stellwagen Bank	Part	Yes
Monitor	Yes	No
Gray's Reef	Yes	No
Florida Keys	Part	No
Flower Garden Banks	Yes	No

Olympic Coast NMS

Designated in 1994, Olympic Coast NMS spans 2,408 nmi^2 (8,259 km^2) of coastal and ocean waters as well as the submerged lands from central and northern coast of the Washington State's Olympic Peninsula coast to the Canadian border (CFR 15 §922.150). Extending seaward 21.6 to 38.9 nmi (40 to 72 km), the sanctuary covers much of the continental shelf and upper continental slope, encompassing the heads of three major submarine canyons (NOAA, 2011). Water depths are at maximum more than 4,500 ft (1,400 m). The sanctuary borders 56 nmi (90 km) of the Olympic National Park's undeveloped coastline. Three national wildlife refuges, collectively called the Washington Island National Wildlife Refuges, are located within the Olympic Coast NMS, and protect over 600 named and unnamed offshore rocks, sea stacks and islands (ONMS, 2008a). The sanctuary, characterized by nutrient-rich upwelled waters, high primary productivity, and varied marine habitats, is occupied by numerous marine mammals, seabirds, diverse populations of kelp and other macroalgae, and diverse fish and invertebrate communities.

<u>Sanctuary Resources</u>

1. *Marine Waters*: The regional circulation is complex and dynamic, with distinct seasonality. Surface winds are a major force driving ocean surface circulation off the Pacific Northwest ocean waters. Spring and summer southerly winds push surface waters southward and offshore, which results in nearshore upwelling of cold, nutrient-rich water to the surface ocean off Washington.

These higher nutrient levels enhance primary production (plankton) and are the foundation for the productive ecosystem of Olympic Coast NMS. Downwelling tends to occur in the fall and winter months, when the winds blow generally toward the north and surface water is forced shoreward. Additionally, the California Current sweeps southward through the sanctuary waters, bringing cold, subarctic waters into the region, which also influences the distribution of organisms (NOAA, 2011). The seafloor topography along with coastal eddies together affect the retention and magnitude of the nutrient concentrations in this region (ONMS, 2008a). Further adding to the dynamic ocean environment of the sanctuary, oceanographic and atmospheric events across the Pacific, such as El Niño-Southern Oscillation, influence the waters of the Olympic Coast NMS. Water quality within the sanctuary is representative of natural ocean conditions, with low pollutant input due largely to the undeveloped adjacent coastal environment, except for widespread nearshore hypoxic areas recently detected (NOAA, 2011).

2. *Marine Habitats:* Olympic Coast NMS contains a broad diversity of habitats including rocky and sandy intertidal, nearshore kelp bed/forest, subtidal rocky reef, plankton-rich pelagic/open ocean, deepwater hard-bottom, and submarine canyon habitats (ONMS, 2008a). The pelagic habitat is the most extensive habitat found in the sanctuary, since the majority of the sanctuary lies over the continental shelf, which is covered by soft sediments such as sand and mud. Sanctuary boundaries extend beyond the edge of the continental shelf and include portions of the Nitnat, Juan de Fuca, and Quinault submarine canyons. The Quinault Canyon is the deepest, descending to water depths of 4,660 ft (1,420 m) at its deepest point within the sanctuary. The nearshore kelp bed habitat is a complex and biologically rich environment. The extent of the kelp canopy cover remains stable (NOAA, 2011). Hard-bottom habitat, with its rich assemblage of invertebrates, has been documented within the canyons as well as along the offshore continental shelf margin (ONMS, 2008a).

3. *Living (Biota):* Sanctuary waters are inhabited by diverse and abundant fish and invertebrate populations. The soft sediment benthic environments are host to brittle stars, sea urchins, worms, snails, shrimp, Dungeness crab, and razor clams (NOAA, 2011), while the hard-bottom substrate is associated with deepwater soft corals and more than 40 species of sponges (ONMS, 2008). Fish, invertebrates, and sea otters are found in association with the nearshore kelp beds. At least 30 species of rockfish, 15 species of flatfishes, and numerous highly migratory species of fish occur in the waters of the sanctuary. Five species of ESA-listed Pacific salmon (multiple ESUs of each species), the threatened eulachon and green sturgeon, may occur at least some part of the year in sanctuary waters (Washington Department of Fish and Wildlife, 2010). Numerous commercially harvested including Pacific halibut, herring, Pacific cod, Pacific whiting, lingcod, sablefish occur in Olympic Coast NMS waters (ONMS, 2008).

Although three species of sea turtles have been reported from sanctuary waters (ONMS, 2008), only the leatherback turtle occurs in Olympic Coast NMS, since it has the highest tolerance for cool water temperatures. Leatherbacks venture to these northern waters to forage seasonally on favored prey, brown sea nettles that are plentiful in this region. This area is so important to leatherback turtle ecology that in 2012 an area from Cape Flattery, WA to Cape Blanco, OR was designated as critical habitat for the leatherback turtle (NOAA, 2012a).

Twenty-nine species of marine mammals have been sighted, at least seasonally, in Olympic Coast NMS waters, including eight species listed under the ESA (NOAA, 2011; ONMS, 2008a). Year-round residents in sanctuary waters include killer whales, sea otters, harbor and elephant seals, Steller and California sea lions, with gray and humpback whales occurring as they migrate between foraging and calving grounds. The sea otter is considered a keystone species in the sanctuary because of the strong effect they have on the nearshore kelp forests (ONMS, 2011). Ninety to 100 species of seabirds

Sea stacks and islands provide critical nesting habitat for 16 species of marine birds, including seven species of murres, puffins, and murrelets, three cormorant species, four gull and tern species, and two storm petrel species (NOAA, 2011).

4. *Maritime Archaeological:* Only recently have surveys been conducted to find and identify shipwrecks in the sanctuary. As of 2011, remains of eight historical shipwrecks had been identified in nearshore waters, although heavily degraded due to the harsh environment (NOAA, 2011). Only two intact shipwreck sites have been documented within the Olympic Coast NMS, a World War II/Korean War troopship and a 19th bark (NOAA, 2011).

<u>Prohibited Activities</u>

Prohibited or regulated activities in sanctuary waters include exploring, developing, or producing oil, gas, or minerals within the sanctuary; discharging or depositing from in or within the sanctuary boundaries; possessing, moving, removing, injuring, or attempting to move, remove, or injure a historical sanctuary resource; drilling or dredging or altering submerged lands; anchoring; constructing, placing, or abandoning any structures on submerged lands; taking or possessing any marine mammals, seabirds, or sea turtles; disturbing marine mammals or seabirds by flying motorized aircraft lower than 2,000 ft within 1 nmi of the wildlife refuges; and interfering in or obstructing law enforcement actions (CFR 15 §922.152).

<u>DoD Exemptions</u>

Per CFR 15 §922.152(d)(1)-, DoD activities must be conducted in a manner that avoids, to the extent practicable, adverse impacts to sanctuary resources and qualities and the activity prohibitions do not apply to the following military activities conducted within military operating areas within the sanctuary: hull integrity tests and other deep water tests; live firing of guns, missiles, torpedoes, and chaff; Quinault Range activities including the in-water testing of non-explosive torpedoes; and anti-submarine warfare operations. New DoD activities may also be deemed exempt following consultation between the DoD and the ONMS. The DoD is prohibited from conducting bombing exercises within the sanctuary. If during the conduct of a DoD activity, a sanctuary resource or its quality is affected, the DoD agency must coordinate with the ONMS to respond to, mitigate, and restore the sanctuary resource and its quality.

Cordell Bank NMS

Designated in 1989, Cordell Bank NMS is an extremely productive, seasonal upwelling marine area off the west coast of northern California. The sanctuary, located entirely offshore, was expanded in 2015 to protect a total area of 971 nmi^2 (3,370 km^2) of offshore ocean waters, and the underlying submerged lands, surrounding the submarine plateau of Cordell Bank. The sanctuary is located off Northern California about 45 nmi (83 km) north-northwest of San Francisco. Cordell Bank NMS is coterminous with Greater Farallones NMS along both its eastern and northern boundaries (CFR §922.110). Cordell Bank, the centerpiece of the sanctuary, is a 3.9 nmi (7.2 km) by 8.2 nmi (15.2 km) rocky bank that rises abruptly from the soft sediments of the outer continental shelf to within 115 ft (35 m) of the ocean surface (ONMS, 2009b). The other distinct underwater feature of the sanctuary is Bodega Canyon, to the north of Cordell Bank, which is over 5,200 ft (1,585 m) deep.

Sanctuary Resources

1. *Marine Waters*: Upwelling, caused by strong, northwesterly winds, dominates the Cordell Bank region during spring and early summer (late February to July), bringing nutrient rich water to the sea surface, which together with high sunlight levels results in greatly increased primary productivity that cascades through the food chain. The upwelling system off Cordell Bank and the Greater Farallones is one of the most consistent and intense coastal upwelling centers in all of North America. By late summer and early fall, the winds driving the upwelling die down, becoming light and variable, causing the upwelling to cease or "relax". Another transition comes in late November, when strong winter storms out of the Gulf of Alaska cause large waves and strong winds along the coast (NOAA, 2014c). In addition to upwelling, circulation in the region is influenced by the southerly flowing California Current, especially during spring and early summer, but by winter, the northward flowing Davidson Current more strongly influences the region (ONMS, 2009b). Freshwater and sediments are input into the sanctuary area from the Russian River, located just north along the coast from Cordell Bank NMS, especially during winter (NOAA, 2014c). Water quality with the sanctuary is considered good, principally because the coastline adjacent to the sanctuary is not heavily developed (NOAA, 2014c).

2. *Marine Habitats:* Cordell Bank NMS includes diverse benthic habitats as well as the pelagic habitat. The benthic environment includes regions of the continental shelf and continental slope that are principally covered by soft sediments (mud) but some hardbottom outcrops appear on the continental slope. The submarine canyon habitat within the sanctuary has not been well studied but provides high topographic complexity. Limited surveys of Bodega Canyon, in the northern part of Cordell Bank NMS, discovered that much of the hardbottom substrate was covered with a layer of mud, which resulted in very sparse invertebrate cover (NOAA, 2014c). Additionally, Bodega Canyon provides habitat for adult lifestages of many groundfish species. The bank itself includes the most diverse benthic habitats ranging from high relief rock pinnacles, flat rock, boulders, cobble, sand, and mud (ONMS, 2009b). The pelagic habitat varies greatly throughout the year in the sanctuary, with well-mixed conditions during the majority of the year except in late summer and fall when winds are low and no storms or upwelling dominates the waters.

3. *Living (Biota):* The sanctuary's nutrient-rich pelagic waters during the upwelling season support large populations of two species of krill (types of zooplankton), which are keystone species and form the basis of a highly biologically-productive, seasonal ecosystem (ONMS, 2009b). During upwelling season, large number of top predators and large whales are drawn to the sanctuary's waters due to the seasonal abundance of fish and krill.

   Hardbottom benthic substrate in the sanctuary is covered with thick assemblages of invertebrates, including sponges, anemones, hard hydrocorals, soft gorgonian corals, hydroids, tunicates, scattered crabs, holothurians, and gastropods. The few exposed areas hardbottom substrate in Bodega Canyon and on the continental slope are host to deep-sea corals and sponges, in addition to other invertebrates (NOAA, 2014c). The soft sediment habitats of the sanctuary include polychaete worms, clams, sea stars, and Dungeness crabs. Although the northern distributional range of jumbo squid was thought to extend only to southern California waters, jumbo squid have recently begun to regularly occur in the waters of the sanctuary (ONMS, 2009b).

More than 180 species of fish have been documented in the Cordell Bank NMS, with rockfish dominating the fish community in both numbers and biomass (NOAA, 2014c; ONMS, 2009b). At least six species of ESA-listed fishes are found in sanctuary waters: yelloweye and canary rockfishes, bocaccio, as well as chinook and coho salmon and steelhead trout. Pelagic fish species include sharks (great white, blue, and thresher), mackerel, sardines, tuna, and anchovies, some of which are highly migratory, only occurring in sanctuary waters seasonally. Anchovies and sardines are the most abundant pelagic fish species (ONMS, 2009b).

Only one species of sea turtle, the leatherback turtle, occurs in the cool waters of Cordell Bank NMS. Leatherbacks are regular seasonal visitors to the sanctuary, arriving to forage from August through November (ONMS, 2009b). This important leatherback foraging area from Point Arena south to Point Arguello was designated as critical habitat in 2012 (NOAA, 2012a), which includes part of Cordell Bank NMS. More than 50 seabird species have been observed foraging in or near sanctuary waters, several of which are listed under the ESA (NOAA, 2014c; ONMS, 2009b). Similarly to the fishes and marine mammals that are observed in sanctuary waters, some seabirds are year-round residents while others only migrate through the region. Tens of thousands of regionally nesting seabirds have been counted in single days on the waters of Cordell Bank and Greater Farallones NMSs (ONMS, 2009b).

Sixteen to 18 species of resident and migratory marine mammal species have been observed within the sanctuary, including the endangered blue, fin, humpback, and sperm whales and threatened southern sea otter and Guadalupe fur seal (NOAA, 2014c and 2014d). Gray, blue, and humpback whales are the most commonly observed migratory cetaceans while Pacific white-sided dolphins, Dall's porpoises, and right whale dolphins are the most commonly observed year-round cetaceans, especially in more offshore waters. Most of the pinniped species, including the most abundant harbor seal, are observed in the most nearshore waters of the sanctuary, are as harbor porpoises.

4. *Maritime Archaeological:* With only a small percentage of the sanctuary's seafloor having been surveyed, only one shipwreck, the USS *Stewart*, has been discovered in Cordell Bank NMS (NOAA, 2014d). The USS *Stewart* was captured by the Japanese Navy in 1946, recaptured by the U.S. Navy near the end of the war, and finally scuttled near Bodega Canyon.

<u>Prohibited Activities</u>

Prohibited or regulated activities in sanctuary waters include exploring for, developing, or producing oil, gas, or minerals; discharging or depositing any material within the sanctuary except those listed in regulations; taking, removing, or injuring any benthic organisms from Cordell Bank; drilling or dredging, or altering the submerged lands of Cordell Bank or placing, constructing, or abandoning any structure on the sanctuary's submerged lands; taking or possessing any marine mammal, sea turtle, or bird within or above the sanctuary; possessing, removing, moving, possessing, or injuring or attempting to remove, move, possess, or injure a historical resource; introducing or releasing any species into the sanctuary except striped bass; interfering in any way with enforcement activities (CFR 15 §922.112).

<u>DoD Exemptions</u>

Per CFR 15 §922.112(9)(c), all DoD activities necessary for national defense that are carried out in sanctuary waters by the effective date of sanctuary designation and expansion are exempt from activity prohibitions. Additional DoD activities initiated after that period will be exempted following consultation between the ONMS and the DoD. DoD activities not necessary for national defense, such as routine exercises and vessel operation are not exempt and are subject to all prohibitions as stated in the sanctuary's regulations.

Greater Farallones NMS

Designated in 1981, the Gulf of the Farallones NMS originally spanned 966 nmi^2 (3,313 km^2) just north and west of San Francisco Bay, and protected open ocean and nearshore habitats. In 2015, the sanctuary was renamed Greater Farallones NMS along with an area expansion. The boundary of Greater Farallones NMS was expanded north and west of its original boundaries to now encompass ocean and coastal waters and the submerged lands thereunder for a total area of 2,488 nmi^2 (8,533 km^2) surrounding the Farallon Islands and Noonday Rock along the northern coast of California (CFR 15 §922.80).

<u>Sanctuary Resources</u>

1. *Marine Waters*: Upwelling, caused by strong, northwesterly winds, dominates the Greater Farallones region during spring and early summer (late February to July), bringing nutrient rich water to the sea surface, which together with high sunlight levels results in greatly increased primary productivity that cascades through the food chain. The upwelling system off Cordell Bank and the Greater Farallones is one of the most consistent and intense coastal upwelling centers in all of North America. By late summer and early fall, the winds driving the upwelling die down, becoming light and variable, causing the upwelling to cease or "relax". Another transition comes in late November, when strong winter storms out of the Gulf of Alaska cause large waves and strong winds along the coast (NOAA, 2014c). In addition to upwelling, circulation in the region is influenced by the southerly flowing California Current, especially during spring and early summer, but by winter, the northward flowing Davidson Current more strongly influences the region. In addition to upwelling, San Francisco Bay may be an important source of nutrients and organic matter for Greater Farallones NMS. Water quality with the sanctuary is considered good, principally because the coastline adjacent to the sanctuary is not heavily developed (NOAA, 2014c).

2. Marine Habitats: A diverse spectrum of marine habitats including soft and hard substrate intertidal, estuarine, shallow and deepwater, soft and hardbottom substrate benthic, submarine canyon, and pelagic water habitats are found in Greater Farallones NMS. The pelagic habitat, which comprises the vast majority of the sanctuary, varies greatly throughout the year in the sanctuary, with well-mixed conditions during the majority of the year except in late summer and fall when winds are low and no storms or upwelling dominates the waters. The Farallon Islands are located near the continental shelf break in the path of the California Current. Benthic habitats consist primarily of soft bottom with small rocky outcroppings and areas of locally high relief. Pioneer Canyon is a small submarine canyon with walls composed of rocky substrate that is complex in relief while the canyon floor is covered with soft sediments (ONMS, 2010).

3. *Living (Biota):* The sanctuary's nutrient-rich pelagic waters during the upwelling season support large populations of two species of krill (types of zooplankton), which are keystone species and form the basis of a highly biologically-productive, seasonal ecosystem (ONMS, 2010). Invertebrates can be found in most habitat types, from rocky shores and mudflats to deep benthic and pelagic habitats throughout the sanctuary. In habitats deeper than 60 ft (18 m) encrusting coralline algae, brittle stars, and serpulid worms are the dominant benthic organisms while polychaete worms, pelecypods and scaphopod mollusks, shrimps, and brittle stars

characterize the deeper continental slope benthic habitats of the sanctuary (ONMS, 2010). In the deepest habitats, such as those of Pioneer Canyon, deepwater corals, sponges, hydroids, anemones, worms, clams, chitons, squid, and octopuses. Dungeness crabs are commonly found in a variety of habitats, but populations are concentrated on sandy to sandy-mud bottoms from the intertidal to a depth of 300 ft (91 m) (NOAA, 2014e).

Fishes found in Greater Farallones NMS include two species of ESA-listed Pacific salmon (chinook and coho), northern anchovy, multiple species of rockfish, of which some are listed under the ESA, and flatfishes. Pelagic habitats include large predatory finfish such as sharks, tunas, and mackerel as well as northern anchovies, sardines, and mackerel (ONMS, 2010). The ESA-listed bocaccio as well as chilipeppers, rockfish, and Pacific hake dominate the deeper water soft substrate habitats in the sanctuary (NOAA, 2014e). The largest known seasonal concentration of adult and sub-adult great white sharks in the world is found in Greater Farallones NMS (ONMS, 2010).

The Farallon Islands are the most important area for nesting seabirds within the contiguous U.S., with over 300,000 adult birds nesting on the islands in May through July, during the height of the breeding season (ONMS, 2010). Eleven of the sixteen seabird species have breeding colonies in the Farallon Islands and forage in sanctuary waters (NOAA, 2014e). Four species of sea turtles, green, olive ridley, and loggerhead turtles have been rarely observed in sanctuary waters, but it is only the leatherback turtle that occurs annually in sanctuary waters, albeit in low numbers (ONMS, 2010). Part of Greater Farallones NMS is located with the critical foraging habitat for the leatherback turtle, which extends from Point Arena south to Point Arguello (NOAA, 2012a). Thirty-six marine mammal species have been observed in the Greater Farallones NMS, including six pinniped species, 28 cetaceans, and two otter species, many of which are ESA-listed (NOAA, 2014e). The sanctuary contains one of the remaining California populations of the Steller sea lion, which occur in these waters year-round, and includes breeding rookeries for five pinniped species (NOAA, 2014e; ONMS, 2010). Seasonally, blue and humpback whales forage in sanctuary waters while the gray whale migrates through the sanctuary. Twelve cetacean species are seen regularly in sanctuary waters, with the minke whale, Pacific white-sided dolphin, as well as harbor and Dall's porpoises considered year-round residents (ONMS, 2010).

4. *Maritime Archaeological:* To date, 392 known ship and aircraft wrecks ranging from the 19th to 20th centuries have been documented in Greater Farallones NMS (NOAA, 2014e). The largest concentration of ship and aircraft wrecks is located in the Point Arena area of the sanctuary while the earliest known shipwreck is a Russian brig sunk in 1820 and one historic shipwreck, the SS *Pomona*, is listed on the National Register of Historic Places (NOAA, 2014e). The sanctuary maintains a database of all known shipwrecks.

Prohibited Activities

Prohibited and unlawful activities within Greater Farallones NMS include exploring for, developing, or producing oil, gas, or minerals; discharging or depositing any material within the sanctuary except those listed in regulations; discharging or depositing any material outside the sanctuary that subsequently enters the Sanctuary and injures a sanctuary resource or quality; placing, constructing, or abandoning any structure on the sanctuary’s submerged lands; drilling or dredging, or altering the submerged lands of the sanctuary in any way; operating motorized personal watercraft anywhere in Bodega Bay and anywhere in the sanctuary south of 38.298°N (the southernmost tip of Bodega Head) except for emergency search and rescue missions or law enforcement operations; taking or possessing any marine mammal, sea turtle, or bird within or above the sanctuary; possessing, removing, moving, possessing, or injuring or attempting to remove, move, possess, or injure a historical resource; introducing or releasing any species into the sanctuary except striped bass; disturbing marine mammals or seabirds by flying motorized aircraft at less than 1,000 ft (305 m) over the waters within any of the sanctuary's seven designated Special Wildlife Protection Zones except as authorized by USFWS or as part of a law enforcement action; operating any commercial cargo vessel within any area designated Special Wildlife Protection Zone or within 1 nmi (1.9 km) from these zones; attracting a white shark anywhere in the sanctuary or approaching within 164 ft (50 m) of any white shark within Special Wildlife Protection Zone 6 and 7 or within 1 nmi (1.9 km) from these zones; deserting a vessel aground, at anchor, or adrift in the sanctuary; leaving harmful matter aboard a grounded or deserted vessel in the sanctuary; anchoring a vessel in a designated seagrass protection zone in Tomales Bay, except as necessary for permitted aquaculture operations; and interfering in any way with enforcement activities (CFR 15 §922.82).

DoD Exemptions

Per CFR 15 §922.82(b), all activities currently carried out by the DoD within the sanctuary are essential for national defense and thus not subject to the sanctuary's activity prohibitions.

Monterey Bay NMS

Monterey Bay NMS, designated in 1992, encompasses a total area of 4,601 nmi^2 (15,783 km^2) offshore of California's central coast. Monterey Bay NMS consists of two units, the main unit of the sanctuary is 4,016 nmi^2 (13,775 km^2) including submerged lands beneath coastal and ocean waters in and surrounding Monterey Bay, while the second sanctuary unit of ocean area and its submerged lands is the rectangular-shaped Davidson Seamount Management Zone, which is located ~65 nmi (120 km) off the coast of San Simeon, California (CFR 15 §922.130). Davidson Seamount rises 7,546 ft (2,300 m) from the seafloor. The sanctuary contains the largest kelp forest in the U.S. and encompasses the deep Monterey Canyon, which extends, at its deepest, to 12,713 ft (3,250 m). Additionally, the sanctuary contains an offshore island, Año Nuevo Island, a 0.029 nmi^2 (0.1 km^2) low-lying island that lies about 40 nmi (74 km) south of San Francisco and is noted for its wildlife. Greater Farallones NMS has administrative jurisdiction over the northern portion of the Monterey Bay NMS, from the San Mateo/Santa Cruz County line northward to the existing boundary between the two sanctuaries. .

Sanctuary Resources

1. *Marine Waters*: Circulation in the Sanctuary is closely tied to processes of the southerly flowing California Current, with the northward moving California Undercurrent beneath. These currents vary in intensity and position, both seasonally and annually. Similarly to the surrounding Cordell Bank and Greater Farallones NMSs, Monterey Bay NMS experiences the three oceanographic seasons of upwelling, relaxation of upwelling, and winter storms. Marine waters are affected by the El Nino/Southern Oscillation. Until 2013, the offshore waters of the sanctuary experienced the cool phase of the Pacific Decadal Oscillation, which is associated with strong upwelling, cool water temperatures, and very high chlorophyll concentrations, all resulting in high levels of primary productivity, with high productivity cascading through the food chain (ONMS, 2015). However, in 2013, the oscillation switched to the warm period with warmer water temperatures, decreased upwelling, and decreased productivity. Water quality parameters in the offshore environment of the sanctuary suggest degraded conditions while the nearshore waters are most impacted by the developed coastline surrounding Monterey Bay. The main

contributors to degraded water quality conditions are land-based activities, including run-off that transports high nutrient loads and pollutants into the sanctuary's offshore waters (ONMS, 2015).

2. Marine Habitats: Monterey Bay NMS contains many diverse habitats, including intertidal, estuarine, kelp forest, subtidal/nearshore, pelagic, hard and soft benthic substrate, deepsea canyon, seamount, and island environments. The pelagic habitat, which comprises the vast majority of the sanctuary, varies greatly throughout the year in the sanctuary, with well-mixed conditions during the majority of the year except in late summer and fall when winds are low and no storms or upwelling dominates the waters. Benthic habitats consist primarily of soft bottom with small rocky outcroppings and areas of locally high relief. Most of Monterey Bank NMS seafloor is covered by soft sediments of sand and mud. In addition to Monterey Canyon, numerous smaller canyons transect the seafloor of the sanctuary (NOAA, 2008a).

3. *Living (Biota):* Two forms of kelp are found in Monterey Bay NMS's vast kelp forests, giant and bull kelp, with giant kelp dominating growth in the Monterey Bay area. The lowest level of kelp forests is covered by various algae, including coralline algae, and a rich diversity of fishes and invertebrates. Sea otters also reside within kelp forests with many marine mammals and fishes visit the forests to forage. Shallow benthic habitats are dominated by crustaceans while the deep benthic habitats are dominated by polychaete worms (NOAA, 2008a). At least 31 phyla of invertebrates are represented in the sanctuary. Nearly 2,000 species of invertebrates have been cataloged in the pelagic and deep benthic environment of the sanctuary, including squid, sponges, anemones, jellies, worms, corals, tunicates, snails, octopus, clams, barnacles, crabs, and spot prawns (NOAA, 2008). Several rare fishes, red jellyfish, and swimming worms as well as deepwater corals and massive sponge communities are found on Davidson Seamount (NOAA, 2008b).

   The walls and ridges of the sanctuary's canyons provide preferred habitat for various species of rockfishes. As of 2013, 525 species of fishes had been identified within Monterey Bay NMS representing near 150 fish families (Burton and Lea, 2013). Numerous (>40) species of rockfishes are found within the sanctuary, several species of which are listed under the ESA, as are other fishes including the green sturgeon, eulachon, and five species of Pacific salmon (Burton and Lea, 2013). Nearly 100 species of seabirds have been reported in the sanctuary including core populations of cormorants, murres, auklets, and guillemots.

   Four species of sea turtles, green, olive ridley, and loggerhead turtles have been rarely observed in sanctuary waters, but it is only the leatherback turtle that occurs annually in sanctuary waters, albeit in low numbers (NOAA, 2008a). Part of Monterey Bay NMS is located with the critical foraging habitat for the leatherback turtle, which extends from Point Arena south to Point Arguello (NOAA, 2012a). A diverse and abundant assemblage of marine mammals occurs, at least seasonally, in Monterey Bay NMS, including six pinniped species, 27 cetacean species, and one fissiped (sea otter) species. Presently, approximately 82 percent of the southern sea otter population occurs within the sanctuary. Large aggregations of pinnipeds, especially the northern elephant seal haul out on the shores of Año Nuevo Island during breeding and pupping season. Including marine mammal species, at least 26 species listed under the ESA as threatened or endangered are found within Monterey Bay NMS, at least seasonally (NOAA, 2008a).

4. *Maritime Archaeological*: Monterey Bay NMS commissioned a study of the submerged maritime archaeological resources within the sanctuary, which resulted in a database of 463 shipwreck records within or adjacent to the sanctuary boundaries (Smith and Hunter, 2003). Only four marine archaeological field investigations have been conducted within Monterey Bay NMS, including the multiple field surveys to locate and then explore and characterize the site where the U.S. Navy USS *Macon*, a 785-ft (239-m) dirigible, was lost off Point Sur in 1935. In 2010, the USS *Macon* was placed on the National Register of Historic Places. No known maritime archaeological resources exist in the Davidson Seamount unit of the sanctuary.

Prohibited Activities

Activities prohibited or regulated within Monterey Bay NMS include exploring for, developing, or producing oil, gas, or minerals; collecting loose jade only in specific areas of the sanctuary; discharging or depositing any material within or into the sanctuary, except for certain specific materials; discharging or depositing any material outside the sanctuary that subsequently enters the Sanctuary and injures a sanctuary resource or quality; possessing, removing, moving, possessing, or injuring or attempting to remove, move, possess, or injure a historical resource; drilling or dredging, or altering the submerged lands of the sanctuary in any way; taking or possessing any marine mammal, sea turtle, or bird within or above the sanctuary; disturbing marine mammals or seabirds by flying motorized aircraft at less than 1,000 ft (305 m) above any of the four sanctuary zones except as part of a law enforcement action; operating motorized personal watercraft within the sanctuary except within the five designated zones and access routes within the sanctuary; deserting a vessel aground, at anchor, or adrift in the sanctuary; leaving harmful matter aboard a grounded or deserted vessel in the sanctuary; moving, removing, taking, collecting, catching, harvesting, disturbing, breaking, cutting, or otherwise injuring, or attempting to move, remove, take, collect, catch, harvest, disturb, break, cut, or otherwise injure, any sanctuary resource located more that 3,000 ft (914 m) below the sea surface within the Davidson Seamount Management Zone; introducing or releasing any species into the sanctuary except striped bass; attracting a white shark anywhere in the sanctuary; interfering in any way with enforcement activities (CFR 15 §922.132).

DoD Exemptions

Per CFR 15 §922.132(c)(1)-(2), DoD activities must be conducted in a manner that avoids, to the extent practicable, adverse impacts to sanctuary resources and qualities. The prohibited or regulated sanctuary activities do not apply to DoD activities existing when the regulations were written in 1992, or 2008 for Davidson Seamount Management Zone; new DoD activities may be exempted from prohibitions after consultation between the DoD and ONMS. Should any loss, injury, or destruction of any sanctuary resource or quality occur during the execution of a DoD activity, the DoD in coordination with ONMS must prevent or mitigate further damage and restore or replace the sanctuary resource or quality.

Channel Islands NMS

Designated in 1980, the Channel Islands NMS is characterized by a unique combination of features including complex oceanography, varied bathymetry, diverse habitats, remarkable biodiversity, rich maritime heritage, a remote yet accessible location, and relative lack of development (NOAA, 2009a). Channel Islands NMS is located 22 nmi (41 km) off the coast of Santa Barbara in Southern California. The sanctuary encompasses 1,110 nmi^2 (3,807 km^2) of ocean and coastal waters and the submerged lands beneath from mean high tide to 6 nmi (11 km) from San Miguel Island, Santa Cruz Island, Santa Rosa Island, Anacapa Island, Santa Barbara Island, Richardson Rock, and Castle Rock (the Islands) (CFR 15

§922.70). Channel Islands National Park lies within the boundaries of Channel Island NMS and consists of terrestrial and marine areas equal to 295 nmi^2 (1,012 km^2) in size that encompass Anacapa, San Miguel, Santa Barbara, Santa Cruz, and Santa Rosa Islands, their submerged lands, and the waters within 1 nmi (1.9 km) of each island (NOAA, 2009a).

Sanctuary Resources

1. *Marine Waters*: Circulation in the Channel Islands NMS is highly dynamic and complex due to the interaction of major ocean currents, mainland geography, and ocean topography. Circulation is dominated by the southerly flowing, cold California Current, which flows along the western perimeter of the Channel Islands, and mixes with the northerly flowing, warm Southern California Countercurrent. The interaction of these ocean currents causes a localized gyre (circular circulation) to form between the islands and California mainland and varies in intensity seasonally. These varying conditions result in local upwelling that fluctuates depending upon the condition (ONMS, 2009a).

   Runoff from the mainland does not reach the islands in significant amounts, which in combination with the low of development on the islands results in little local land-based nutrient inputs. While numerous contaminants have been identified in sanctuary waters, these levels appear much lower than that of mainland metropolitan areas (ONMS, 2009a).

2. *Marine Habitat*: Habitats in the sanctuary include intertidal, kelp beds/forests, sandy and hardbottom subtidal substrate, open ocean or pelagic, and deepwater benthic (>99 ft [>30 m]) environments. Hard substrate is the least common habitat type in the Channel Islands, but it is among the most important fish habitat because it supports kelp. Kelp grows on hard substrate in water depths from about 10 to 99 ft (3 to 30 m) (ONMS, 2009a) and form dense aggregations that resemble terrestrial forests that are characteristic features of Southern California nearshore marine environments (NOAA, 2009). Kelp beds are highly productive habitats and serve as important nursery habitat for juvenile fishes in the upper canopy, as well as providing food, attachment sites, and shelter for a diverse assemblage of pelagic and benthic invertebrates and other species of algae.

   Nearshore, including the intertidal zone, the benthic environment consists of a mixture of hardbottom, gravel, sand, mud, and cobbles, while the deepwater benthic environment is largely (90 percent) sandy substrate. In the sanctuary, deepwater hardbottom substrate forms low-relief reefs, typically <3.3 ft (<1 m) in height, along with undersea ridges and pinnacles, such as have formed off the northwest end of San Miguel Island (ONMS, 2009a).

3. *Living (Biota)*: Giant kelp is a keystone species of Channel Islands NMS as it forms such a productive habitat for so many other species. More than 5,000 species of invertebrates occur regionally (ONMS, 2009a). Select invertebrates in the sanctuary include species of corals, prawns, spiny lobster, crabs, sea urchins, sea cucumbers, sea stars, abalone, nudibranchs, scallops, mussels, squid, clams, barnacles, snails, salps, tunicates, jellyfish, sea slugs, worms, and anemones (NOAA, 2009). Several of these species are harvested commercially and represent significant fisheries in the Southern California Bight region.

   More than 400 species of fish have been documented in the sanctuary, representing a greater species richness than at nearby coastal regions along the Southern California mainland (ONMS, 2009a). Some of the common fish species occurring in the sanctuary, including several species listed under the ESA, are the Pacific bonito, white seabass, bocaccio, rockfishes, soles, sardines, and mackerel. Species not endemic to sanctuary waters, but occurring at least seasonally are the highly migratory fishes including albacore, skipjack, yellowfin, and bluefin tuna, swordfish, striped marlin, and sharks.

Channel Islands NMS is located on a major migratory bird route (Pacific Flyway), where migrating birds stop seasonally. The sanctuary's diverse habitats have resulted in a diverse seabird assemblage, with 19 seabird species nesting and breeding within the sanctuary, including storm petrels, brown pelicans, terns, gulls, auklets, cormorants, murrelets, and snowy plovers (NOAA, 2009; ONMS, 2009a).

Four species of sea turtles have been reported in the offshore waters of Southern California, including the green, loggerhead, olive-ridley, and leatherback turtles. However, sightings of sea turtles are rare in the waters of the Channel Islands (ONMS, 2009). At least 33 species of marine mammals have been reported in sanctuary waters, at least seasonally (NOAA, 2009). Commonly occurring cetaceans include: short-beaked and long-beaked common, bottlenose, Pacific white-sided, and Risso's dolphins as well as gray, blue, sei, and humpback whales. The sanctuary provides vital habitat for pinnipeds, including feeding areas, breeding sites, and haul outs. Six species of pinnipeds have historically occurred in the Northern Channel Islands: northern and Guadalupe fur seals, northern elephant and harbor seals, as well as Steller and California sea lions. The most common pinniped in the northern Channel Islands is the California sea lion and the least common is the Steller sea lion, which has declined throughout its range and now occurs only rarely in Southern California waters. Once plentiful in the region, the population of threatened southern sea otters in the Channel Islands is increasing (ONMS, 2009a).

4. *Maritime Archaeological*: Over 150 historic ship and aircraft wrecks, ranging from 1853 to 1980, have been reported lost in the waters of the sanctuary and Channel Islands National Park, but only 25 of the wreck sites have been located and surveyed (Channel Islands NMS [CINMS], 2011). These identified and surveyed wrecks include the passenger steamer *Cuba*, which ran aground off San Miguel Island in 1923, and the California Gold Rush passenger steamer *Winfield Scott,* which stranded in 1853 on Anacapa Island and is listed in the National Register of Historic Places (CINMS, 2011). The significant number of shipwrecks within the sanctuary can largely be attributed to prevailing currents and weather conditions, combined with natural hazards.

<u>Prohibited Activities</u>

The exploration, development, and production of hydrocarbons or minerals except by lease; discharging within or outside the sanctuary with certain exceptions; seabed drilling or dredging or alteration of the seafloor; abandonment of objects on/in the submerged lands of the sanctuary; transportation of people or goods, disturbance of wildlife by overflights; removing or possessing a historical resource of the sanctuary; taking or possessing any marine mammal, seabird, or sea turtles; introduction of any species; or operation of a personal watercraft in the coterminous waters of the Channel Island National Park are highly restricted or prohibited within the sanctuary's boundaries.

<u>DoD Exemptions</u>

Per CFR 15 §922.72(b)(1), the activity prohibitions do not apply to military activities carried out by DoD and specifically identified in the Final Management Plan (FMP) and FEIS for the Channel Islands NMS, which are considered pre-existing activities (NOAA, 2011). Other military activities carried out by DoD may be exempted after consultation between the DoD and the ONMS. A military activity carried out by DoD and specifically identified in the FMP/FEIS is not considered a pre-existing activity if:

1. It is modified in such a way that requires the preparation of a NEPA document relevant to a Sanctuary resource or quality.
2. It is modified, including but not limited to changes in location or frequency, in such a way that its possible adverse effects on sanctuary resources or qualities are significantly greater than previously considered for the unmodified activity.
3. It is modified, including but not limited to changes in location or frequency, in such a way that its possible adverse effects on sanctuary resources or qualities are significantly different in manner than previously considered for the unmodified activity.
4. There are new circumstances or information relevant to a sanctuary resource or quality that was not addressed in the FMP/FEIS.

In the event of destruction of, loss of, or injury to a sanctuary resource or quality resulting from an incident caused by a DoD activity, DoD in coordination with the ONMS must promptly prevent and mitigate further damage and must restore or replace the sanctuary resource or quality in a manner approved by the ONMS. Last, all DoD activities must be carried out in a manner that avoids, to the maximum extent practicable, any adverse impacts on sanctuary resources and qualities.

Hawaiian Islands Humpback Whale NMS

Designated in 1992, the Hawaiian Islands Humpback Whale NMS was created to protect humpback whales and their habitat in Hawaii. Encompassing 1,218 nmi^2 (3,548 km^2) of the submerged lands and waters surrounding the Main Hawaiian Islands from the shoreline to the 600-ft (183-m) isobath, the sanctuary is separated into five discrete protected area around Maui, Lanaʻi, and Molokaʻi, including Penguin Bank, as well as parts of Oʻahu, Kauaʻi and Hawaiʻi. The sanctuary encompasses waters used by an estimated half of the North Pacific population of humpback whales for calving and breeding from late fall through spring (roughly October through May (ONMS, 2010). The ONMS is currently considering a proposed expansion, name change, regulations changes, and new action plans for the Hawaiian Islands Humpback Whale NMS (NOAA, 2015c).

<u>Sanctuary Resources</u>

1. *Marine Waters*: The waters surrounding the Hawaiian Islands are seasonally variable, subject to long-period swells sweeping across both the North and South Pacific, and dominated by three current systems, the North Equatorial, North Hawaiian Ridge, and Hawaiian Lee Counter Currents (NOAA, 2015c; ONMS, 2010). Waves are largest in winter months and are generally larger on the northern island shores. Any water quality issues, such as sedimentation, high nutrient concentrations, or runoff typically only affect nearshore waters and do not affect sanctuary qualities or resources (ONMS, 2010).
2. *Marine Habitats:* The sanctuary encompasses a variety of marine habitats, including seagrass beds, coral reefs, pelagic waters, and humpback breeding/calving habitat. Non-structural coral communities and fringing coral reefs are found close to shore with deeper reefs at water depths below 200 ft (61 m). Coral and coralline algae are the principal reef-builders of Hawaiian reef systems. Coral rock and hardbottom substrate dominate the benthic environment around all the Main Hawaiian Islands except Maui, where sand and coral/hardbottom substrate is found in equal cover (NOAA, 2015c). Humpback breeding/calving habitat is not equally distributed throughout the sanctuary; the largest concentrations of humpbacks occurs in the waters between the islands of Maui, Molokaʻi, Lanaʻi, and Kahoʻolawe, as well around Penguin Bank,

which is a bank that extends ~25 nmi (46 km) southwest of west Molokaʻi. This humpback whale habitat is characterized by the vast expanse of shallow waters (<600 ft [183 m]) and somewhat protected waters (ONMS, 2010).

3. *Living (Biota):* The sanctuary's coral reefs support diverse groups of algae, coral, and fish species. The predominant corals found in shallower water reefs within the sanctuary include the endemic finger, cauliflower, rice, and lobe corals (NOAA, 2015c). Black and precious corals grow in the deeper reef environments, typically below 100 ft (30.5 m). None of the 22 coral species listed under the ESA occur in Hawaii (NMFS, 2014). In sandy benthic habitats, crabs, goby fish, bonefish, flounder, scorpion fish, sting rays, and sea cucumbers predominate (NOAA, 2015c). The pelagic environment is not only the seasonal home for humpback whales, but also for other marine mammals, pelagic fish, squid, and sea turtles.

   Although five species of ESA-listed sea turtles, the green, loggerhead, leatherback, hawksbill, and olive ridley turtles, may occur in Hawaiian waters, the green turtle is the most commonly occurring sea turtle in Hawaiian waters, with the hawksbill observed more infrequently (NOAA, 2015c). Loggerhead, leatherback, and olive ridley turtles are less common and most often observed in offshore waters. Twenty-two species of seabirds breed in the Hawaiian Islands, including albatrosses, shearwaters, petrels, storm-petrels, frigatebirds, boobies, tropicbirds, terns, and noddies (NOAA, 2015c). Two of the Hawaiian seabird species, the Hawaiian petrel and short-tailed albatross, are listed under the ESA. In addition to the humpback whale, at least 29 other marine mammal species may occur at least seasonally in Hawaiian waters, including seven species listed under the ESA. Hawaiian humpback whales are part of the Hawaii DPS, which is not listed under the ESA, as it is not at risk (NOAA, 2015b).

4. *Maritime Archaeological*: Although limited surveys to locate and identify maritime archaeological resources have been conducted in the Hawaiian Islands Humpback Whale NMS, 185 ships and aircraft, dating back to 1824, have been reported lost in sanctuary waters (ONMS, 2010). Seventy historic civilian, army, and navy aircraft were lost within the current sanctuary boundary, and 33 of the aircraft and ship wreck sites have been confirmed with some degree of field study, with another 18 having been archaeologically surveyed and assessed (NOAA, 2015c; ONMS, 2010).

Prohibited Activities

Activities prohibited or regulated in the sanctuary include approaching a humpback whale within 100 yd (91 m) by any means; operating aircraft above the sanctuary within 1,000 ft (304 m) of a humpback whale except as necessary to take off or land the aircraft; taking a humpback whale; possessing a living or dead humpback whale or its parts; discharging or depositing any materials within or outside the sanctuary that may enter the sanctuary and injure a humpback whale or its habitat; altering the seabed; and interfering in any manner with an enforcement action (CFR 15 §922.184).

DoD Exemptions

According to CFR 15 §922.183, all classes of military activities that were being or have been conducted before the effective date of the sanctuary regulations are allowed activities in the sanctuary and are not subject to further consultation under the NMSA. Military activities proposed after the effective date of the sanctuary regulations are also included as allowed activities if the DoD consults with the ONMS on the activities. If an allowable military action is modified so that it may destroy, injure, or cause the loss of a sanctuary resource significantly greater than was considered in a previous consultation, then the modified activity will be considered a new activity for which consultation is required. If a military activity subject to consultation under section 304 of the NMSA is required to respond to an emergency situation, and the DoD determines in writing that failure to conduct the activity will threaten national defense, the DoD may request that the military activity proceed during the consultation process. If the request is denied, the secretary of the pertinent military branch may decide to proceed with the execution of the military activity; in this case, the secretary of the military branch must provide the ONMS director with a written statement of any effects of the activity on sanctuary resources.

NMS of American Samoa (formerly Fagatele Bay NMS)

The NMS of American Samoa is the largest sanctuary in the NMS system and protects nearshore coral reefs and offshore open ocean waters across the Samoan Archipelago, including areas that are considered to represent the greatest biological diversity in the NMS system and some of the oldest and largest *Porites* coral heads in the world. Fagatele Bay NMS was originally designated in 1986 to protect 0.19 nmi^2 (0.66 km^2) of pristine tropical bay area formed by a collapsed volcanic crater off the southwest coast of Tutuila Island, Territory of American Samoa. The entirety of Fagatelle Bay is included and the area includes a coral reef ecosystem of exceptional productivity. In 2012, the NMS was expanded to include a network of five additional units in the Territory of American Samoa and was renamed the NMS of American Samoa (NOAA, 2012c).

In addition to Fagatele Bay, the NMS of American Samoa includes Fagalua/Fogama'a, Aunu'u (Zones A and B), Swains Island, Muliāva (Rose Atoll), and Ta'u units (CFR 15, §922.101). This expansion increased the size of the NMS to a total area of 10,246 nmi^2 (35,142 km^2), with 99 percent of the expansion resulting from the inclusion of marine areas within the Rose Atoll Marine National Monument (NOAA, 2012d). The Fagalua/Fogama'a unit encompasses 0.35 nmi^2 (1.2 km^2) of bay area from Steps Point across to Sail Rock on the southwest shore of Tutuila, just east of Fagatele Bay; the ecosystem protected in the Fagalua/Fogama'a unit is very similar to that of Fagatele Bay (NOAA, 2012d). Aunu'u is a small volcanic island southeast of Tutuila Island, and 4.4 nmi^2 (15 km^2) of reef and offshore waters around Aunu’u Island are encompassed in the sanctuary. Ta'u is an island located 61 nmi (113 km) east of Tutuila Island and 6 nmi (11 km) southeast of Olosega Island; the Ta’u unit includes about 11 nmi^2 (37.8 km^2) of nearshore and deep waters from Si’ufa’alele Point to Si’u Point (NOAA, 2012d). Swains Island is a privately owned island located about 174 nmi (322 km) northwest of Tutuila Island, with the Swains unit covering 39.5 nmi^2 (135 km^2) of territorial waters within a 3 nmi (5.6 km) circle around the island, excluding the area around two existing channels to the island (NOAA, 2012d). Last, the largest unit, Muliāva (Rose Atoll), encompasses 10,155 nmi^2 (34,830 km^2) of marine waters surrounding Rose Atoll in the Rose Atoll National Marine Monument and the submerged volcanic cone known as the Vailulu’u Seamount; the Rose Atoll National Wildlife Refuge is not included in the NMS (NOAA, 2012d).

Sanctuary Resources

1. *Marine Waters***:** Overall, the waters of the NMS of American Samoa are located on the northern edge of the South Pacific gyre, but circulation within the islands of American Samoa are dominated by the westward flowing South Equatorial Current and to a lesser extent by the South Equatorial Counter Current and eddies that form just south of the archipelago. The nearshore waters of the NMS, particularly in Fagatelle and Fagalua/Fogama'a bays, are exposed to pollution and increased turbidity from land development and runoff, which increases the nutrient concentrations in the bay waters compared to the surrounding oceanic waters (NMSP, 2007). Despite these issues, the water quality of these two NMS units is considered good

(NOAA, 2012d). The water quality of the other sanctuary units is less impacted by coastal development and most represent pristine water conditions. Periodic increases in the sea temperature cause coral bleaching and sometimes death and pose a greater risk to coral reef health than any other water quality factor. As in many other tropical areas, concern is heightened as the frequency of elevated water temperatures and subsequent bleaching events is increasing (NMSP, 2007).

2. *Marine Habitat:* A variety of habitats comprise the NMS of American Samoa, with nearshore benthic habitats including coral reefs, seagrass beds, sand, hard bottom and rubble, as well as mangrove forest habitats. Since American Samoa is an archipelago, pelagic, open ocean habitat is the principle habitat, and with the addition of the vast Muliāva (Rose Atoll) unit, pelagic and deep ocean habitats are the dominant habitat types in the sanctuary. The pelagic habitat is dynamic, heterogeneous, and actually consists of different habitats or zones determined by water depth, light penetration, and water mass properties. The seafloor of the sanctuary's vast and deep pelagic environment represents yet another habitat, one that is covered by hard and soft substrate at water depths below 655 ft (200 m). The soft sediments typically are mud or sand and are generally low in biological productivity. The sanctuary's deep ocean benthic habitat includes an unique type of benthic habitat, hydrothermal vent communities, found only rarely over the ocean's bottom. Hydrothermal vent communities are located around the hydrothermally active Vailulu'u Seamount, in the western most section of the Muliāva unit (NOAA, 2012d). In 2003, American Samoa declared all its territorial seas as a Whale and Turtle Sanctuary in which taking or harassing marine mammals and sea turtles is prohibited.

3. *Living (Biota)*: About 2,700 species have been documented in the coral reef habitats of the American Samoa's, with all but one phylum of animals represented among the coral reef inhabitants (NOAA, 2012d). The American Samoan coral reef communities are dominated by coralline algae (crustose calcareous algae), followed by live hard corals, dead corals (upon which live corals settle and grow), and to a much lesser extent, brown macroalgae. Over 250 species of corals occur in the American Samoa islands (NOAA, 2012d). Seven of the 20 coral species listed as threatened under the ESA occur in the American Samoa Islands (NMFS, 2014; Veron, 2014). As many as 890 reef fishes have been identified in American Samoa, with largely small to medium-sized herbivores dominating the fish assemblage, while large herbivorous reef fish species are uncommon to rare. Of the predatory fish species, eels, sharks, and barracudas commonly occur on the reefs. Invertebrate reef inhabitants include mollusks, crustaceans, echinoderms, sea anemones. Other notable species include an abundance of giant clams, with the highest densities of the giant clams found in Ta'u and Rose Atoll waters.

   As many as 45 pelagic and 56 deep, benthic fish species have been documented in the American Samoan Islands (NOAA, 2012d). Aunu'u's Nafanua Bank is known for its coastal pelagic fish including dog-tooth tuna, giant trevally, and rainbow runner. Sharks and schools of humphead wrasse are frequently seen in Swains' nearshore waters, and dogtooth tuna are more common here than anywhere else in American Samoa. Specialized organisms capable of growing in the extreme environment of the low-temperature hydrothermal vent communities found on the seafloor of the Vailulu'u Seamount include microbial mats, colonies of polychaete worms, and thick aggregations of cutthroat eels (Staudigel et al., 2006).

   Twenty-nine species of seabirds have been reported to occur at least seasonally in the American Samoa Islands, including shearwaters, terns, gulls, boobies, petrels, and frigatebirds (NOAA, 2012d). Hawksbill and green turtles are the most commonly occurring species of sea turtles in the waters of American Samoa, with hawksbill turtles nesting on Tutuilla Island and green turtles nesting on Rose Atoll, which is the primary site for green turtle nesting in American Samoa, where several dozen nests laid annually between October and March. Green turtles occurring in the American Samoan Islands are part of the endangered South Central Pacific DPS. Leatherback and olive ridley turtles are extremely rare to uncommon, respectively, in the waters of the NMS (NOAA, 2012d).

Little information is available on marine mammals in the waters of the NMS, but 12 species of cetaceans have been observed in American Samoan waters, at least seasonally (Dolar, 2005). These species include two mysticetes (humpbacks and common minke whales) and 10 odontocete species (sperm, dwarf sperm, false killer, short-finned pilot, and Cuvier's beaked whales and common bottlenose, spinner, pan-tropical spotted, rough-toothed dolphins (NOAA, 2012d). Humpback whales occurring in the NMS of American Samoa belong to the Oceania DPS, which is not proposed for listing under the ESA (NOAA, 2015b).

4. *Maritime Archaeological:* No systematic field surveys to identify the maritime heritage resources in American Samoa have yet been conducted over the vast area of the NMS. Maritime heritage and archaeological resources in American Samoa represent over 3,000 years of human history in the region and represent five aspects of Samoan history: archaeological sites; marine and coastal natural resources associated with American Samoan legends , folklore, and culture; historic shipwrecks; World War II naval aircraft; and, World War II fortifications, gun emplacements, and coastal pillboxes.

Ten historic shipwrecks ranging from 1828 to 1949 have been reported in America Samoan waters, with three 19th century wrecks occurring near Rose Atoll. These shipwrecks include brigs, schooners, whalers, barkentines, destroyers, steamers, and tankers, and represent British colonization, whaling, and World War II (NOAA, 2012d). As many as 43 World War II military aircraft were reported to have crashed in the waters of America Samoa, although none have yet been discovered. As many as 81 World War II-era coastal fortifications, pillboxes, and gun emplacements are located in the American Samoa Islands (NOAA, 2012d). Coastal petroglyphs, ruins of coastal villages, and other artifacts of Samoan cultural heritage have been reported, some only poorly documented. Twenty coastal sites represent stories and legends in American Samoa as well as several historical sites that are listed on the National Register of Historic Places (NOAA, 2012d).

Prohibited Activities

Prohibited or regulated activities in sanctuary waters include introducing/releasing species; anchoring or abandoning a vessel or structure; boat operating restrictions; diving restrictions; discharging in or beyond sanctuary boundaries; dredging, mining, or altering the seafloor; taking marine mammals, seabirds, sea turtles, giant clams, or corals (or live rock); using or discharging explosives or weapons; fishing with certain gear, explosives, or electrical charges; and defacing or removing any sanctuary signs or markers (CFR 15 §922.103-105). Additional unit-specific prohibitions apply.

DoD Exemptions

Per CFR 15 §922.103, the prohibited activities do not apply to any activity necessary for national defense.

Gerry E. Studds-Stellwagen Bank NMS

Stellwagen Bank NMS was designated for a multitude of reasons, including its long history of human use and high productivity (NOAA, 2010). The bank causes localized upwelling of nutrient-rich water from the Gulf of Maine, leading to high primary and secondary productivity. The area is an important feeding ground for man species, including the endangered humpback, northern right, sei, and fin whales, as well as bluefin tuna and sharks. Whale-watching in sanctuary waters, attracted by the large whales feeding in the area, has become an important industry in eastern Massachusetts. In addition, the area is heavily used for commercial and recreational fishing, shipping, and sewage and materials disposal (NOAA, 2010). Designated in 1992, Stellwagen Bank NMS is located at the mouth of Massachusetts Bay in the northwestern Atlantic Ocean, 22 nmi (40 km) east of Boston, between Cape Cod and Cape Ann, MA in waters that are about 89 ft (27 m) in depth. Stellwagen NMS covers an area of 638 nmi^2 (2,188 km^2), including state and Federal waters and the submerged lands of Stellwagen Bank, Tillies Bank, and portions of Jeffrey's Ledge (CFR 15 §922.140).

Sanctuary Resources

1. *Marine Waters*: The oceanic waters of the sanctuary are nutrient-rich as a result of the dynamic circulation and topography of the area. Circulation is influenced by diurnal tidal fluctuations, wind-driven coastal currents, freshwater input from nearby rivers, and the proximity to the counterclockwise circulation of the Gulf of Maine (ONMS, 2006). This combination of water movements causes upwelling of nutrient-rich bottom waters onto the sanctuary's banks. This concentration of nutrients along with increased sunlight in the spring and summer result in high levels of primary production, or plankton, seasonally. The level of primary productivity (plankton concentrations) is three times that of the surrounding Gulf of Maine and twice as high as that found on Georges Bank (NOAA, 2010).

2. *Marine Habitat*: Both the seasonally productive, marine pelagic habitat and a complex system of benthic habitats are found within Stellwagen NMS. Benthic (seafloor) habitats include rocky outcrops (<1 percent cover), piled boulders and gravel (38 percent cover), sand (34 percent cover), and mud (28 percent cover) substrates (Valentine et al., 2001). Seafloor habitats exist both within and on top of the substrate covering the sanctuary's ocean bottom.

3. *Living (Biota)*: Stellwagen Bank NMS is an important area of high biodiversity, with over 575 marine species having been reported in sanctuary waters (NOAA, 2010). Rich benthic communities of sea anemones, sponges, hydroids, and worms cover the sanctuary's seafloor and provide a source of both food and shelter for benthic and pelagic species. Every taxonomic group of marine invertebrates occurs in Stellwagen Bank NMS (ONMS, 2006). The pelagic waters and seafloor habitats of the sanctuary support more than 80 species of demersal (benthic) and pelagic fishes, with economically important fish species such as cod, haddock, hake, and herring being seasonally abundant. Twenty-two species of marine mammals, including the endangered North Atlantic right, humpback, and fin whales, at least seasonally utilize the sanctuary waters for foraging and as nursery habitat (NOAA, 2010; ONMS, 2006). The waters of the sanctuary also support foraging for 53 species of seabirds, particularly gulls, storm petrels, gannets, auks, sea ducks, and shearwaters as well as two sea turtle species, the leatherback and Kemp's ridley turtles, seasonally occur in the waters of Stellwagen Bank NMS; typically only juvenile Kemp's ridley turtles occur in sanctuary waters (NOAA, 2010; ONMS, 2006).

4. *Maritime Archaeological*: Thus far, the only archaeological resources identified in Stellwagen Bank NMS are numerous shipwrecks located on the seafloor. These shipwrecks represent not only historical shipwrecks but also the 400 years of maritime commerce that traversed the waters of the sanctuary, with wrecks of fishing and merchant vessels lodged on the seafloor. Since active surveys of the seafloor began in 2000 to locate and identify the archaeological resources off Stellwagen Bank NMS, 40 shipwrecks have been identified, 35 of which are historic shipwrecks (NOAA, 2010). Four of the historical shipwrecks, most notably the steamer *Portland*, are listed on the National Register of Historic Places (ONMS, 2006).

<u>Prohibited Activities</u>

Prohibited or regulated activities within Stellwagen Bank NMS include discharges within or beyond sanctuary boundaries; exploring, developing, or producing industrial materials; drilling, dredging, or altering the seafloor, including anchoring and installing navigation aids; disturbing or possessing historical resources; taking or possessing any marine mammal, seabird, or sea turtle; lightering; and interference with an enforcement action (CFR 15 §922.142).

<u>DoD Exemptions</u>

Stellwagen Bank NMS's management plan does not prohibit any DoD activity necessary for national defense in an emergency (NOAA, 2010). Per CFR 15 §922.142(c)(2), all DoD military activities are exempt from the prohibited list of sanctuary activities after consultation with ONMS, but DoD activities must be conducted in a manner that avoids, to the extent practicable, adverse impacts to sanctuary resources. If during the conduct of a DoD activity, a sanctuary resource or its quality is affected, the DoD agency must coordinate with the ONMS to respond to, mitigate, and restore the sanctuary resource and its quality.

Monitor NMS

The *Monitor* NMS, designated as the first NMS in January 1975, was established to preserve and protect one of the most famous shipwrecks in U.S. history, the Civil War-era United States Ship (U.S.S.) *Monitor*. The U.S.S. *Monitor* was the Navy's first ironclad turreted warship and is listed on the National Register of Historic Places as a resource of national significance. The Monitor NMS is located 16.1 nmi (29.8 km) south-southeast of Cape Hatteras, NC in northwestern Atlantic Ocean waters that average 230 ft (70 m) in depth (NOAA, 2013). The sanctuary includes the remains of the U.S.S. *Monitor* wreck as well as the vertical water column of the Atlantic Ocean one mile in diameter extending from the surface to the seabed that is centered at 35°00'23"N and 75°24'32"W (CFR 15 §922.60).

<u>Sanctuary Resources</u>

1. *Marine Waters*: The waters of the *Monitor* NMS are well-mixed, as the sanctuary lies on the western boundary of the Gulf Stream Current, and exhibit no seasonal eutrophication. The Gulf Stream Current not only dominates the circulation in waters of the sanctuary but also the chlorophyll concentration and associated level of primary production. Current velocity in the sanctuary waters ranges from 0.2 to 1.5 kt (0.04 to 2.8 kph) (National Marine Sanctuary Program [NMSP], 2008). The *Monitor* NMS lies near the oceanographic boundary where the tropical warm, northward flowing waters of the Gulf Stream Current meet the temperate cold, southward flowing "shelfbreak jet". Intrusions of cold waters from the north can alter the temperature of the water column of the sanctuary dramatically (NOAA, 2013).
2. *Marine Habitat*: The wreck of the *Monitor* lies on the continental slope, which is covered by sand and mud substrate with some hard rock outcroppings (NMSP, 2008). In addition to these benthic habitats, artificial hard substrate is provided by the wreck and its associated scattered

artifacts. The wreck of the *Monitor* functions as an artificial reef habitat, attracting benthic fishes and invertebrates that otherwise may not be found in the area (NOAA, 2013). The water column of the sanctuary provides pelagic habitat.

3. *Living (Biota)*: Although no key species have been identified in the sanctuary (NMSP, 2008), many marine species occur in the sanctuaries waters at least seasonally. The most abundant taxa occurring seasonally in sanctuary waters are the more than 25 species of sub-tropical and temperate fish species, including greater amberjack, black seabass, bank seabass, scup and grouper (NMSP, 2008; NOAA, 2013). Other seasonal migrants through the sanctuary include cetaceans, sharks, and rays. The artificial reef habitat created by the *Monitor* wreck provides overwinter habitat for the loggerhead turtle. Finally, numerous encrusting and mobile invertebrate species occur in the sanctuary, including crabs, brittle stars, sea urchins, snapping shrimp, spiny lobsters, corals (whip and tree), sea anemones, barnacles, oysters, and at least 40 species of sponges (NMSP, 2008).
4. *Maritime Archaeological*: Maritime archaeological resources are the reason the *Monitor* NMS was established, to protect and preserve the remains of the U.S.S. *Monito*r. The maritime historical and archaeological resources of the *Monitor* NMS include the *Monitor* wreck, artifacts, and archaeological information from the wreck site, the archaeological collection, and the *Monitor*'s records.

<u>Prohibited Activities</u>

Commercial fishing and trawling, anchoring, discharging waste material into the water, seabed drilling, seabed cable-laying, detonation of explosive material, dredging, are highly restricted or prohibited within the sanctuary's boundaries.

<u>DoD Exemptions</u>

DoD activities are not exempt within the bounds of the Monitor NMS (CFR 15 §922.62).

<u>*Monitor* NMS Expansion</u>

NOAA has proposed expanding the boundaries of the *Monitor* NMS to include additional submerged maritime cultural and archaeologic resources (NOAA, 2013; NOAA, 2016c). The proposed expansion would protect a nationally significant collection of shipwrecks that currently have little or no legal protection as well as other potential maritime heritage resources that are located or believed to be located in the adjacent waters of North Carolina in an area known as the "Graveyard of the Atlantic". Four expansion models are being considered: Model 1, which would only encompass individual shipwrecks of historic significance; Model 2 that would encompass an additional small area off the coast of North Carolina that includes at least 65 shipwrecks in Federal waters, adjacent waters, and culturally significant features in the landscape, such as Diamond Shoals; Model 3 encompasses a larger area off North Carolina's coast that would include 75 Federal shipwrecks and possibly as many as 175 shipwrecks in state waters; and Model 4, which includes three specific areas that together encompass a representative collection of the shipwrecks in Federal and state waters and include the wrecks of primary historical significance (NOAA, 2013; NOAA, 2016c).

Gray's Reef NMS

Gray's Reef is the largest nearshore sandstone reef in southeastern U.S. waters, rising above the surrounding sandy bottom of the nearly flat continental shelf. The reef is formed not by coral but by the consolidation and cementing of marine and terrestrial sediments, which resulted in a carbonate-cemented sandstone rock formation that is the base of the reef structure. The sanctuary was designated to protect the vibrant live-bottom communities of Gray's Reef. "Live bottom" is a term that refers to hard or rocky seafloor substrate upon which large numbers of invertebrates are established such as sponges, corals (non-reef building), and sea squirts, which require a hard substrate upon which to attach and grow. Designated in 1981, Gray's Reef NMS is located about 17.5 nmi (32 km) off the coast of Sapelo, GA in water as deep as 70 ft (21 m). Gray's Reef NMS consists of approximately 16.7 nmi^2 (57 km^2) of ocean waters and the submerged lands that lie beneath (CFR 15 §922.90).

Sanctuary Resources

1. *Marine Waters*: Gray's Reef NMS lies on the continental shelf in seasonally variable waters that are influenced by the Gulf Stream Current, which transports deep, nutrient-rich waters into the region along with tropical species. The influx of nutrient filled waters results in increased primary production of sanctuary waters. The water quality of the sanctuary is considered good with no pollution issues from runoff of the nearby developed coastline, and no eutrophication is known to occur (NOAA, 2012e).

2. *Marine Habitat:* The seafloor of Gray's Reef NMS is covered with scattered rock outcroppings that rise about 4 to 6 ft (1 to 2 m) above the surrounding flat, sandy areas. These rock ledges and sand expanses have produced a complex habitat of caves, burrows, troughs, and overhangs that provide a hard base for a variety of live-bottom invertebrates that live their lives permanently attached to rock. While Gray's Reef NMS is noted for its live-bottom communities, sand substrate actually comprises 75 percent of the benthic habitat of the sanctuary (NOAA, 2014b). Additionally, the sanctuary's pelagic waters represent an additional available habitat for pelagic animals such as sea turtles, pelagic fishes, or cetaceans.

3. *Living (Biota)*: Algae and invertebrates grow and live on the exposed rock surfaces of sanctuary's seafloor with the most common invertebrates including sponges, tunicates (sea squirts), barnacles, sea fans, bryozoans, non-reef-building hard corals, sea stars, crabs, lobsters, snails, shrimp, and hard-tubed worms. These animals form a dense living carpet that in places completely covers the rock substrate. The sandy bottom sediments support a highly diverse and abundant community of organisms that live in and on the soft substrate and consist primarily of annelid, sedentary worms; mollusks (clams and snails); arthropods (mostly crustaceans like small shrimp); echinoderms (sea stars, sand dollars and sea cucumbers); and other invertebrate species (NOAA, 2014b).

   The reef attracts more than 200 species of benthic and pelagic fishes, including black sea bass, red snapper, and grouper (NOAA, 2014b). Coastal pelagic fish species, including the king and Spanish mackerel, great barracuda, and cobia are attracted to the reef environment, likely by the large abundance of schooling prey fish, such as round scad and Spanish sardine (NOAA, 2014b). The sandy habitats of the sanctuary support a number of benthic fish species including flounders, tonguefishes, cusk eels, stargazers, and lizardfishes.

   Sea turtles, marine mammals, and pelagic birds also occur in sanctuary waters. Although Kemp's ridley, hawksbill, leatherback, green, and loggerhead turtles all occur in the region, it is only juvenile and adult loggerhead turtles that are documented to occur in Gray's Reef NMS, using the waters of the sanctuary to rest and forage throughout the year and nest on nearby Georgia beaches in the summer (NOAA, 2008c). Likewise, numerous marine mammal species may potentially occur, at least seasonally, in Georgia waters, but the most commonly occurring cetacean species in waters of Gray's Reef NMS are common bottlenose and Atlantic spotted dolphins and the North Atlantic right whale (NOAA, 2008c and 2014b). North Atlantic right whales have been observed in sanctuary waters during the winter migration and calving season (NOAA, 2014). The calving grounds for the endangered North Atlantic right whale, which extend from the waters of northeastern Florida, through Georgia, and northward into South Carolina, have been designated as critical habitat. The northern and southern critical habitat units for the North Atlantic right whale were expanded in 2016 (NOAA, 2016d). Gray's Reef NMS is now encompassed within the southeastern critical habitat for the North Atlantic right whale. Although as many as 30 species of seabirds occur in the region, only seven of those species (gulls, petrels, shearwaters, northern gannet, phalaropes, jaegers, and terns) have been observed in sanctuary waters (NOAA, 2014).

4. *Maritime Archaeological:* No known maritime archaeological resources are contained in Gray's Reef NMS, as no wrecks of ships or aircrafts have been documented (NOAA, 2012d).

Prohibited Activities

Prohibited or regulated activities within Gray's Reef NMS include construction; drilling, dredging, or altering submerged lands; discharging; operating watercraft except by Federal rules/regulations; injuring, harvesting, or collecting any organisms or bottom formations, living or dead, except by rod and reel; fishing restricted to using specific gear (rod and reel); using underwater explosives or electrical charges; disturbing or possessing historical resources; anchoring; and possession of fishing gear other than rod and reel (CFR 15 §922.92).

DoD Exemptions

Per CFR 15 §922.92(b), all activities currently carried out by the DoD within the sanctuary are essential for the national defense and, therefore, not subject to activity prohibitions. If a DoD activity would result in significant impacts to any sanctuary resource, consultation between the ONMS and DoD would be required.

Florida Keys NMS

The Florida Keys NMS encompasses the world's third largest barrier reef and additionally protects historical shipwrecks and other archaeological treasures of the Florida Strait, between the northwestern Atlantic Ocean and northeastern Gulf of Mexico. The sanctuary includes the most diverse assemblage of underwater plants and animals in North America. Designated in 1990, the Sanctuary consists of an area of 2,857 nmi^2 (9,800 km^2) of coastal and ocean waters and the submerged lands surrounding the Florida Keys, Florida, from south of Miami westward to encompass the Dry Tortugas, excluding Dry Tortugas National Park (CFR 15 §922.161), with the shoreward boundary as the mean high-water mark and the seaward boundary ranging from the 300-ft (91-m) to the 60-ft (18-m) isobaths. The sanctuary includes a separate, non-contiguous, 60 nmi^2 (206 km^2) area, the Tortugas Ecological Reserve South, which is located west of the main Florida Keys NMS. The sanctuary is located ~220 nmi (407 km) southwest from the southern tip of the Florida peninsula and is bordered by three national parks: Everglades, Biscayne, and Dry Tortugas National Parks, and overlaps additional Federal national wildlife refuges and state aquatic preserves. About 60 percent of Florida Keys NMS is located in Federal waters with the remaining 40 percent of the sanctuary located in state waters (ONMS, 2011). Florida Keys NMS established the nation's first comprehensive network of marine zones in 1997: special use areas, ecological preserves, sanctuary preservation areas, wildlife management areas, existing management areas (NOAA, 2007).

Sanctuary Resources

1. *Marine Waters*: The sanctuary is dominated by the Loop Current to the western part of the sanctuary, which transforms into the Florida Current as it sweeps through the Florida Strait to the Atlantic Ocean. Eddies form along the perimeter of the Florida Keys and current boundary. Upwelling occurs along the outer reef tract. Tidal fluctuations also add to the movement of waters through the sanctuary. These circulation factors lead to high fluctuations in sea temperature and salinity (ONMS, 2011). Water quality, particularly nutrient concentrations, varies geographically within sanctuary waters and between surface and bottom waters (higher concentrations in surface waters) (NOAA, 2007). Eutrophication (an outcome of excess nutrients in the water, such as fertilizers) has been documented in nearshore waters (NOAA, 2007).

2. *Marine Habitat*: In addition to the extensive coral reef tract, fringing mangroves, seagrass beds, hard bottom, patch and bank reefs occur in the Florida Keys NMS (ONMS, 2011). Nearshore waters of the sanctuary are well flushed, sandy shoals that are dominated by seagrass beds and patch reefs. The Florida Keys coral reef tract is series of semi-continuous offshore bank reefs, which extend in a southwesterly direction for 191 nmi (354 km) from the southern tip of Florida, and all but the northern part of the coral reef tract are included within the sanctuary (ONMS, 2011). The relatively shallow pelagic waters of the sanctuary also support additional habitats.

3. *Living (Biota)*: The sanctuary waters are a transition area between sub-tropical and tropical species of the Atlantic Ocean and warm temperate species of the Gulf. More than 6,000 marine species have been documented in the Florida Keys NMS, with more than 520 fish, 367 algae, 117 sponge, 55 soft coral, 65 hard coral, 128 echinoderm, and 89 polychaete worm species (NOAA, 2007). Seven species of ESA threatened coral species occur in the Florida Keys NMS: Elkhorn, staghorn, lobed star, boulder star, mountainous star, pillar, and rough cactus corals (Brainard et al., 2011; NMFS, 2015). Spiny lobsters are one of the most economically exploited species in the sanctuary waters. In addition to numerous reef species, fishes include highly migratory species such as tuna, swordfish, billfishes, and large coastal sharks (NOAA, 2000).

   Seabirds found in the sanctuary include terns, plovers, gulls, cormorants, pelicans, herons, and frigatebirds. The Florida Keys NMS represents an important migratory stop-over for birds migrating between North and South America. Five sea turtle species occur within the sanctuary, with leatherback, green, and loggerhead turtles nesting along the shore of the sanctuary (ONMS, 2011), and the largest green and loggerhead nesting beaches occurring in the Dry Tortugas (NOAA, 2000). Twenty-one species of marine mammals, including the West Indies manatee, may occur within sanctuary waters, with coastal bottlenose, Atlantic spotted, pantropical spotted, and Risso's dolphins occurring most commonly (NOAA, 2000; ONMS, 2011).

4. *Maritime Archaeological*: The sanctuary's maritime archaeological resources represent resources from over 500 years of American history, from the European Colonial to the Modern historical periods and include hundreds of documented shipwreck sites and artifacts, cultural remains of early peoples and historical activities, railroad remnants, and historical offshore structures (ONMS, 2011). As many as 2,000 shipwrecks have been estimated to have sunk in the Florida Keys, 14 of which have been listed in the National Register of Historic Places. Maritime heritage resources also include remnants of navigational aids that were placed along the Florida Keys' reefs in the 19th century.

Prohibited Activities

Prohibited or regulated activities within Florida Keys NMS include exploring, developing, or producing minerals or hydrocarbons; removing, injuring, or possessing coral or live rock; drilling, dredging, or altering the seafloor, including anchoring and installing navigation aids; discharges any materials within or beyond sanctuary boundaries; operating vessels to strike or injure sanctuary biota; diving without a dive flag; releasing exotic species; disturbing or possessing historical resources; damaging or removing sanctuary markers; taking or possessing any protected wildlife; possessing or using explosives or electrical charges; and interference with an enforcement action.

DoD Exemptions

Per CFR 15 §922.163(d)(1)-(2), all DoD and military activities must be conducted so that adverse impacts on sanctuary resources and qualities are affected to the least extent practicable. The prohibitions do not apply to military activities that existed when sanctuary regulations were established, and any new military activities may be permitted only after consultation between the DoD and the ONMS (If a military activity is modified so that it may impact sanctuary resources significantly, the activity is considered a new military activity that requires consultation. If a DoD activity threatens, destroys, or injures a sanctuary resource or quality incidental to the conduct of the activity, the DoD agency must coordinate with the ONMS to mitigate, respond, restore, or replace sanctuary resources.

Flower Garden Banks NMS

The Flower Garden Banks NMS provides protection to coral reef ecosystems, which are some of the healthiest coral communities in the Western Atlantic Ocean, and deepwater hardbottom communities. The coral reefs within Flower Garden Banks NMS represent the northern most coral reefs in the continental U.S. These reefs, located in the northern Gulf of Mexico, have grown atop salt dome features that rise to within 53 ft (16 m) of the sea surface. Flower Garden Bank NMS includes three separate ocean areas that cover and surround East and West Flower Garden Banks and Stetson Bank as well as the submerged lands under the banks (CFR 15 §922.120). The East and West Flower Garden Banks are located about 11 nmi (21 km) apart, while Stetson Bank lies about 26 nmi (48 km) northwest of West Flower Garden Bank. The open ocean waters between the banks range in depth from 200 to 500 ft (61 to 152 m). The area designated as the East Bank is located about 120 nmi south-southwest of Cameron, LA, and encompasses an area of 19.2 nmi^2 (65.9 km^2), while the West Bank is located ~110 nmi (204 km) southeast of Galveston, TX, and encompasses 22.5 nmi^2 (77.2 km^2), and finally, Stetson Bank lies nearly 70 nmi (130 km) southeast of Galveston, TX, and encompasses 0.64 nmi^2 (2.2 km^2) of area (CFR 15 §922.120). Coral reefs cap the East and West Flower Garden Banks but the environmental conditions at Stetson Bank do not support hard coral (reef-building) growth (NOAA, 2012f).

Sanctuary Resources

1. *Marine Waters*: Surface circulation in the NMS area is due to the northeasterly flowing shelf currents that sweep north along the continental shelf of Texas and over the Flower Garden Bank NMS. Freshwater input from the Mississippi, Atchafalaya, Brazos and other Texas rivers generally moves westward into the Gulf and mixes with the nearshore easterly flowing wind-driven waters. During times of heavy freshwater input, freshwater intrusions can extend as far south as the NMS waters, bringing select pollutants to the bank region (NOAA, 2012f and g). No eutrophication exists in the NMS waters (ONMS, 2008b).
2. *Marine Habitat:* Coral reef, coral communities (non-reef building corals), coralline algae, deepwater coral, soft-bottom, and pelagic habitats have been documented in Flower Garden

Bank NMS (ONMS, 2008b). About 0.4 to 0.8 nmi^2 (1.4 to 2.7 km^2), or <2 percent, of coral reef habitat exists on both East and West Flower Garden Banks, with about 50 percent coral cover above 100 ft (30 m) and up to 70 percent coral cover to water depths of 130 ft (39 m) (NOAA, 2012g; ONMS, 2008b). The amount of coral community habitat is much less, representing only 0.015 nmi^2 (0.05 km^2) or 0.03 percent of the sanctuary area, while deepwater coral habitat represents 8.5 percent of the sanctuary's area (ONMS, 2008b). Deepwater habitat (<120 ft [<37 m]) overall encompasses up to 98 percent of the area within sanctuary boundaries and includes mud flats and volcanoes, highly eroded rock outcroppings, and one brine seep (NOAA, 2012f). Coralline algae habitats are much more extensive, covering about 22.9 percent of the sanctuary's area, but the largest habitat in areal extent is soft-bottom (sand) habitat that covers 66.7 percent of the sanctuary's areas or about 28 nmi^2 (97 km^2) (ONMS, 2008b).

3. *Living (Biota):* Although at least 21 species of corals have been observed on the Flower Garden Banks, the bank's coral reefs are dominated by star and brain corals. Four threatened species of coral, including elkhorn coral, are found in Flower Garden Banks NMS (NMFS, 2015). Coral communities on Stetson Bank are principally algae-sponge assemblages while the deepwater coral habitat at Flower Garden Banks are populated by non-reef building, solitary hard corals, gorgonian corals, reef fishes, sponges, bryzoans, and crinoids (ONMS, 2008b). The coralline algae habitat in Flower Garden Banks NMS includes encrusting coralline algae, sponges, black coral, gorgonians, and deep-reef fishes (ONMS, 2008b). The soft-bottom communities include squat lobsters, stalked anemones, echinoderms, and reef-associated fishes. Nine species of coral (non-reef building) are found on Stetson Bank, with fire corals and sponges covering the pinnacles (NOAA, 2012f).

   At least 280 species of reef, benthic, and pelagic fishes, including 20 species of sharks and rays, have been documented in sanctuary waters (NOAA, 2012f; ONMS, 2008b). Some fish species, such as mackerel, only occur in the area seasonally. Loggerhead and hawksbill turtles have been observed in sanctuary waters around the banks throughout the year, while the leatherback turtle has only been rarely observed (NOAA, 2012f; ONMS, 2008b). Loggerhead and hawksbill turtles use the sanctuary waters for resting and foraging. Although the waters of Flower Garden Banks NMS are within the distributional range of many of the Gulf of Mexico's marine mammal species, marine mammals are only rarely observed in sanctuary waters, with infrequent sightings of Atlantic spotted and common bottlenose dolphins as well as one unidentified beaked whale (NOAA, 2012f).

4. *Maritime Archaeological:* No submerged archaeological resources have been discovered to date (ONMS, 2008).

<u>Prohibited Activities</u>

Prohibited or regulated activities within Flower Garden Banks NMS include exploring, developing, or producing minerals or hydrocarbons except outside of no-activity zones; anchoring (vessels <100 ft in size may moor); discharges any materials within or into the sanctuary; drilling, dredging, or altering the seafloor or constructing, placing, or abandoning any structure, material, or other matter on the seafloor of the sanctuary; removing, injuring, or possessing coral, live rock, or any coral reef organisms within the sanctuary; taking any marine mammal or sea turtle; killing, injuring, disturbing, touching, or attracting rays or whales; Injuring, catching, harvesting, collecting, feeding, or attempting to do any of these action on any fish within the sanctuary by use of any gear except rod and reel; and use of explosives or electrical charges.

DoD Exemptions

The activity prohibitions do not apply to activities carried out by DoD agencies in sanctuary waters as of 1994. Any DoD activities must be conducted to minimize adverse impacts to sanctuary resources and qualities. The activity prohibitions are not relevant to new DoD activities that have no potential for significant adverse impacts on sanctuary resources or qualities after consultation between the DoD and ONMS is conducted. Should loss, destruction, or injury occur to a sanctuary resource during execution of a DoD action, the DoD will take action in consultation with the ONMS to mitigate, restore, or replace the sanctuary resource or quality (CFR 15 §922.122(e)(1)).

Flower Garden Bank NMS Expansion

NOAA is proposing to incorporate 15 additional nationally significant reefs and banks in the north central Gulf of Mexico to Flower Garden Banks NMS. The locations of the proposed banks range from 61 to 104 nmi (113 to 193 km) from shore and are encompass about 289 nmi^2 (992 km^2) of reefs and bottom features that provide habitat for fish and other biological resources in the northern Gulf of Mexico. NOAA is also proposing to extend the existing protections of Flower Garden Banks NMS to these additional areas to limit the impact of bottom-disturbing activities on their sensitive biological resources and geological features.

3.3.5.4 Essential Fish Habitat

In recognition of the critical importance that habitat plays to all lifestages of fish and invertebrate species, the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), as amended, protects habitat essential to the production of federally managed marine and anadromous species within the U.S. EEZ. The MSFCMA, reauthorized and amended by the Sustainable Fisheries Act, called for the identification and protection essential fish habitat (EFH). Under the MSFCMA, the NMFS has exclusive federal management authority over U.S. domestic fisheries resources and oversees the nine regional fishery management councils (FMCs) and approves all Fishery Management Plans (FMPs). The 1996 EFH mandate and 2002 Final EFH Rule require that regional FMCs, through federal FMPs, describe and identify EFH for each federally managed species, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitats. The NMFS' Highly Migratory Species (HMS) Division functions as a FMC (Secretarial FMC) to oversee EFH designation and FMP preparation for Atlantic highly migratory species, such as sharks and tuna, since the habitat essential to these species may cross FMC and federal jurisdictional boundaries (NMFS, 2009a).

Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" and the term "fish" as "finfish, mollusks, crustaceans, and all other forms of marine animals and plant life other than marine mammals and birds" (16 U.S.C. §1802[10]). The regulations for implementing EFH clarify that "waters" include all aquatic areas and their biological, chemical, and physical properties, while "substrate" includes the sediment, hard bottom, structures underlying the waters, and associated biological communities that make these areas suitable fish habitats (NOAA, 2002). Habitats used at any time during a species' life cycle (i.e., during at least one of its lifestages) must be accounted for when describing and identifying EFH, including inshore bays and estuaries (NOAA, 2002). Habitat areas of particular concern (HAPC) are subsets of EFH areas that are designated to indicate an areas' rarity, susceptibility to anthropogenic-induced degradation, special ecological importance, or location in an environmentally stressed region. HAPC do not confer additional protection or restriction but are intended to prioritize conservation efforts.

The MSFCMA requires federal agencies that fund, permit, or carry out activities that may adversely affect EFH to consult with the NMFS regarding the potential impacts of the federal actions on EFH and respond in writing to the NMFS or FMC recommendations. NMFS' conservation recommendations are non-binding (NMFS, 2002). Adverse effects are defined as "any impact that reduces quality and/or quantity of EFH"; adverse effects include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH (50 CFR §600). Adverse effects to EFH may result from actions occurring within or outside of the areal extent of the designated EFH and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of federal actions. NMFS (2002) describes the process by which federal agencies can integrate MSFCMA EFH consultations with ESA Section 7 consultations.

Nine FMCs, including the HMS Division of NMFS, are responsible for designating EFH and HAPC in all U.S. territorial waters for hundreds of marine and anadromous fish and invertebrate species (Table 3-8). The types of general habitat that have been designated as EFH in U.S. territorial waters include:

- **Benthic Habitat:** These seafloor habitats may be designated for specific substrate types (e.g., rocks, gravel, sand, clay, mud, silt, shell fragments, and hard bottom). These habitats are utilized by a variety species for spawning/nesting, development, dispersal, and feeding (SAFMC, 1998).
- **Structured Habitats:** Areas that provide shelter for a variety of species and include:
  - Artificial Reef: Human-made structures made of various types of materials and used primarily by adult fishes, especially spawning adults (SAFMC, 1998).
  - Biogenic Habitat: Created by living organisms such as sponges, mussels, hydroids, amphipod tubes, hydroids, red algae, bryozoans, vermeteid and coral reefs, all of which are home to many reef fishes and invertebrates.
- **Pelagic *Sargassum*:** Mats of the pelagic species of the brown algae, *Sargassum,* that are found on the surface of open ocean areas of the North Atlantic Ocean and play a unique role by providing shelter, food source, and a prey aggregating site for numerous fishes, especially the larval lifestage.
- **Marine Waters:** All seawater from the surface of the ocean to the seafloor (i.e., water column) but not including the ocean bottom. Depending upon the species, the designated habitat may refer only to a specific part of the water column, such as surface or bottom waters, to specific water depths in the water column, such as waters from 100 to 1,000 m, or to the entire water column. This habitat may also specify the part of the continental margin over which the marine waters are located, such as continental shelf waters, or to the marine ecological zone of the ocean, such as pelagic waters. This habitat is important for a wide variety of species and lifestages.
  - Surge Zone: This high energy shoreline area is the region of the littoral zone where waves break onto the shore or beach.
- **Surface Water Currents:** Currents such as the Gulf Stream, which is the dominant surface circulation feature in the U.S. Atlantic EEZ waters, is a key dispersal mechanism for larvae of many species of fishes and crustaceans.

- **Topographic Features:** These seafloor habitat areas have high vertical (bathymetric) relief and include seamounts, hard rock banks, escarpments, submarine canyons, deep slope terraces, and the continental or insular shelf break.
- **Estuarine Areas:** Inshore aquatic areas where saltwater and freshwater mix typify estuarine (e.g., bay, river, lagoon) habitats. Specific estuarine habitats, such as salt marshes or beds of submerged aquatic vegetation, may be designated. These types of EFH are very important early developmental habitats for many commercially valuable species that may spend their later juvenile and adult lifestages in marine waters
- **Vegetated Beds:** Inshore and nearshore beds or communities of algae (e.g., kelp beds), mangroves, or aquatic vegetation (seagrasses). These densely vegetated habitats are sources of shelter and food for many fish and invertebrate species.
- **Marine Protected Areas (MPAs):** Specific waters within the U.S. EEZ where fishing is prohibited or only allowed by special permit. Waters landward of the 299-ft (91-m) isobath surrounding Howland, Baker, and Jarvis Islands, Rose Atoll, and Kingman Reef and in a box designated by four corner geographic coordinates around French Frigate Shoals have been designated as no-take (no fishing) MPAs while waters from shore to the 299-ft (91-m) isobath surrounding Palmyra and Johnson Atolls and Wake Island are low-use MPAs, where fishing is only allowed by special permit (WPRFMC, 2006).

Since SURTASS LFA sonar routinely operates at a minimum distance of at least 12 nmi (22 km) from shore, the inshore and nearshore types of EFH, such as estuarine areas, vegetated beds, surge zones, structured habitat, and marine protected areas, would not occur in potential SURTASS LFA operational areas within the waters of the U.S. EEZ (Table 3-7). Thus, the amount of EFH designated in potential operating areas is somewhat reduced (Table 3-7). Although EFH is designated for adult lifestages in potential U.S. operating areas, EFH for early developmental stages (i.e., eggs and larvae or equivalent lifestages) dominates much of the oceanic areas in which SURTASS LFA will potentially operate, particularly in U.S. tropical waters.

3.3.5.5 Offshore Biologically Important Areas (OBIAs)

Under the MMPA, NMFS regulations under section 101(a)(5)(A) for incidental take authorization must set forth the permissible methods of taking and of other means of effecting the least practicable adverse impact on marine mammal species or stocks and their habitat, paying particular attention to rookeries, mating grounds, and areas of similar significance, and on the availability of the species or stock for subsistence uses. Practicability assessments for military readiness activities include a consideration of personnel safety, the practicality of implementation of any mitigation, and the impact on the effectiveness of the subject military readiness activity, and the requirements pertaining to the monitoring and reporting of such taking. These regulations must provide a determination that the operation of SURTASS LFA sonar would have no more than a negligible impact on the affected marine mammal stocks or habitats and would not have an unmitigable adverse impact on subsistence uses.

To meet MMPA least practicable adverse impact standard on species or stocks and their habitat, NMFS and the Navy developed mitigation measures to reduce the potential for adverse impacts. Given the unique operational characteristics of SURTASS LFA sonar, Navy and NMFS developed the concept of marine mammal OBIAs for SURTASS LFA sonar and created a systematic process for designating OBIAs in the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001). Since the majority of areas of biological importance to protected marine mammal species and stocks are in coastal waters, the Navy established the policy of the coastal standoff range, in which waters within 12 nmi (22 km) of any land would not be ensonified with SURTASS LFA sonar at levels at or above 180 dB re 1 µPa (rms). In recognition that certain areas of biological importance lie outside of the coastal standoff range (i.e., 12 nmi from any land), the Navy and NMFS developed the concept of OBIAs. OBIAs are part of a comprehensive suite of mitigation measures used in previous authorizations to minimize adverse effects to marine mammal populations. OBIAs for SURTASS LFA sonar are not intended to apply to any other Navy activities or sonar operations and were established solely as a mitigation measure to reduce incidental takings associated with the employment of SURTASS LFA sonar (NOAA, 2007).

OBIAs were defined in the 2001 SURTASS LFA Sonar FOEIS/EIS (DoN, 2001) as those areas of the world's oceans outside of the coastal stand-off range (greater than 12 nmi [22 km]) from a coastline (including islands) where marine animals of concern (those animals listed under the ESA and/or marine mammals) carry out biologically important activities, including migration, foraging, breeding, and calving. In 2012, the Navy considered whether it was appropriate to establish OBIAs for listed marine species other than marine mammals but determined that there was no basis for doing so because impacts to protected sea turtles and marine fishes from exposure to SURTASS LFA sonar transmissions would be negligible, necessitating no additional preventative measures for these taxa. A sea turtle would have to be well inside the LFA mitigation zone (i.e., 180-dB sound field) during a SURTASS LFA sonar transmission to be affected. Additionally, research on the effects of SURTASS LFA sonar on some fish species (Popper et al., 2005, 2007; Halvorsen et al., 2006; Kane et al., 2010) showed that exposure to SURTASS LFA sonar sounds at relatively high levels (up to 193 dB re 1 µPa [rms] RL) had minimal effects, did not damage or injure fish tissues or organs, and resulted in no mortality, at least in the species of fish that were studied. The conclusion was that no basis existed for establishing OBIAs for sea turtles or marine fishes since no additional mitigation measures were required for these taxa above those already established for SURTASS LFA sonar. The same conclusion is reached in this SEIS/SOEIS, in which the analysis of the potential for impacts to fishes and sea turtles (Chapter 4) has been updated with the best available data, concluding that impacts to sea turtle and marine fishes from exposure to SURTASS LFA sonar transmissions would be negligible, necessitating no additional preventative measures for these taxa. Further, geospatial analysis conducted on the existing OBIAs and proposed OBIAs in support of this SEIS/SOEIS has necessitated a further clarification that OBIAs are areas greater than 12 nmi (22 km) from any emergent land or feature.

Associated with each OBIA is an effective period during which the marine mammals for which the OBIA was designated carry out biologically significant activities. During that time period, SURTASS LFA sonar cannot be transmitted at RLs of 180 dB re 1 µPa (rms) at or within the boundary of an OBIA.

OBIA Selection Criteria

The process of identifying potential marine mammal OBIAs involves an assessment by both NMFS and the Navy to identify marine areas that met established criteria. In their comprehensive reassessment of potential OBIAs for marine mammals conducted for the 2012 SEIS/SOEIS, NMFS and the Navy established geographical and biological criteria as the basis for consideration of an area's eligibility as a candidate OBIA.

Geographic Criteria for OBIA Eligibility

The Navy will not operate SURTASS LFA sonar in certain geographic areas of the world (Figure 1-1, Chapter 1). For a marine area to be eligible for consideration as an OBIA for marine mammals, the area must be located where SURTASS LFA sonar operates but cannot be located in:

- Coastal standoff zone or range—the area within 12 nmi (22 km) of the coastline of any land including islands or island systems.
- Polar regions—including the Arctic (portions of the Norwegian, Greenland, and Barents seas north of 72°N latitude, plus Baffin Bay, Hudson Bay, the Bering Sea, and the Gulf of St. Lawrence) and Antarctic (south of 60°S latitude).

<u>Low-Frequency Hearing Sensitivity Criterion</u>

For an area to be further considered as an OBIA for SURTASS LFA sonar, the area must be inhabited at least seasonally by marine mammal species whose best hearing sensitivity is in the LF range. Since SURTASS LFA sonar transmissions are well below the range of best hearing sensitivity for odontocetes and most pinnipeds based on the measured hearing thresholds (Richardson et al., 1995; Nedwell et al., 2004; Southall et al., 2007; Au and Hastings, 2008; Houser et al., 2008; Kastelein et al., 2009; Mulsow and Reichmuth, 2010), OBIAs are designed to protect those marine mammal species, such as baleen whales, most likely to hear and be affected by LFA sonar transmissions.

<u>Biological Criteria for OBIA Eligibility</u>

In addition to meeting the geographical criteria, a marine area must also meet at least one of the following biological criteria to be considered as a marine mammal OBIA for SURTASS LFA sonar:

- *<u>High Densities</u>*: a region of high density for one or more species of marine mammals. In addition to survey data, predictive habitat or density modeling may be used to identify areas of high density. The exact definition of “high density” may differ across species and should generally be treated and justified on a stock-by-stock or species-by-species basis, although combining species or stocks may be appropriate in some situations, if well justified. For locations/regions and species for which adequate density information is available (e.g., most waters off the U.S.), high density areas should be defined as those areas where density measurably, within a definable and justifiable area, meaningfully exceeds the average density of the species or stock in that location/region regularly or regularly within a designated time period of the year. For locations/regions and species and stocks for which density information is limited or not available, high density areas should be defined (if appropriate) using some combination of the following: available data, regional expertise, and/or habitat suitability models utilizing static and/or predictable dynamic oceanographic features and other factors that have been shown to be associated with high marine mammal densities.
- *<u>Known Breeding/Calving or Foraging Ground or Migration Route:</u>* An area representing a location of known biologically important activities including defined breeding or calving areas, foraging grounds, or migration routes, potential designation under this criterion is indicative that these areas are concentrated areas for at least one biologically important activity. For the purpose of this SEIS/SOEIS, “concentrated” means that more of the animals are engaged in the particular behavior at the location (and perhaps time) than are typically engaged in that behavior elsewhere
- *<u>Small, Distinct Populations of Marine Mammals with Limited Distributions:</u>* Geographic areas in which small, distinct populations of marine mammals occur and whose distributional range are limited.

- *U.S. ESA-designated Critical Habitat for an ESA-listed Marine Mammal Species or Stock:* Areas designated as critical habitat under the ESA for listed marine mammal species. Effective seasonal periods are consistent with that designated for the critical habitat area.

Navy Practicability Criterion

- Once an area has been assessed to meet the geographical, LF frequency hearing sensitivity, and biological criteria and is eligible as a candidate OBIA for SURTASS LFA sonar, the Navy conducts a review of the potential OBIAs to assess personnel safety, practicality of implementation, and impacts on the effectiveness on military readiness activities, including testing, training, and military operations. If no issues are found during the Navy's practicability review, then an area meets all criteria for designation as a SURTASS LFA sonar OBIA for marine mammals.

Existing Marine Mammal OBIAs for SURTASS LFA Sonar

For the 2012 SEIS/SOEIS, the Navy designated 21 OBIAs for SURTASS LFA sonar, and NMFS designated one additional OBIA as part of the MMPA Final Rule for SURTASS LFA sonar, resulting in 22 designated marine mammal OBIAs for SURTASS LFA sonar (Table 3-10; Figure 3-11; DoN, 2012; NOAA, 2012). Some of these areas, such as the Antarctic Convergence Zone, had been OBIAs previously designated by the Navy and NMFS for SURTASS LFA sonar. The season or period in which the biological activity occurs annually is specified for each designated OBIA.

3.4 Economic Resources

As SURTASS LFA sonar operates in open ocean areas it has the potential to interact with other activities taking place in these areas, including: commercial fishing, aboriginal subsistence whaling, and recreational activities including diving and whale watching. The following section will outline activities that may take place concurrently with SURTASS LFA sonar operations. Many aquatic activities take place in nearshore or inland water areas where SURTASS LFA sonar is not proposed to operate.

3.4.1 Commercial Fisheries

Global commercial fisheries were discussed in detail in subchapter 3.3.1 of the 2012 EIS/SEIS (DoN, 2012); that information remains pertinent and valid to the discussion of commercial fisheries going forward and is therefore provided herein by reference. The following discussion relates to new and updated information on global commercial fisheries.

3.4.1.1 Global Fisheries Production

Global fishery statistics are compiled per year by the United Nation's Fish and Agriculture Organization (FAO). The general composition of the global fisheries catches in 2012 was marine fishes, crustaceans, and mollusks with a total of 87.9 million tons (79.7 million metric tons) of overall landings (Table 3-11). Between 2012 and 2013, the largest difference in global landings was in the anchoveta fishery (Table 3-12). Regardless of the variations highlighted between 2012 and 2013, global fishery harvest/production totals have been stable for the last fifteen years, varying between 97.3 and 103.4 million tons (107.3 and 114 metric tons), despite variations in production by country, fishing area, and species every year (FAO, 2015).

Table 3-10. Existing 22 Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar, the Relevant Low-Frequency Marine Mammal Species, and the Effective Seasonal Period for each OBIA.

OBIA Number	*Name of OBIA*	*Location/Water Body*	*Relevant Low-Frequency Marine Mammal Species*	*Effectiveness Seasonal Period*
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	June through December, annually
3	Great South Channel, U.S. Gulf of Maine, and Stellwagen Bank NMS	Northwest Atlantic Ocean/ Gulf of Maine	North Atlantic right whale	January 1 to November 14, annually
4	Southeastern U.S. Right Whale Critical Habitat	Northwest Atlantic Ocean	North Atlantic right whale	November 15 to April 15, annually
5	North Pacific Right Whale Critical Habitat	Gulf of Alaska	North Pacific right whale	March through August, annually
6	Navidad Bank[22]	Caribbean Sea/Northwest Atlantic Ocean	Humpback whale	December through April, annually
7	Coastal Waters of Gabon, Congo and Equatorial Guinea	Southeastern Atlantic Ocean	Humpback whale and Blue whale	June through October, annually
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, annually
10	Central California National Marine Sanctuaries	Northeastern Pacific Ocean	Blue whale and Humpback whale	June through November, annually
11	Antarctic Convergence Zone	Southern Ocean	Blue whale, Fin whale, Sei whale, Minke whale, Humpback whale, and Southern right whale	October through March, annually
12	Piltun and Chayvo Offshore Feeding Grounds	Sea of Okhotsk	Western Pacific gray whale	June through November, annually

22 OBIA name changed to indicate that Silver Bank is no longer encompassed within OBIA boundary but is instead encompassed in and afforded the protections of the coastal standoff range for SURTASS LFA sonar

Table 3-10. Existing 22 Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar, the Relevant Low-Frequency Marine Mammal Species, and the Effective Seasonal Period for each OBIA.

OBIA Number	*Name of OBIA*	*Location/Water Body*	*Relevant Low-Frequency Marine Mammal Species*	*Effectiveness Seasonal Period*
13	Coastal Waters off Madagascar	Western Indian Ocean	Humpback whale and Blue whale	July through September, annually for humpback whale breeding, November through December for migrating blue whales
14	Madagascar Plateau, Madagascar Ridge, and Walters Shoal	Western Indian Ocean	Pygmy blue whale, Humpback whale, and Bryde's whale	November through December, annually
15	Ligurian-Corsican-Provençal Basin and Western Pelagos Sanctuary	Northern Mediterranean Sea	Fin whale	July to August, annually
16	Penguin Bank, Hawaiian Islands Humpback Whale National Marine Sanctuary	North-Central Pacific Ocean	Humpback whale	November through April, annually
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, annually
19	Bonney Upwelling	Southern Ocean	Blue whale, Pygmy blue whale, and Southern right Whale	December through May, annually
20	Northern Bay of Bengal and Head of Swatch-of-No- Ground (SoNG)	Bay of Bengal/Northern Indian Ocean	Bryde's whale	Year-round
21	Olympic Coast National Marine Sanctuary and The Prairie, Barkley Canyon, and Nitnat Canyon	Northeastern Pacific Ocean	Humpback whale	Olympic National Marine Sanctuary: December, January, March, and May, annually; The Prairie, Barkley Canyon, and Nitnat Canyon: June through September, annually
22	Abrolhos Bank	Southwest Atlantic Ocean	Humpback whale	August through November, annually

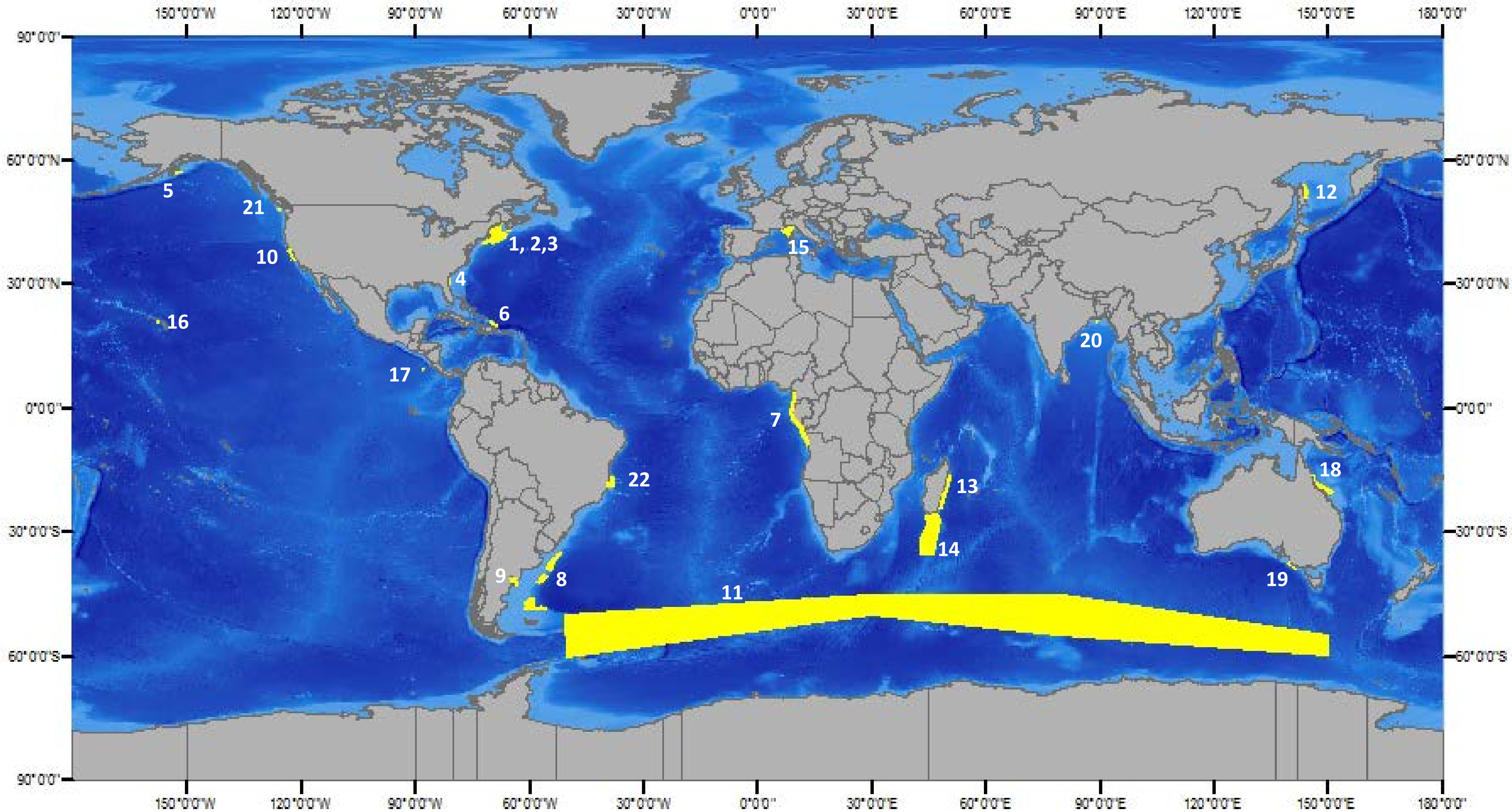


Figure 3-11. The Locations of the 22 Existing Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar (Names of OBIAs by Number Follows).

•

FIGURE 3-11: EXISTING OBIA NAMES BY NUMBER

1. Georges Bank
2. Roseway Basin Right Whale Conservation Area
3. Great South Channel, U.S. Gulf of Maine, and Stellwagen Bank National Marine Sanctuary
4. Southeastern U.S. Right Whale Critical Habitat
5. North Pacific Right Whale Critical Habitat
6. Navidad Bank
7. Coastal Waters of Gabon, Congo and Equatorial Guinea
8. Patagonian Shelf Break
9. Southern Right Whale Seasonal Habitat
10. Central California National Marine Sanctuaries
11. Antarctic Convergence Zone
12. Piltun and Chayvo Offshore Feeding Grounds
13. Coastal Waters off Madagascar
14. Madagascar Plateau, Madagascar Ridge, and Walters Shoal
15. Ligurian-Corsican- Provençal Basin and Western Pelagos Sanctuary
16. Penguin Bank, Hawaiian Islands Humpback Whale National Marine Sanctuary
17. Costa Rica Dome
18. Great Barrier Reef Between 16°S and 21°S
19. Bonney Upwelling
20. Northern Bay of Bengal and Head of Swatch-of-No-Ground (SoNG)
21. Olympic Coast National Marine Sanctuary, The Prairie, Barkley Canyon, and Nitnat Canyon
22. Abrolhos Bank

The inland and marine fisheries (minus anchoveta) increased slightly between 2012 and 2013, but the anchoveta (*Engraulis ringens*) fishery harvest increased significantly between the two years, with the landings increasing by about 1.1 million tons (1.2 million metric tons). The total global capture production reached a new maximum in 2013 at 33.2 million tons (30.1 million metric tons). The Peruvian anchovy (anchoveta) was the top marine species landed globally during both 2012 and 2013 (Table 3-13).

In 2012, the top worldwide fisheries producing countries were China, Indonesia, and the U.S. With the increase in anchoveta catches in 2013, Peru became the second top worldwide fish producing nation after China (Table 3-14). China's fishery harvest/production was more than twice that of any other nation in 2012 and 2013 (Table 3-14). The northwest Pacific Ocean region of the world had significantly more mass landed for both 2012 and 2013 than any other fishing regions (Table 3-15).

3.4.1.2 Trends of the Top Fish Producing Countries

As of 2012, Vietnam and Myanmar became two of the top 10 worldwide fishery producing nations (Table 3-13). Since the descriptive information for the remaining top fishery producing nations has changed little from that presented in the 2012 SEIS/SOEIS for SURTASS LFA sonar (DoN, 2012), the national fishery information presented in subchapter 3.3.1.1 of the Navy's 2012 SEIS/SOEIS remains pertinent and valid, and is incorporated herein by reference. Information on Myanmar and Vietnam's fishery production follows.

Myanmar

In Myanmar, which is the largest country in Southeast Asia, fishery products are a staple diet and a major source of animal protein for Myanmar's people. With a shoreline over 1,864 miles (3,000 km) in length, large river systems, and an extensive area of inland lakes and reservoirs, which results in fisheries playing an important role as a source of food, income, and employment (FAO, 2010). In 2011, Myanmar's population was 18 million people and the fishery sector provided direct employment for about 2.9 million people. In 2007, the per capita consumption of fish of 93.7 pounds (lb)/year (42.5 kilograms [kg]/year) was one of the highest in the world (FAO, 2012a).

The total fish production was estimated at 4.2 million tons (3.8 million metric tons) in 2011, with capture fisheries contributing 3.3 million tons (3.1 million metric tons) (FAO, 2012a). By 2013, fishery landings were estimated at 2.7 million tons (2.5 million metric tons) (FAO, 2015). Some 31,600 fishing vessels were reported for Myanmar, but more than half of which were not equipped with an engine. The fish-food supply during 2011 was 3,193 thousand tons (2,897 thousand metric tons) in live weight equivalent (FAO, 2012a).

In 2011, Myanmar exported the equivalent of $555.4 million U.S. dollars (USD) in fish and fishery products compared to import of $14.5 million USD (FAO, 2012a). Myanmar fishery harvest production decreased from 2013/2014 to 2014/2015, with 137,918 metric tons of fishery products exported in 2013/2014 at a value of 291.6 million USD (Win, 2015). China is the largest importer of Myanmar's fisheries products, particularly marine fishery products. Myanmar exported between 5 and 10 percent of its production to the European Union in 2010 (FAO, 2012a).

Vietnam

The fisheries industry in Vietnam consists of marine fisheries, inland fisheries, and aquaculture, with the marine fisheries sector being the largest contributor to the countries' fisheries production. The main

Table 3-11. Landings of Global Marine Fisheries in 2012 (FAO, 2012).

ISSCAAP[23] Division	*Landings (tons)*	*Percent of World Landings*
Freshwater fish	22,845	<0.1
Diadromous[24] fish	1,490,807	1.70
Marine fish	72,194,064	82.17
Crustaceans	6,339,012	7.21
Mollusks	7,222,234	8.22
Whales, seals, other aquatic mammals[25]	NA[26]	
Miscellaneous aquatic animals	591,765	0.67
Miscellaneous aquatic products	NA	
Aquatic plants[2]	NA	
Total	87,860,726	100

Table 3-12. World Fishery Production in 2012 and 2013 (FAO, 2015).

Fishery	*2012 (million tons)*	*2013 (million tons)*	*Variation (percent)*
Inland Capture	12.8	12.9	0.6 percent
Marine capture (excluding anchoveta)	82.7	82.9	0.3 percent
Anchoveta	5.2	6.3	20.9 percent
World Total	100.6	102.1	1.4 percent

Table 3-13. Principal Marine Fish Species Landed Globally in 2012 and 2013 (FAO, 2015).

Fishery Species Landed	*2012 Landings (tons)*	*2013 Landings (tons)*
Anchoveta (Peruvian anchovy) (*Engraulis ringens)*	5,172,987	6,254,554
Alaska Pollock (*Theragra chalcogramma)*	3,606,130	3,571,179
Skipjack tuna (*Katsuwonus pelamis)*	3,116,162	3,336,949
Sardinellas (*Sardinella* spp.)	2,598,984	2,492,550
Atlantic herring (*Clupea harengus)*	1,954,657	2,002,885
Chub mackerel (*Scomber japonicus)*	1,742,953	1,823,824
Decapterus spp*(Jacks)	1,590,193	1,558,662
Atlantic Cod (*Gadus morhua)*	1,228,417	1,498,667
Yellowfin tuna (*Thunnus albacares)*	1,480,055	1,463,134
Japanese anchovy (*Engraulis japonicus)*	1,429,018	1,461,750

23 ISSCAAP = International Standard Statistical Classification of Aquatic Animals and Plants.

24 Diadromous fishes are those species that regularly migrate between freshwater and saltwater.

25 Data on aquatic mammals and plants are excluded from all national, regional, and global totals.

26 NA= not available or unobtainable

Table 3-13. Principal Marine Fish Species Landed Globally in 2012 and 2013 (FAO, 2015).

Fishery Species Landed	*2012 Landings (tons)*	*2013 Landings (tons)*
Largehead hairtail (*Trichiurus lepturus)*	1,358,550	1,385,845
European pilchard (Sardine) (*Sardina pilchardus)*	1,123,189	1,103,553
Atlantic mackerel (*Scomber scombrus)*	1,004,488	1,082,339
Seerfishes (*Scomberomorus* spp.)	1,004,079	1,031,768
Jumbo flying squid (*Dosidicus gigas)*	1,047,890	933,980
Capelin (*Mallotus villosus)*	1,094,034	836,362
Blue whiting (Poutassou) (*Micromesistius poutassou)*	417,659	696,148
Akiami paste shrimp (*Acetes japonicus)*	648,998	645,329

Table 3-14. Top 10 Worldwide Fishing Nations in 2012 and 2013 by Mass Fishery Landings (FAO, 2015).

Country	*Total 2012 Landings (tons)*	*Total 2013 Landings (tons)*
China	15,288,621	15,396,824
Peru	5,308,301	6,423,093
Indonesia	5,974,800	6,270,539
United States of America	5,630,120	5,736,971
Russian Federation	4,485,139	4,501,639
Japan	3,988,168	3,996,531
India	3,757,735	3,768,605
Viet Nam	2,767,793	2,875,269
Myanmar	2,571,461	2,737,998
Philippines	2,344,804	2,348,747

fishing areas in the country are in the Gulf of Tonkin, central Vietnam, southeastern Vietnam, and southwestern Vietnam. Marine catches are the highest in central and southeast Vietnam (FAO, 2005). The fisheries sector, which has been growing considerably, plays an important role in the national economy. In 2003, the per capita consumption of 42.8 lb (19.4 kg) provided about half of the annual supply of animal protein in the national human diet. Nearly 10 percent of the population derives its main income from fisheries, with over 10 percent of the total export earnings also derived from fisheries. Vietnam exports mainly seafood products, and imported sea products, mainly salmon, crab meat, and caviar from Norway, France, the U.S., and other countries in 2001 (FAO, 2005). In 2012, the latest year for which FAO statistics are available, fishery exports were valued at $653,850 USD (FAO, 2012b).

The marine fishery resources potential has been estimated at 4.6 million tons (4.2 million metric tons), of which the annual allowable catch is 1.9 million tons (1.7 million metric tons). This included 936,964 tons (850,000 metric tons) of demersal fish, 771,617 tons (700,000 metric tons) of small pelagic fish, and 132,277 tons (120,000 metric tons) of oceanic pelagic fish. The most important commercial fishery species' groups are shrimp, tuna, squid, sea bream, snappers, groupers, and small pelagics. In 2013, the fishery landings were estimated at 2.9 million tons (FAO, 2015). In recent years the number of fishing

Table 3-15. Nominal Worldwide Fishery Landings for 2012 and 2013 by Mass for Marine Fishing Regions (FAO, 2015).

Marine Fishing Area	*FAO Area*	*2012 Landings (tons)*	*2013 Landings (tons)*
Atlantic, Northwest	21	2,183,868	2,047,582
Atlantic, Northeast	27	8,833,099	9,313,401
Atlantic, Western Central	31	1,620,007	1,509,297
Atlantic, Eastern Central	34	4,472,070	4,346,664
Mediterranean and Black Sea	37	1,416,545	1,369,453
Atlantic, Southwest	41	2,073,181	2,180,193
Atlantic, Southeast	47	1,721,168	1,377,747
Indian Ocean, Western	51	5,004,992	5,038,177
Indian Ocean, Eastern	57	8,054,431	8,500,000
Pacific, Northwest	61	23,664,768	23,621,684
Pacific, Northeast	67	3,213,892	3,549,912
Pacific, Western Central	71	13,396,501	13,672,799
Pacific, Eastern Central	77	2,179,663	2,305,504
Pacific, Southwest	81	662,479	641,978
Pacific, Southeast	87	9,147,915	9,425,321
Arctic and Antarctic Areas	18, 48, 58, 88	197,090	260,826

boats in Vietnam has increased, but only a small number have the capacity for deep-sea fishing. In 2012, 129,376 powered fishing boats were reported for Vietnam. Foreign boats often penetrate into Vietnamese waters to fish illegally. The quantity of marine catches taken by these foreign boats is estimated at about 110,231 tons (100,000 metric tons) per year (FAO, 2005).

3.4.2 Subsistence Harvest of Marine Mammals

Detailed information on subsistence harvest of marine mammals globally was described in subchapter 3.3.2 of the 2012 SEIS/SOEIS (DoN, 2012). Only recent information is presented herein with the 2012 SEIS/SOEIS information on subsistence hunting and harvest being incorporated by reference herein.

The IWC recognizes that indigenous or aboriginal subsistence whaling is different than commercial whaling. The objectives of the IWC for management of aboriginal subsistence whaling are to ensure that the hunted whale populations are maintained at healthy levels while still enabling the native people to hunt whales at levels that are appropriate to their cultural and nutritional requirements (IWC, 2016a).

It is the responsibility of national governments to provide the IWC with evidence of the cultural and subsistence needs of their people. The IWC Scientific Committee provides scientific advice on safe catch limits for such stocks and whether the requests for hunting by the governments are sustainable. Interpretation of the countries' needs statements within the IWC has proved to be controversial since each hunt is unique and different factors are relevant (IWC, 2016c). Aboriginal catch quotas are set in six year blocks, with the current quotas up for review in 2018. The development of these quotas is an important and complex issue, and the IWC has established an additional working group, the Aboriginal Subsistence Whaling Working Group, to oversee these issues. The objective of this working group is to prepare for the 2018 review by providing recommendations to the IWC on ways to improve the setting of catch quotas (IWC, 2016c).

In the past, it has been difficult to achieve consensus when establishing catch limits. In 2014, the IWC adopted a resolution that established a program to develop a consistent and long term approach for agreement on limits to aboriginal subsistence whaling. The objective of the working group is to assist the IWC in reaching a consensus when the next six year block of catch limits are set in 2018 for all aboriginal hunts (IWC, 2016d).

Under current IWC regulations, aboriginal subsistence whaling is permitted for Denmark (specifically for takes of fin, minke, bowhead, and humpback whales in West Greenland's waters and for common minke whales in East Greenland's waters), the Russian Federation (for the people of Chukotka with takes of gray and bowhead whales), St. Vincent and The Grenadines (for takes of humpback whales), and the U.S. (for Alaska native groups with takes of bowhead whales and for the Makah tribe, Washington with takes of gray whales) (Table 3-16). In 2007, the IWC approved a 5-year quota (2008 to 2012) of 620 gray whales, with an annual maximum of 140 whales for Russian and the U.S. (Makah Indian Tribe) aboriginals. Russia and the U.S. agreed to a shared annual harvest of 120 and 4 whales, respectively; however, all takes during this time period were from Russia (IWC, 2013). Alaskan hunters no longer intentionally pursue gray whales, and the U.S. has not pursued a gray whale catch limit from the International Whaling Commission for Alaska hunters (Norberg, 2013). The IWC also regulates the number of bowhead whales taken by subsistence hunting. For 2013-2018, the IWC quota is 306 landed bowheads, with a strike limit of 67 whales per year and an allowance of 5 takes by Russian natives per year (Muto et al. 2016). Bowhead whales are also subsistence hunted in the Eastern Canadian Arctic. From 2009 to 2013, 44 bowheads were harvested by U.S., Russian, and Canadian natives (Muto et al., 2016). No humpback or minke whales were taken by Alaskan or Russian subsistence communities from 2009 to 2013. Beluga whales are subsistence hunted in the Beaufort (U.S. and Canadian waters) and Chukchi seas and by one village in Cook Inlet. Due to the current abundance of the Cook Inlet beluga whale stock, no harvests are allowed from 2013 to 2017 (Muto et al., 2016).

In the U.S., subsistence hunting also occurs for several pinniped species. Much of the subsistence hunting for pinniped species occurs in areas of Alaska's Arctic region that are not part of SURTASS LFA sonar's operational area. Subsistence of Steller sea lions, for instance, occurs in the Bering Sea as well as Gulf of Alaska. Information is only included herein, to the extent possible, on the subsistence hunting that occurs in the Gulf of Alaska or other waters. In Alaska during 2011, the last year for which data are available, 20 adult Steller sea lions in the western stock/DPS of the Gulf of Alaska were harvested, while in 2012, 9 Steller sea lions (statewide) in the eastern stock were harvested, and an unknown number of Steller sea lions were harvested in Canadian waters (Muto et al., 2016). Subsistence hunting of harbor seals occurs throughout the coastal areas of the Gulf of Alaska, with 758 harbor seals having been taken in subsistence hunts in 2011 to 2012 (Muto et al., 2016). The subsistence harvest of northern fur, bearded, ringed, ribbon, and spotted seals in Alaska all occurs in the Bering Sea and Yukon area (Muto et al., 2016).

3.4.3 Recreational Marine Activities

Marine recreational activities include swimming, snorkeling, recreational diving, and whale watching. Swimming and snorkeling may occur anywhere in relatively shallow waters near any shoreline. Recreational dive sites are less numerous, as they typically occur in nearshore waters where some underwater feature or habitat, such as coral reefs or shipwrecks, create destinations for recreational divers. Likewise, whale watching only occurs in marine waters in which marine mammals can be observed, at least seasonally.

Table 3-16. Global Aboriginal Subsistence Hunting as Reported by the International Whaling Commission from 2007 Through 2014 (IWC, 2016b).

Subsistence Nation	*Ocean Area*[27]	*Harvested Marine Mammal Species*						
		Fin	*Humpback*	*Sei*	*Gray*	*Minke*	*Bowhead*	*Total*
2011								
Denmark: W. Greenland	NA	5	8	0	0	179	1	193
Denmark: E. Greenland	NA	0	0	0	0	10	0	10
St. Vincent and The Grenadines	NA	0	2	0	0	0	0	2
Russia	NP	0	0	0	128	0	0	128
U.S. (Alaska)	NP	0	0	0	0	0	51	51
Total		5	10	0	128	189	52	384
2012								
Denmark: W. Greenland	NA	5	10	0	0	148	0	163
Denmark: E. Greenland	NA	0	0	0	0	4	0	4
St. Vincent and The Grenadines	NA	0	2	0	0	0	0	2
Russia	NP	0	0	0	143	0	0	143
U.S. (Alaska)	NP	0	0	0	0	0	69	69
Total		5	12	0	143	152	69	381
2013								
Denmark: W. Greenland	NA	9	8	0	0	175	0	192
Denmark: E. Greenland	NA	0	0	0	0	6	0	6
St. Vincent and The Grenadines	NA	0	4	0	0	0	0	4
Russia	NP	0	0	0	127	0	1	128
U.S. (Alaska)	NP	0	0	0	0	0	57	57
Total		9	12	0	127	181	58	387
2014								
Denmark: W. Greenland	NA	12	7	0	0	146	0	165
Denmark: E. Greenland	NA	0	0	0	0	11	0	11
St. Vincent and The Grenadines	NA	0	2	0	0	0	0	2
Russia	NP	0	0	0	124	0	0	124
U.S. (Alaska)	NP	0	0	0	0	0	53	53
Total		12	9	0	124	157	53	355

3.4.3.1 Recreational Diving

Recreational dive sites are typically located between the coastline and the 130 ft (40 m) depth contour, which is about the limit to which most recreational scuba divers ascend. With more advanced training, diving could ascend to water depths deeper than 130 ft (40 m), but this type of diving would no longer be considered recreational diving (PADI, 2016). The Professional Association of Diving Instructors (PADI), which is the largest dive training organization in the world, has issued over 23 million diver certifications globally between 1967 and 2014 (PADI, 2015). Additional popular diving sites not identified in Table 3-23 of the 2012 SEIS/ SOEIS for SURTASS LFA sonar (DoN, 2012) are included in this SEIS/SOEIS (Table 3-17).

27 NA= North Atlantic Ocean, NP=North Pacific Ocean

Table 3-17. Worldwide Major Recreational Diving Locations (LTD, 2015).

Dive Site	*Dive Location*
Albatross Passage	Kavieng, Papua New Guinea
Alcyone	Cocos Island, Costa Rica
Aldabra Atoll	Seychelles
Apo Reef	Philippines
Canyon, Thomas Reef	Egypt
Cathédrale	Hienghène, New Caledonia
East of Eden	Ko Similan, Thailand
El Quadim Bay and El Quseir	Red Sea
Great White Wall	Tavieuni, Fiji
Hilma Hooker	Bonaire
Jardines de la Reina	Cuba
Maaya Thila, South Ari Atoll	Maldives
Magic Mountain	Raja Ampat, Indonesia
Manta Point	Maldives
Manta Ray Night Dive, Fesdhoo Lagoon, North Ari Atoll	Maldives
Molokini Crater Wall	Hawaii
Monad Shoal	Malapascua, Philippines
Neptune's Arm	Vamizi Island, Mozambique
Paradise Point	Milne Bay, Papua New Guinea
Pinnacles, Ponto Malongane	Mozambique
Punta Sur / Devils Throat	Cozumel, Mexico
Raja Ampat	Irian Jaya, Indonesia
Sangalaki Island	East Kalimantan, Indonesia
Scotts Head Pinnacle	Dominica
Seaventure House Reef	Mabul, Malaysia
Silfra	Thingvellir, Iceland
The Boiler, Socorro	Revillagigedo Islands, Mexico
Split Rock	Kadavu Isle, Fiji
Verde Island or Drop Off	Philippines

3.4.3.2 Whale Watching

Sustainable whale watching conducted in harmony with cetacean populations in a healthy environment is the goal of the IWC. The IWC works with scientists, governments, and the whale watching industry to assess threats and identify best practices to provide safe observing conditions for both humans and cetaceans. This ongoing research has resulted in the development of principles and guidelines for whale watching which have helped guide the development of whale watching regulations around the world. The IWC's Whale-watching Working Group has produced a five-year whale watching strategy that has been adopted by the IWC and is developing a Handbook for Whale Watching. This handbook will be a web-based tool that will provide guidelines and support to whale watching operators, national, and regional regulators to ensure that whale watching is sustainable into the future (IWC, 2016e).

3.5 Literature Cited

Abecassis, M., Senina, I., Lehodey, P., Gaspar, P., Parker, D., Balazs, G., & Polovina, J. (2013). A model of loggerhead sea turtle (*Caretta caretta*) habitat and movement in the oceanic North Pacific. *PLoS ONE, 8*(9), e73274. doi:10.1371/journal.pone.0073274.

Aburto, A., Rountry, D. J., & Denzer, J. L. (1997). *Behavioral response of blue whales to active signals.* (Technical Report 1746). San Diego, CA: Naval Command, Control and Ocean Surveillance Center, RDT&E Division.

Acebes, J. M. V., Darling, J.D., & Yamaguchi, M. (2007). Status and distribution of humpback whales (*Megaptera novaeangliae*) in northern Luzon, Philippines. *Journal of Cetacean Research and Management, 9*(1), 37-43.

Acevedo, J., Mora, C., & Aguayo-Lobo, A. (2014). Sex-related site fidelity of humpback whales (*Megaptera novaeangliae*) to the Fueguian Archipelago feeding area, Chile. *Marine Mammal Science, 30*(2), 433-444. doi:10.1111/mms.12048

Adams, P. B., Grimes, C. B., Hightower, J. E., Lindley, S. T., & Moser, M. L. (2002). Status review for North American green sturgeon, *Acipenser medirostris*. National Marine Fisheries Service. 57 pages. Retrieved from <http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/greensturgeon.pdf>.

Agardy, T. (2000). Key steps taken to preserve the U.S.'s marine heritage. *Issues in Science and Technology, 17*(1), 26.

Aguilar, A. (2009). Fin whale (*Balaenoptera physalus*). In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 433-437): Academic Press.

Aguilar de Soto, N., M.P. Johnson, P.T. Madsen, F. Diaz, I. Dominguez, A. Brito, & P. Tyack. (2008). Cheetahs of the deep sea: deep foraging sprints in short-finned pilot whales off Tenerife (Canary Islands). *Journal of Animal Ecology, 77*, 936-947.

Airoldi, S., Bendinoni, F., Azzellino, A., Fadda, V., & Profice, A. (2005). Abundance estimate of Risso's dolphins (*Grampus griseus*) in the western Ligurian Sea through photographic mark-recapture. *European Research on Cetaceans, 19*, 109.

Akamatsu, T., M. H. Rasmussen, & M. Iversen. (2014). Acoustically invisible feeding blue whales in Northern Icelandic waters. *The Journal of the Acoustical Society of America, 136*(2), 939-944. doi:10.1121/1.4887439.

Alfaghi, I. (2013). First confirmed sighting of the Mediterranean monk seal (*Monachus monachus*) in Libya since 1972. *Aquatic Mammals, 39*(1), 81-84. doi:10.1578/am.39.1.2013.81.

Allen, B. M., & Angliss, R. P. (2010). *Alaska marine mammal stock assessments, 2009.* (NOAA Technical Memorandum NMFS-AFSC-206). Seattle, Washington: Alaska Fisheries Science Center, National Marine Fisheries Service.

Allen, B. M., & Angliss, R. P. (2014). *Alaska marine mammal stock assessments, 2013*. (NOAA Technical Memorandum NMFS-AFSC-277). Seattle, Washington: Alaska Fisheries Science Center, National Marine Fisheries Service.

Allen, B. M., & Angliss, R. P. (2015). *Alaska marine mammal stock assessments, 2014*. (NOAA Technical Memorandum NMFS-AFSC-301). Seattle, Washington: Alaska Fisheries Science Center, National Marine Fisheries Service.

Allen, G. R., & Donaldson, T. J. (2007). *Pterapogon kauderni* Banggai cardinalfish. IUCN RedList. Retrieved from <http://www.iucnredlist.org/details/63572/0>.

Alves, F., A. Dinis, I. Cascão, and L. Freitas. (2010). Bryde's whale (*Balaenoptera brydei*) stable associations and dive profiles: New insights into foraging behavior. *Marine Mammal Science, 26*(1), 202-212.

Alves, F., Dinis, A., Ribeiro, C., Nicolau, C., Kaufmann, M., Fortuna, C. M., & Freitas, L. (2013). Daytime dive characteristics from six short-finned pilot whales *Globicephala macrorhynchus* off Madeira Island. *Arquipelago-Life and Marine Sciences, 31*, 1-8.

Alves, A., R. Antunes, A. Bird, P. L. Tyack, P. J. O. Miller, F.-P. A. Lam, & P. H. Kvadsheim. (2014). Vocal matching of naval sonar signals by long-finned pilot whales (*Globicephala melas*). *Marine Mammal Science, 30*(3), 1248-1257. doi:10.1111/mms.12099.

American National Standards Institute (ANSI) (2006). ANSI reference quantities for acoustical levels. New York, NY: Acoustic Society of America.

Andersen, J. M., Skern-Mauritzen, M., Boehme, L., Wiersma, Y. F., Rosing-Asvid, A., Hammill, M. O., & Stenson, G. B. (2013). Investigating annual diving behaviour by hooded seals (*Cystophora cristata*) within the Northwest Atlantic Ocean. *PLoS ONE, 8*(11), e80438. doi:10.1371/journal.pone.0080438.

Andersen, J. M., Stenson, G. B., Skern-Maurizen, M., Wiersma, Y. F., Rosing-Asvid, A., Hammill, M. O., & Boehme, L. (2014). Drift diving by hooded seals (*Cystophora cristata*) in the northwest Atlantic Ocean. *PLoS ONE, 9*(7), e103072. doi:10.1371/journal.pone.0103072.

André, M., Solé, M., Lenoir, M., Durfort, M., Quero, C., Mas, A., Lombarte, A., van der Schaar, M. López-Bejar, M., Morell, M., Zaugg, S., &. Houégnigan, L. (2011). Low-frequency sounds induce acoustic trauma in cephalopods. *Frontiers in Ecology and the Environment, 9*(9), 489-493. doi:10.1890/100124.

Andrew, R.K., Howe, B.M. and Mercer, J.A. (2011). Long-time trends in ship traffic noise for four sites off the North American West Coast. *The Journal of the Acoustical Society of America, 129*(2), 642-651. doi:10.1121/1.3518770.

Andrew, R.K., Howe, B.M., Mercer, J A., & Dzieciuch, M.A. (2002). Ocean ambient sound: Comparing the 1960s with the 1990s for a receiver off the California coast. *Acoustics Research Letters Online, 3*(2), 65. doi:10.1121/1.1461915.

Andrews, K. R., Karczmarski, L., Au, W. W. L., Rickards, S. H., Vanderlip, C. A., & Toonen, R. J. (2006). Patterns of genetic diversity of the Hawaiian spinner dolphin (*Stenella longirostris*). *Atoll Research Bulletin, 543*, 65-73.

Ansmann, I. C., J. C. Goold, P. G. H. Evans, M. Simmonds, & S. G. Keith. (2007). Variation in the whistle characteristics of short-beaked common dolphins, *Delphinus delphis*, at two locations around the British Isles. *Journal of the Marine Biological Association of the United Kingdom, 87*(01), 19-26.

Aragones, L. V., M. A. A. Roque, M. B. Flores, R. P. Encomienda, G. E. Laule, B. G. Espinos, F. E. Maniago, G. C. Diaz, E. B. Alesna, & R. C. Braun. (2010). The Philippine Marine Mammal Strandings from 1998 to 2009: Animals in the Philippines in Peril? *Aquatic Mammals, 36*(3), 219-233. doi:10.1578/am.36.3.2010.219.

Archer, F. I., II (2009). Striped dolphin *Stenella coeruleoalba*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 1127-1129). New York, NY: Academic Press.

Archer, F. I., II, and W. F. Perrin. (1999). *Stenella coeruleoalba*. *Mammalian Species, 603*, 1-9.

Arendt, M. D., A. L. Segars, J. I. Byrd, J. Boynton, J. A. Schwenter, J. D. Whitaker, & L. Parker. (2012). Migration, distribution, and diving behavior of adult male loggerhead sea turtles (*Caretta caretta*) following dispersal from a major breeding aggregation in the Western North Atlantic. *Marine Biology, 159*(1), 113-125. doi:10.1007/s00227-011-1826-0.

Arnould, J. P. Y., & Hindell, M. A. (2001). Dive behaviour, foraging locations, and maternal-attendance patterns of Australian fur seals (*Arctocephalus pusillus doriferus*). *Canadian Journal of* Zoology, *79*: 35-48.

Arnould, J. P. Y. (2009). Southern Fur Seals *Arctocephalus* spp. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals*. New York, NY: Academic Press.

Aroyan, J. L., M. A. McDonald, S. C. Webb, J. A. Hildebrand, C. D., J. T. Laitman, & J. S. Reidenberg. (2000). Acoustic models of sound production. In W. W. L. Au, A. Popper, and R. Fay (Eds.), *Hearing by whales and dolphins* (pp. 409-469). New York, NY: Springer-Verlag.

Aschettino, J. M. (2010). Population size and structure of melon-headed whales *(Peponocephala electra)* around the Main Hawaiian Islands: Evidence of multiple populations based on photographic data. (Master's thesis). Hawai'i Pacific University, Honolulu, HI.

Asselin, S., O. Hammill Mike, and C. Barrette. (1993). Underwater vocalizations of ice breeding grey seals. *Canadian Journal of Zoology, 71*(11), 2211-2219.

Au, W. W., G. Giorli, J. Chen, A. Copeland, M. Lammers, M. Richlen, S. Jarvis, R. Morrissey, D. Moretti, & H. Klinck. (2013). Nighttime foraging by deep diving echolocating odontocetes off the Hawaiian islands of Kauai and Ni'ihau as determined by passive acoustic monitors. *The Journal of the Acoustical Society of America, 133*(5), 3119-3127. doi:10.1121/1.4798360.

Au, W. W. L. (1993). *The sonar of dolphins*. New York, NY: Springer-Verlag.

Au, W. W. L., & M. C. Hastings. (2008). *Principles of Marine Bioacoustics* (1st ed.). New York, NY: Springer.

Au, W. W. L., & D. L. Herzing. (2003). Echolocation signals of wild Atlantic spotted dolphin (*Stenella frontalis*). *Journal of the Acoustical Society of America, 113*(1), 598-604.

Au, W. W. L., P. E. Nachtigall, & J. A. Pawloski. (1997). Acoustic effects of the ATOC signal (75 Hz, 195 dB) on dolphins and whales. *Journal of the Acoustical Society of America, 101*, 2973-2977.

Au, W. W. L., A. A. Pack, M. O. Lammers, L. M. Herman, M. H. Deakos, & K. Andrews. (2006). Acoustic properties of humpback whale songs. *The Journal of the Acoustical Society of America, 120*(2), 1103-1110.

Au, W. W. L., R. H. Penner, & C. W. Turl. (1987). Propagation of beluga echolocation signals. *Journal of the Acoustical Society of America, 82*(3), 807-813.

Au, W. W. L., & B. Würsig. (2004). Echolocation signals of dusky dolphins (*Lagenorhynchus obscurus*) in Kaikoura, New Zealand. *The Journal of the Acoustical Society of America, 115*(5), 2307-2313.

Australian Government. (2016). *Aipysurus fuscus in species profile and threats database*. Department of the Environment, Australian Government, Canberra, Australia. Accessed April 2016. Retrieved from: <http://www.environment.gov.au/sprat>.

Awbrey, F. T. (1982). Ross Sea killer whale vocalizations: Preliminary description and comparison with those of some Northern Hemisphere Killer Whales. *Reports to the International Whaling Commission, 32*, 667-670.

Awbrey, F. T., J. C. Norris, A. B. Hubbard, & W. E. Evans. (1979). *The bioacoustics of the Dall porpoise-salmon drift net interaction*. (Hubbs/Sea World Research Institute Technical Report 79-120). San Diego, CA: Hubbs/Sea World Research Institute.

Awbrey, F. T., J. A. Thomas, & R. A. Kastelein. (1988). Low-frequency underwater hearing sensitivity in belugas, *Delphinapterus leucas*. *Journal of the Acoustical Society of America, 84*(6), 2273-2275.

Azevedo, A. F., L. Flach, T. L. Bisi, L. G. Andrade, P. R. Dorneles, & J. Lailson-Brito. (2010). Whistles emitted by Atlantic spotted dolphins (*Stenella frontalis*) in southeastern Brazil. *The Journal of the Acoustical Society of America, 127*(4), 2646. doi:10.1121/1.3308469.

Azzolin, M., E. Papale, M. O. Lammers, A. Gannier, & C. Giacoma. (2013). Geographic variation of whistles of the striped dolphin (*Stenella coeruleoalba*) within the Mediterranean Sea. *The Journal of the Acoustical Society of America, 134*(1), 694-705. doi:10.1121/1.4808329.

Babushina, Y. S., G. L. Zaslavskii, & L. I. Yurkevich. (1991). Air and underwater hearing characteristics of the northern fur seal audiograms frequency and differential thresholds. *Biophysics, 36*(5), 909-913.

Bain, D. E., B. Kriete, & M. E. Dahlheim. (1993). Hearing abilities of killer whales (*Orcinus orca*). *Journal of the Acoustical Society of America, 94*(3), 1829.

Baird, R. W. (2009a). False killer whale *Pseudorca crassidens*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 405-406). New York: Academic Press.

Baird, R. W. (2009b). Risso's Dolphin *Grampus griseus*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 975-976). New York: Academic Press.

Baird, R. W., J. F. Borsani, M. B. Hanson, & P. L. Tyack. (2002). Diving and night-time behavior of long-finned pilot whales in the Ligurian Sea. *Marine Ecology Progress Series, 237*, 301-305.

Baird, R. W., Dill, L. M., & Hanson, B. (1998). *Diving behaviour of killer whales.* Paper presented at the *World Marine Mammal Science Conference, Monaco*.

Baird, R. W., Gorgone, A. M., McSweeney, D.J., Ligon, A. D., Deakos, M. H., Webster, D. L., Schorr, G. S., Martien, K.K., Salden, D. R., & Mahaffy, S. D. (2009). Population structure of island-associated dolphins: Evidence from photo-identification of common bottlenose dolphins (*Tursiops truncatus*) in the main Hawaiian Islands. *Marine Mammal Science, 25*(2), 251-274.

Baird, R. W., Hanson, M. B., & Dill, L. M. (2005). Factors influencing the diving behaviour of fish-eating killer whales: sex differences and diel and interannual variation in diving rates. *Canadian Journal of Zoology, 83*(2), 257-267.

Baird, R. W., Ligon, A. D., Hooker, S. K., & Gorgone, A. M. (2001). Subsurface and nighttime behaviour of pantropical spotted dolphins in Hawai'i. *Canadian Journal of Zoology, 79*, 988-996.

Baird, R. W., D. J. McSweeney, A. D. Ligon, & D. L. Webster. (2004). *Tagging feasibility and diving of Cuvier's beaked whales (Ziphius cavirostris) and Blainville's beaked whales (Mesoplodon densirostris) in Hawaii.* (Contract report, order number AB133F-03-SE-0986). La Jolla, CA.

Baird, R. W., Schorr, G. S., Webster, D. L., McSweeney, D. J., Hanson, M. B. and Andrews, R. D. (2011). Movements of two satellite-tagged pygmy killer whales (*Feresa attenuata*) off the island of Hawaiʻi. *Marine Mammal Science, 27*(4), E332–E337. doi:10.1111/j.1748-7692.2010.00458.x.

Baker, A. N. (1985). Pygmy right whale *Caperea marginata*. In S. H. Ridgway & R. Harrison (Eds.), *The Sirenians and Baleen Whales* (Vol. 3, pp. 345-354).

Baldwin, R., G. R. Hughes, & R. I. T. Prince. (2003). Loggerhead turtles in the Indian Ocean. In A. B. Bolten and B. E. Witherington (Eds.), *Loggerhead sea turtles* (pp. 218-232). Washington, D.C.: Smithsonian Institution Press.

Ballance, L. T. (2009). Cetacean ecology. In W. F. Perrin, B. Wursig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (2nd edition ed., pp. 196-201). San Diego, California: Academic Press.

Ballance, L. T., D. G. Ainley, & G. L. Hunt, Jr. (2001). Seabird foraging ecology. In J. H. Steele, S. A. Thorpe, & K. K. Turekian (Eds.), *Encyclopedia of ocean sciences, Volume 5* (Vol. 5, pp. 2636-2644). London, England: Academic Press.

Ballance, L. T., & R. L. Pitman. (1998). Cetaceans of the western tropical Indian Ocean: Distribution, relative abundance, and comparisons with cetacean communities of two other tropical ecosystems. *Marine Mammal Science, 14*(3), 429-459.

Banner, A. (1967). Evidence of sensitivity to acoustic displacements in the lemon shark, *Negaprion brevirostris* (Poey). In P. H. Cahn (Ed.), *Lateral line detectors*. Bloomington, IN: Indiana University Press.

Banner, A. (1972). Use of sound in predation by young lemon sharks, *Negaprion brevirostris* (Poey). *Bulletin of Marine Science, 22*(2), 251-283.

Bannister, J. L. (2009). Baleen whales. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 80-89). New York, NY: Academic Press.

Bannister J. L., & Hedley, S. L. (2001). Southern Hemisphere Group IV humpback whales: Their status from recent aerial survey. *Memoirs of the Queensland Museum, 47*, 587-598.

Bannister, J. L., Kemper, C. M., & Warneke, J. M. (1996). *The action plan for Australia cetaceans.* Canberra, AU: Australian Nature Conservation Agency. ISBN 0 642 21388 7.

Barco, S. G., W. A. McLellan, J. M. Allen, S. R. A. Asmutis, D. R. Mallon, E. M. Meagher, D. A. Pabst, J. Robbins, R. E. Seton, W. M. Swingle, M. T. Weinrich, & P. J. Clapham. (2002). Population identity of humpback whales (*Megaptera novaeangliae*) in the waters of the US mid-Atlantic states. *Journal of Cetacean Research and Management, 4*(2), 135-141.

Barlow, J. (1995). The abundance of cetaceans in California waters: Part I. Ship surveys in summer and fall of 1991. *Fishery Bulletin, 93*(1), 1-14.

Barlow, J. (1999). Trackline detection probability for long-diving whales. In G. W. Garner, S. C. Amstrup, J. L. Laake, B. F. J. Manly, L. L. McDonald, & D. G. Robertson (Eds.), *Marine Mammal Survey and Assessment Methods* (pp. 209-221). Brookfield, IL: A.A Balkema.

Barlow, J. (2006). Cetacean abundance in Hawaiian waters estimated from a summer/fall survey in 2002. *Marine Mammal Science, 22*(2), 446-464.

Barlow, J. (2010). *Cetacean abundance in the California Current from a 2008 ship-based line-transect survey.* (NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-456). La Jolla, CA: Southwest Fisheries Service, National Marine Fisheries Service.

Barlow, J., & Forney, K. (2007). Abundance and population density of cetaceans in the California Current ecosystem. *Fishery Bulletin, 105*, 509-526.

Barlow, J., Forney, K. A., Hill, P. S., Brownell, R. L., Jr., Carretta, J. V., DeMaster, D. P., Julian, F., Lowry, M. S., Ragen, T., & Reeves, R. R. (1997). *U.S. Pacific marine mammal stock assessments: 1996*. (NOAA Technical Memorandum NMFS-SWFSC-248:1-223). La Jolla, CA: Southwest Fisheries Science Center, National Marine Fisheries Service.

Barlow, J., Ferguson, M. C., Perrin, W. F., Ballance, L., Gerrodette, T., Joyce, G., Macleod, C. D., Mullin, K., Palka, D. L., & Waring, G. (2006). Abundance and densities of beaked and bottlenose whales (family Ziphiidae). *Journal of Cetacean Research and Management, 7,* 263-270.

Barlow, J., Ferguson, M. C., Becker, E. A., Redfern, J. V., Forney, K. A., Vilchis, I. L., Fiedler, P.C., Gerrodette, T., & Ballance, L. T. (2009). *Predictive modeling of cetacean densities in the Eastern Pacific Ocean*. (NOAA-TM-NMFS-SWFSC-444). La Jolla, CA: Southwest Fisheries Science Center, National Marine Fisheries Service.

Bartholomew, G. A., & N. E. Collias. (1962). The role of vocalization in the social behaviour of the northern elephant seal. *Animal Behaviour, 10*(1-2), 7-14.

Bartol, S. M. (2008). A review of auditory function of sea turtles. *Bioacoustics, 17*(1-3), 57-59. doi:10.1080/09524622.2008.9753763

Bartol, S. M., & Ketten, D. R. (2006). Turtle and tuna hearing. Pages 98-105 in Y. Swimmer, & R. Brill, eds. *Sea turtle and pelagic fish sensory biology: Developing techniques to reduce sea turtle bycatch in longline fisheries*. NOAA Technical Memorandum NMFS-PIFSC-7. Retrieved from <http://www.pifsc.noaa.gov/tech/NOAA_Tech_Memo_PIFSC_7.pdf>.

Bartol, S. M., and J. A. Musick. (2003). Sensory Biology of Sea Turtles. In P. L. Lutz, J. A. Musick, & J. Wyneken (Eds.), *The Biology of Sea Turtles, Volume II* (Vol. II, pp. 79-102): CRC Press.

Bartol, S. M., J. A. Musick, & M. L. Lenhardt. (1999). Auditory evoked potentials of the loggerhead sea turtle (*Caretta caretta*). Copeia*,* 3, 836-840.

Bass, A. H., & F. Ladich. (2008). Vocal-acoustic communication: from neurons to brain. In J. F. Webb, R. R. Fay, & A. N. Popper (Eds.). *Fish bioacoustics* (pp. 253-278). Springer.

Baum, J., Clarke, S., Domingo, A., Ducrocq, M., Lamónaca, A. F., Gaibor, N., Graham, R., Jorgensen, S., Kotas, J. E., Medina, E., Martinez-Ortiz, J., Monzini Taccone di Sitizano, J., Morales, M. R., Navarro, S. S., Pérez-Jiménez, J. C., Ruiz, C., Smith, W., Valenti, S. V. and Vooren, C. M. (2007). *Sphyrna lewini*. The IUCN red list of threatened species. Version 2014.3. Retrieved from <www.iucnredlist.org>.

Baumann-Pickering, S., M. A. Roch, S. M. Wiggins, H. U. Schnitzler, & J. A. Hildebrand. (2015). Acoustic behavior of melon-headed whales varies on a diel cycle. *Behavioral Ecology and Sociobiology, 69*(9), 1553-1563. doi:10.1007/s00265-015-1967-0.

Baumann-Pickering, S., A. E. Simonis, E. M. Oleson, R. W. Baird, M. A. Roch, & S. M. Wiggins. (2015). False killer whale and short-finned pilot whale acoustic identification. *Endangered Species Research, 28*(2), 97-108. doi:10.3354/esr00685.

Baumann-Pickering, S., S. M. Wiggins, J. A. Hildebrand, M. A. Roch, & H.-U. Schnitzler. (2010). Discriminating features of echolocation clicks of melon-headed whales (*Peponocephala electra*), bottlenose dolphins (*Tursiops truncatus*), and Gray's spinner dolphins (*Stenella longirostris longirostris*). *The Journal of the Acoustical Society of America, 128*(4), 2212. doi:10.1121/1.3479549.

Baumgartner, M. F., & B. R. Mate. (2003). Summertime foraging ecology of North Atlantic right whales. *Marine Ecology-Progress Series, 264*, 123-135.

Baylis, A. M. M., B. Page, K. Peters, R. McIntosh, J. Mckenzie, & S. Goldsworthy. (2005). The ontogeny of diving behaviour in New Zealand fur seal pups (*Arctocephalus forsteri*). *Canadian Journal of Zoology, 83*(9), 1149-1161.

Bazua-Duran, C., & W. W. L. Au. (2002). The whistles of Hawaiian spinner dolphins. *Journal of the Acoustical Society of America, 112*(6), 3064-3072.

Bazua-Duran, C., & W. W. L. Au. (2004). Geographic variations in the whistles of spinner dolphins (*Stenella longirostris*) of the Main Hawai'ian Islands. *Journal of the Acoustical Society of America, 116*(6), 3757-3769.

Beacham, T. D., Hay, D. E., & Le, K. D. (2005). Population structure and stock identification of eulachon (*Thaleichthys pacificus*), an anadromous smelt, in the Pacific Northwest. *Marine Biotechnology, 7,* 363-372.

Bearzi, G., Reeves, R. R., Remonato, E., Pierantonio, N., & Airoldi, S. (2011). Risso's dolphin *Grampus griseus* in the Mediterranean Sea. *Mammalian Biology, 76*(4), 385-400.

Belcher, R. L., & Lee, Jr., T. E. (2002). *Arctocephalus townsendi*. *Mammalian Species 700*:1-5.

Bel'kovich, V. M., & M. N. Sh'ekotov. (1993). *The belukha whale: Natural behavior and bioacoustics*.

Bellido, J. J., J. Cabot, J. J. Castillo, J. C. Báez, J. J. Martín, J. L. Mons, J. Larios, J. Rubia, & R. Real. (2009). First record of the harp seal (*Pagophilus groenlandicus*) extralimital presence in the Mediterranean Sea. *Marine Biodiversity Records, 2*. doi:10.1017/s1755267209990959

Berkson, H. (1967). Physiological adjustments to deep diving in the Pacific green turtle (*Chelonia mydas agassizii*). *Comparative Biochemistry and Physiology, 21*(3), 507-524.

Bernasconi, M., L. Nøttestad, B. E. Axelsen, & J. O. Krakstad. (2011). Acoustic observations of dusky dolphins *Lagenorhynchus obscurus* hunting Cape horse mackerel *Trachurus capensis* off Namibia. *Marine Ecology Progress Series, 429*, 209-218. doi:10.3354/meps09071.

Berta, A. (2009). Pinnipeds, overview. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 878-884). New York, NY: Academic Press.

Best, P. B. (1960). Further information on Bryde's whale (*Balaenoptera edeni* Anderson) from Saldanha Bay, South Africa. *Norsk Hvalfangst-Tidende, 49*, 201-215.

Best, P. B. (1975). *Status of Bryde's whale (Balaenoptera edeni* or *B. brydei)*. (Paper presented at the Marine Mammal Symposium, Rome, Italy).

Best, P. B., Bannister, J. L., Brownell, Jr., R. L., & Donovan, G. P. (Eds). (2001). Right whales: Worldwide status. *Journal of Cetacean Research and Management, (Special Issue 2)***,** 1-309.

Best, P.-B., R.-A. Rademeyer, C. Burton, D. Ljungblad, K. Sekiguchi, H. Shimada, D. Thiele, D. Reeb, & D.-S. Butterworth. (2003). The abundance of blue whales on the Madagascar Plateau, December 1996. *Journal of Cetacean Research and Management 5*(3), 253-260.

Bettridge, S., Baker, C. S., Barlow, J., Clapham, P. J., Ford, M., Gouveia, D., Mattila, D. K., Pace, III, R. M., Rosel, P. E., Silber, G. K., & Wade, P. R. (2015). *Status review of the humpback whale (Megaptera novaeangliae) under the Endangered Species Act.* (NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-540). La Jolla, CA: Southwest Fisheries Service, National Marine Fisheries Service.

Bigg, M. (1981). Harbour seal *Phoca vitulina* and *P. largha*. In S. H. Ridgway & R. J. Harrison (Eds.), *Handbook of marine mammals*. San Diego, CA: Academic Press.

Bjorge, A., & K. A. Tolley. (2009). Harbor porpoise *Phocoena phocoena*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 530-533). New York, NY: Academic Press.

Bjørge, A., & K. A. Tolley. (2009). Harbor porpoise *Phocoena phocoena*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), (pp. 530-533). San Diego, CA: Elsevier.

Bjorndal, K. A. (1997). Feeding ecology and nutrition in sea turtles. In P. Lutz & J. A. Musick (Eds.), *The biology of sea turtles* (pp. 199-231). Boca Raton, FL: CRC Press.

Black, N. (2009). Pacific white-sided dolphin *Lagenorhynchus obliquidens*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 817-819). New York, NY: Academic Press.

Black, N. A. (1994). *Behavior and ecology of Pacific white-sided dolphins (Lagenorhynchus obliquidens) in Monterey Bay, California.* (Unpublished Masters thesis). San Francisco State University, San Francisco, CA.

Blackwell, S. B., T. L. McDonald, K. H. Kim, L. A. M. Aerts, W. J. Richardson, C. R. Greene Jr, & B. Streever. (2012). Directionality of bowhead whale calls measured with multiple sensors. *Marine Mammal Science, 28*(1), 200-212. doi:10.1111/j.1748-7692.2011.00464.x.

Blanco, G. S., S. J. Morreale, J. A. Seminoff, F. V. Paladino, R. Piedra, & J. R. Spotila. (2013). Movements and diving behavior of internesting green turtles along Pacific Costa Rica. *Integrated Zoology 8*(3), 293-306. doi:10.1111/j.1749-4877.2012.00298.x.

Blumenthal, J. M., T. J. Austin, J. B. Bothwell, A. C. Broderick, G. Ebanks-Petrie, J. R. Olynik, M. F. Orr, J. L. Solomon, M. J. Witt, & B. J. Godley. (2009). Diving behavior and movements of juvenile hawksbill turtles *Eretmochelys imbricata* on a Caribbean coral reef. *Coral Reefs, 28*(1), 55-65. doi:10.1007/s00338-008-0416-1.

Bocast, C., Bruch, R. M., & Koenigs, R. P. (2014). Sound production of spawning lake sturgeon (*Acipenser fulvescens* Rafinesque, 1817) in the Lake Winnebago watershed, Wisconsin, USA. *Journal of Applied Ichthyology, 30*,1186–1194.

Bolten, A. (2003). Active swimmers—passive drifters: the oceanic juvenile stage of loggerheads in the Atlantic system. In A. B. Bolten & B. Witherington (Eds.), *Loggerhead Sea Turtles* (pp. 63-78). Washington, DC: Smithsonian Instituion Press.

Bonner, W. N. (1990). *The natural history of seals*. New York, NY: Facts on File.

Born, E. W., J. Teilmann, M. Acquarone, & F. F. Riget. (2004). Habitat use of ringed seals, Phoca hispida, in the North Water area (north Baffin Bay). *Arctic, 57*(2), 129-142.

Bort, J., S. M. Van Parijs, P. T. Stevick, E. Summers, and S. Todd. (2015). North Atlantic right whale Eubalaena glacialis vocalization patterns in the central Gulf of Maine from October 2009 through October 2010. *Endangered Species Research, 26*(3), 271-280. doi:10.3354/esr00650.

Bøthun, G., Skaug, H. J., & Øien, N. I. (2008). *Towards an estimate of minke whale abundance in the Northeast Atlantic based on survey data collected over the period 2002-2007*. (Unpublished Scientific Committee meeting document number SC/60/PFI4). Cambridge, UK: International Whaling Commission.

Boveng, P. L., Bengtson, J. L., Buckley, T. W., Cameron, M. F., Dahle, S. P., Kelly, B. P., Megrey, B. A., Overland, J. E., & Williamson, N. J. (2009). *Status review of the spotted seal (Phoca largha).* (NOAA Technical Memorandum NMFS-AFSC-200). Seattle, WA: Alaska Fisheries Science Center, National Marine Fisheries Service.

Boveng, P. L., Bengtson, J. L., Cameron, M. F., Dahle, S. P., Logerwell, E. A., London, J. M., Overland, J. E., Sterling, J. T., Stevenson, D. E., Taylor, B. L., & Ziel, H. L. (2013). *Status review of the ribbon seal.* (NOAA Technical Memorandum NMFS-AFSC-255). Seattle, WA: Alaska Fisheries Science Center, National Marine Fisheries Service.

Bowen, B. W., F. A. Abreu-Grobois, G. H. Balazs, N. Kamezaki, C. J. Limpus, & R. J. Ferl. (1995). Trans-Pacific Migrations of the Loggerhead Turtle (*Caretta caretta*) Demonstrated with Mitochondrial DNA Markers. *Proceedings of the National Academy of Sciences of the United States of America, 92*(9), 3731-3734.

Bowen, D. W., C. A. Beck, & D. A. Austin. (2009). Pinniped ecology. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 852-861). San Diego, CA: Academic Press.

Boyd, I. L. (2009). Pinniped life history. In W. F. Perrin, B. Würsig, &J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 868-873). San Diego, CA: Academic Press.

Boyle, M. C., N. N. Fitzsimmons, C. J. Limpus, S. Kelez, X. Velez-Zuazo, & M. Waycott. (2009). Evidence for transoceanic migrations by loggerhead sea turtles in the southern Pacific Ocean. Proc Biol Sci, 276(1664), 1993-1999. doi:10.1098/rspb.2008.1931

Bradford, A.L., K.A. Forney, E.M. Oleson, & J. Barlow. (2012). *Line-transect abundance estimates of false killer whales (Pseudorca crassidens) in the pelagic region of the Hawaiian Exclusive Economic Zone and in the insular waters of the Northwestern Hawaiian Islands.* (Pacific Islands Fishery Science Center Administration Report H-12-02). Honolulu, HI: Pacific Islands Fishery Science Center, National Marine Fisheries Service.

Bradford. A. L., Forney, K. A., Oleson, E. M., & Barlow, J. (2013). *Line-transect abundance estimates of cetaceans in the Hawaiian EEZ*. (PIFSC Working Paper WP-13-004; PSRG-2013-18). Honolulu, HI: Pacific Islands Fishery Science Center, National Marine Fisheries Service.

Bradford, A. L., Forney, K. A., Oleson, E. M., & Barlow, J. (2014). Accounting for subgroup structure in line-transect abundance estimates of false killer whales (*Pseudorca crassidens*) in Hawaiian waters. *PLoS ONE 9*(2), e90464. doi:10.1371/journal.pone.0090464.

Bradford, A. L., Oleson, E. M., Baird, R. W., Boggs, C. H., Forney, K. A., & Young, N. C. (2015). *Revised stock boundaries for false killer whales (Pseudorca crassidens) in Hawaiian waters.* (NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-47). Honolulu, HI: Pacific Islands Fishery Science Center, National Marine Fisheries Service.

Braham, H. W. (1984). The bowhead whale, *Balaena mysticetus*. *Marine Fisheries Review, 46*(4), 45-53.

Brainard, R. E., Birkeland, C., Eakin, C. M., McElhany, P., Miller, M. W., Patterson, M., & Piniak, G. A. (2011). *Status review report of 82 candidate coral species petitioned under the U.S. Endangered Species Act*. (NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-27). Honolulu, HI: Pacific Islands Fishery Science Center, National Marine Fisheries Service.

Branch, T. A., and D. S. Butterworth. (2001). Southern Hemisphere minke whales: Standardised abundance estimates from the 1978/79 to 1997/98 IDCR-SOWER surveys. *Journal of Cetacean Research and Management, 3*(2), 143-174.

Branch, T. A., & Butterworth, D. S. (2001). Estimates of abundance south of 60°S for cetacean species sighted frequently on the 1978/79 to 1997/98 IWC/IDCR-SOWER sighting surveys. *Journal of Cetacean Research and Management, 3*(3), 251-270.

Branch, T. A., K. M. Stafford, D. M. Palacios, C. Allison, J. L. Bannister, C. L. K. Burton, E. Cabrera, C. A. Carlson, B. G. vernazzani, P. C. Gill, R. Hucke-gaete, K. C. S. Jenner, M.-N. M. Jenner, K. Matsuoka, Y. A. Mikhalev, T. Miyashita, M. G. Morrice, S. Nishiwaki, V. J. Sturrock, D. Tormosov, R. C. Anderson, A. N. Baker, P. B. Best, P. Borsa, R. L. B. jr, S. Childerhouse, K. P. Findlay, T. Gerrodette, A. D. Ilangakoon, M. Joergensen, B. Kahn, D. K. Ljungblad, B. Maughan, R. D. Mccauley, S. Mckay, T. F. Norris, Oman whale and dolphin research group, S. Rankin, F. Samaran, D. Thiele, K. V. Waerebeek, & R. M. Warneke. (2007). Past and present distribution, densities and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean. *Mammal Review, 37*(2), 116–175. doi:10.1111/j.1365-2907.2007.00106.x.

Braulik, G. T., S. Ranjbar, F. Owfi, T. Aminrad, S. M. H. Dakhteh, E. Kamrani, & F. Mohsenizadeh. (2010). Marine mammal records from Iran. *Journal of Cetacean Research and Management, 11*(1), 49-63.

Breese, D., & B. R. Tershy. (1993). Relative abundance of Cetacea in the Canal de Ballenas, Gulf of California. *Marine Mammal Science, 9*(3), 319-324.

Brewer, P. G., & K. Hester. (2009). Ocean acidification and the increasing transparency of the ocean to low-frequency sound. *Oceanography, 22*(4), 86-93.

Brill, R. W., G. H. Balazs, K. N. Holland, R. K. C. Chang, S. Sullivan, & J. George. (1995). Daily movements, habitat use, and submergence intervals of normal and tumor-bearing juvenile green turtles (*Chelonia mydas* L.) within a foraging area in the Hawaiian islands. *Journal of Experimental Marine Biology and Ecology, 185*, 203-218.

Brodie, P. F. (1989). The white whale—*Delphinapterus leucas*. In S. H. Ridgeway & R. J. Harrisom (Eds.), *Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales* (pp. 119-144). San Diego, CA: Academic Press.

Brown, D. H., D. K. Caldwell, & M. C. Caldwell. (1966). Observations on the behavior of wild and captive false killer whales, with notes on associated behavior of other genera of captive delphinids. *Los Angeles County Museum Contributions in Science, 95*, 1-32.

Brownell, R. L., Jr., & C. Chun. (1977). Probable existence of the Korean stock of the gray whale (*Eschrichtius robustus*). *Journal of Mammalogy, 58*(2), 237-239.

Buchan, S. J., K. M. Stafford, and R. Hucke-Gaete. (2015). Seasonal occurrence of southeast Pacific blue whale songs in southern Chile and the eastern tropical Pacific. Marine Mammal Science, 31(2), 440-458. doi:10.1111/mms.12173

Buckland, S.T., Cattanach, K. L., & Miyashita, T. (1992). Minke whale abundance in the northwest Pacific and the Okhotsk Sea, estimated from 1989 and 1990 sighting surveys. *Report of the International Whaling Commission, 42*, 387-392.

Buckland, S.T., Cattanach, K. L., and Hobbs, R. C. (1993). Abundance estimates of Pacific white-sided dolphin, northern right whale dolphin, Dall's porpoise and northern fur seal in the North Pacific, 1987-1990. *International North Pacific Fisheries Commission Bulletin, 53*, 387-407.

Budelmann, B. U. (1994). Cephalopod sense organs, nerves and the brain: Adaptations for high performance and life style. Marine and Freshwater Behaviour and Physiology, 25(1-3), 13-33.

Budelmann, B. U., and R. Williamson. (1994). Directional sensitivity of hair cell afferents in the octopus statocyst. Journal of Experimental Biology 187, 187(1), 245-259.

Buerki, C. B., T. W. Cranford, K. M. Langan, and K. L. Marten. (1989). *Acoustic recordings from two stranded beaked whales in captivity.* Paper presented at the Abstracts of the 8th Biennial Conference on the Biology of Marine Mammals,, Pacific Grove, California.

Buran, B. N., X. Deng, and A. N. Popper. (2005). Structural variation in the inner ears of four deep-sea elopomorph fishes. Journal of Morphology, 265(2), 215-225.

Burgess, W. C., P. L. Tyack, B. J. LeBoeuf, and D. P. Costa. (1998). A programmable acoustic recording tag and first results from free-ranging northern elephant seals. Deep Sea Research Part II: Topical Studies in Oceanography, 45(7), 1327-1351.

Burgner, R. L. (1991). Life history of sockeye salmon (*Oncorhynchus nerka*). Pages 1-117 in Groot, C. & L. Margolis, eds. *Pacific salmon life histories*. Vancouver, British Columbia: UBC Press.

Burns, J. J. (1981). Ribbon seal *Phoca fasciata* Zimmerman, 1783. *Handbook of marine mammals, Vol. 2: Seals* (pp. 89-109). New York, NY: Academic Press.

Burns, J. J. (2009). Harbor seal and spotted seal *Phoca vitulina* and *P. largha.* In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), (pp. 533-542). San Diego, CA: Elsevier.

Burton, E. J., & Lea, R. N. (2013). *Checklist of fishes known to occur in Monterey Bay National Marine Sanctuary*. Monterey Bay National Marine Sanctuary Technical Report. Retrieved from <http://montereybay.noaa.gov/research/techreports/mbnms_fishes_checklist.pdf>.

Busby, P., Grant, S., Iwamoto, R., Kope, R., Mahnken, C., Matthews, G., Myers, J., Roni, P., Schiewe, M., Teel, D., Wainwright, T., Waknitz, F.W., Waples, R., Williams, J., Bryant, G., Wingert, C., Lindley, S., Adams, P., Wetheimer, A., & Reisnbichler, R. (1997). *Reivew of the status of Chinook salmon (Oncorhynchus tshawytscha) from Washington, Oregon, California, and Idaho under the U.S. Endangered Species Act.* National Marine Fisheries Service. 448 pages.

Busby, P. J., Wainwright, T. C., Bryant, G. J., Lierheimer, L. J., Waples, R. S., Waknitz, F. W., & Lagomarsino, I. V. (1996). *Status review of west coast steelhead from Washington, Idaho, Oregon, and California.* NOAA Technical Memorandum NMFS-NWFSC-27. National Marine Fisheries Service, Northwest Fisheries Science Center. 261 pages.

Buscaino, G., G. Buffa, F. Filiciotto, V. Maccarrone, V. Di Stefano, M. Ceraulo, S. Mazzola, & G. Alonge. (2015). Pulsed signal properties of free-ranging bottlenose dolphins (*Tursiops truncatus*) in the central Mediterranean Sea. Marine Mammal Science, 31(3), 891-901. doi:10.1111/mms.12194.

Busnel, R. G., & A. Dzeidzic. (1966). Acoustic signals of the pilot whale *Globicephala melaena* and of the porpoises *Delphinus delphis* and *Phocoena phocoena.* Pages 606-646 in *Whales, dolphins and porpoises*. Los Angeles, CA: University of California Press.

Busnel, R. G., and Z. Dziedzic. (1968). Caracteristiques physiques des signaux acoustiques de pseudorca crassidens owen (cetaces odontocetes). Extrait de Mammalia, 32(1), 1-5.

Byrne, R., J. Fish, T. K. Doyle, and J. D. R. Houghton. (2009). Tracking leatherback turtles (*Dermochelys coriacea*) during consecutive inter-nesting intervals: Further support for direct transmitter attachment. Journal of Experimental Marine Biology and Ecology, 377(2), 68-75. doi:10.1016/j.jembe.2009.06.013

Calambokidis, J. (2013). Updated abundance estimates of blue and humpback whales off the US west coast incorporating photo-identifications from 2010 and 2011. *Document PSRG-2013-13 presented to the Pacific Scientific Review Group, April 2013, Southwest Fisheries Science Center, National Marine Fisheries Service.*

Calambokidis, J., Falcone, E. A., Quinn, T. J., Burdin, A. M., Clapham, P. J., Ford, J.K.B., Gabriele, C.M., Leduc, R., Mattila, D., Rojas-Bracho, L., Straley, J. M., Taylor, B.L., Urbán R., J., Weller, D., Witteveen, B.H., Yamaguchi, M., Bendlin, A., Camacho, D., Flynn, K., Havron, A., Huggins, J., & Maloney, N. (2008). *SPLASH: Structure of populations, levels of abundance and status of humpback whales in the North Pacific.* (Final report for Contract AB133F-03-RP-00078, Report prepared for U.S. Department of Commerce, Western Administrative Center, Seattle, Washington). Olympia, WA: Cascadia Research.

Calderan, S., B. Miller, K. Collins, P. Ensor, M. Double, R. Leaper, and J. Barlow. (2014). Low-frequency vocalizations of sei whales (*Balaenoptera borealis*) in the Southern Ocean. The Journal of the Acoustical Society of America, 136(6), EL418-EL423. doi:10.1121/1.4902422

Caldwell, D. K. (1971). The pygmy killer whale in the western atlantic with a summery of world records. Journal of Mammalogy, 52(1), 207-209.

Caldwell, D. K., and M. C. Caldwell. (1989). Pygmy sperm whale Kogia breviceps (de Blainville, 1838): Dwarf sperm whale Kogia simus Owen, 1866 *Handbook of marine mammals, Vol. 4: River dolphins and the larger toothed whales* (pp. 234-260): Academic Press.

Caldwell, M. C., and D. K. Caldwell. (1969). Simultaneous but different narrow-band sound emissions by a captive eastern Pacific pilot whale, *Globicephala scammoni*. Mammalia, 33, 505-508.

Cameron, M. F., Bengtson, J. L., Boveng, P. L., Jansen, J. K., Kelly, B. P., Dahle, S. P., Logerwell, E. A., Overland, J. E., Sabine, C. L., Waring, G. T., and Wilder, J. M. (2010). Status review of the bearded seal (*Erignathus barbatus*). U.S. Dep. Commer., NOAA Technical Memorandum NMFS-AFSC-211. 246 pages.

Campagna, C., R. Werner, W. Karesh, M. R. Marín, F. Koontz, R. Cook, and C. Koontz. (2001). Movements and location at sea of South American sea lions (*Otaria avescens*). Journal of Zoology, 257, 205-220.

Cañadas, A., Macleod, K., Mikkelsen, B., Rogan, E, Uriarte, A., Vazquez, J.A., Van Canneyt, O., & Hammond, P. S. (2011). Abundance and distribution of beaked whales in the European Atlantic. *Paper presented to the IWC Scientific Committee, May 2011 SC/63/SM13. IWC, Cambridge*. Retrieved from <https://iwc.int/private/downloads/Tvt6CI11eSpzWfsVCViSxw/SC-63-SM13.pdf>.

Cañadas, A., and Vázquez, J. A. (2014). Conserving Cuvier's beaked whales in the Alboran Sea (SW Mediterranean): Identification of high density areas to be avoided by intense man-made sound. *Biological Conservation 178*, 155-162.

Cappozzo, H. L., and W. F. Perrin. (2009). South American Sea Lion *Otaria flavescens*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 1076-1079): Academic Press.

Carder, D., S. H. Ridgway, B. Whitaker, and J. Geraci. (1995). *Hearing and echolocation in a pygmy sperm whale Kogia.* Paper presented at the 11th biennial conference on the biology of marine mammals, Orlando, FL.

Carretta, J. V., Forney, K. A., Oleson, E., Martien, K., Muto, M. M., Lowry, M. S., Barlow, J., Baker, J., Hanson, B., Lynch, D., Carswell, L., Brownell, Jr., R. L., Robbins, R., Mattila, D. K., Ralls, K., & Hill, M. C. (2011). *U.S. Pacific marine mammal stock assessments: 2010*. (NOAA-TM-NMFS-SWFSC-476). La Jolla, CA: Southwest Fisheries Science Center, National Marine Fisheries.

Carretta, J. V., Oleson, E., Weller, D. W., Lang, A. R., Forney, K. A., Baker, J., Hanson, B., Martien, K., Muto, M. M., Orr, A. J., Huber, H., Lowry, M. S., Barlow, J., Lynch, D., Carswell, L., Brownell, Jr, R. L., & Mattila, D. K. (2014). *U.S. Pacific Marine Mammal Stock Assessments, 2013.* (NOAA-TM-NMFS-SWFSC-532). LaJolla, CA: Southwest Fisheries Science Center, National Marine Fisheries Service.

Carretta, J. V., Oleson, E. M., Weller, D. W. , Lang, A. R., Forney, K. A., Baker, J., Muto, M. M., Hanson, B., Orr, A. J., Huber, H., Lowry, M. S., Barlow, J., Moore, J. E., Lynch, D., Carswell, L., & Brownell, Jr., R. L. (2015). *U.S. Pacific Marine Mammal Stock Assessments: 2014*. (NOAA-TM-NMFS-SWFSC-549). LaJolla, CA: Southwest Fisheries Science Center, National Marine Fisheries Service. doi:10.7289/V5/TM-SWFSC-549.

Carretta, J. V., Oleson, E. M., Baker, J., Weller, D. W. , Lang, A. R., Forney, K. A., Muto, M. M., Hanson, B., Orr, A. J., Huber, H., Lowry, M. S., Barlow, J., Moore, J. E., Lynch, D., Carswell, L., & Brownell, Jr., R. L. (2016). *U.S. Pacific Marine Mammal Stock Assessments: 2015*. (NOAA-TM-NMFS-SWFSC-561). LaJolla, CA: Southwest Fisheries Science Center, National Marine Fisheries Service. doi:10.7289/V5/TM-SWFSC-561.

Carroll, E. L., W. J. Rayment, A. M. Alexander, C. S. Baker, N. J. Patenaude, D. Steel, R. Constantine, R. Cole, L. J. Boren, and S. Childerhouse. (2014). Reestablishment of former wintering grounds by New Zealand southern right whales. Marine Mammal Science, 30(1), 206-220. doi:10.1111/mms.12031

Casper, B. (2011). The Ear and Hearing in Sharks, Skates, and Rays *Encylopedia of Fish Physiology* (pp. 262-269).

Casper, B. M., P. S. Lobel, and H. Y. Yan. (2003). The hearing sensitivity of the little skate, *Rana erinacea*: A comparison of two methods. Environmental Biology Of Fishes, 68, 371-379.

Casper, B. M., and D. A. Mann. (2006). Evoked Potential Audiograms of the Nurse Shark (*Ginglymostoma cirratum*) and the Yellow Stingray (*Urobatis jamaicensis*). Environmental Biology Of Fishes, 76(1), 101-108. doi:10.1007/s10641-006-9012-9

Casper, B. M., and D. A. Mann. (2007). The directional hearing abilities of two species of bamboo sharks. J Exp Biol., 210(3), 505-511.

Casper, B. M., and D. A. Mann. (2009). Field hearing measurements of the Atlantic sharpnose shark Rhizoprionodon terraenovae. J Fish Biol, 75(10), 2768-2776. doi:10.1111/j.1095-8649.2009.02477.x

Casper, B. M., Halvorsen, M. B., Popper, A. N. (2012). Are sharks even bothered by a noisy environment? Pages 93-97 in A.N. Popper, and A. Hawkins, eds. *The effects of noise on aquatic life.* Advances in Experimental Medicine and Biology, Volume 730. Springer: New York.

Castellote, M., C. W. Clark, and M. O. Lammers. (2012). Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. Biological Conservation, 147(1), 115-122. doi:10.1016/j.biocon.2011.12.021

Castellote, M., T. A. Mooney, L. Quakenbush, R. Hobbs, C. Goertz, and E. Gaglione. (2014). Baseline hearing abilities and variability in wild beluga whales (*Delphinapterus leucas*). *The Journal of Experimental Biology,* 217(Pt 10), 1682-1691. doi:10.1242/jeb.093252

Cattanach, K. L., Sigurjonsson, J., Buckland, S. T., & Gunnlaugsson. T. (1993). Sei whale abundance in the North Atlantic, estimated from NASS-87 and NASS-89 data. (*Balaenoptera borealis*). *Report of the International Whaling Commission SC/44/Nab10, 43*, 315-321.

Cerchio, S., B. Andrianantenaina, A. Lindsay, M. Rekdahl, N. Andrianarivelo, and T. Rasoloarijao. (2015). Omura's whales (*Balaenoptera omurai*) off northwest Madagascar: ecology, behaviour and conservation needs. Royal Society Open Science, 2(10), 150301. doi:10.1098/rsos.150301

Cerchio, S., S. Strindberg, T. Collins, C. Bennett, and H. Rosenbaum. (2014). Seismic Surveys Negatively Affect Humpback Whale Singing Activity off Northern Angola. PloS one, 9(3), e86464. doi:10.1371/journal.pone.0086464

Chaloupka, M., P. Dutton, and H. Nakano. (2004). Status of sea turtle stocks in the Pacific (FAO Fisheries Report No. 738)

Channel Islands National Marine Sanctuary (CINMS). (2011). *Channel Islands shipwrecks*. Channel Islands NMS, Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://sanctuaries.noaa.gov/shipwrecks/pdfs/shipwreck_final.pdf>.

Chapman, C. J. (1973). Field studies of hearing in teleost fish. *Helgoland Marine Research, 24*(1), 371-390.

Chapman, C. J., & Hawkins, A. D. (1973). A field study of hearing in the cod, *Gadus morhua* L. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology, 85*(2), 147-167.

Chapman, N. R., and Price, A. (2011). Low frequency deep ocean ambient noise trend in the Northeast Pacific Ocean. *The Journal of the Acoustical Society of America, 129*(5), EL161-165. doi:10.1121/1.3567084.

Chapman, C. J., and O. Sand. (1974). Field studies of hearing in two species of flatfish *Pleuronectes platessa* (L.) and *Limanda limanda* (L.) (Family Pleuronectidae). *Comp. Biochem. Physiol., 47A*, 371-385.

Chapman, F.A., Hartless, C. S., & Carr, S. H. (1997). Population size estimates of sturgeon in the Suwannee River, Florida, U.S.A. *Gulf of Mexico Science, 15*(2), 88-91.

Charif, R. A., D. K. Mellinger, K. J. Dunsmore, and C. W. Clark. (2002). Estimated source levels of fin whale *(Balaenoptera physalus)* vocalizations: Adjustments for surface interference. Marine Mammal Science, 18(1), 81-98.

Charif, R. A., A. Rahaman, C. A. Muirhead, M. S. Pitzrick, A. M. Warde, J. Hall, C. Pyć, and C. W. Clark. (2013). Bowhead whale acoustic activity in the southeast Beaufort Sea during late summer 2008–2010. The Journal of the Acoustical Society of America, 134(6), 4323. doi:10.1121/1.4824679

Chen, X. (2007). *Biological characteristics and current situation of resource of species of Acipenseriformes [in Chinese].* Beijing, China: Ocean Publishing House.

Chmelnitsky, E. G., and S. H. Ferguson. (2012). Beluga whale, *Delphinapterus leucas*, vocalizations from the Churchill River, Manitoba, Canada. The Journal of the Acoustical Society of America, 131(6), 4821-4835. doi:10.1121/1.4707501

Cholewiak, D., S. Baumann-Pickering, and S. Van Parijs. (2013). Description of sounds associated with Sowerby's beaked whales (*Mesoplodon bidens*) in the western North Atlantic Ocean. The Journal of the Acoustical Society of America, 134(5), 3905-3912. doi:10.1121/1.4823843

Christensen, I., Haug, T., & Oien, N. (1992). A review of feeding and reproduction in large baleen whales (Mysticeti) and sperm whales *Physeter macrocephalus* in Norwegian and adjacent waters. *Fauna norvegica Series A, 13*, 39-48.

Christensen, C. B., J. Christensen-Dalsgaard, C. Brandt, and P. T. Madsen. (2012). Hearing with an atympanic ear: good vibration and poor sound-pressure detection in the royal python, Python regius. *The Journal of Experimental Biology,* 215(Pt 2), 331-342. doi:10.1242/jeb.062539

Christensen, I., T. Haug, and N. Oien. (1992). A Review Of Feeding and Reproduction In Large Baleen Whales Mysticeti and Sperm Whales *Physeter macrocephalus* In Norwegian and Adjacent Waters. Fauna Norv Ser a*,* 13, 39-48.

Christiansen, F., N. M. Lynas, D. Lusseau, and U. Tscherter. (2015). Structure and dynamics of minke whale surfacing patterns in the gulf of st. Lawrence, Canada. PloS one*,* 10(5), e0126396. doi:10.1371/journal.pone.0126396

Chu, K. C. (1988). Dive times and ventilation patterns of singing humpback whales (*Megaptera novaeangliae*). Canadian Journal of Zoology*,* 66(6), 1322-1327.

Cipriano, F. (2009). Atlantic white-sided dolphin *Lagenorhynchus acutus*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (2nd ed.) (pp. 56-58). San Diego, CA: Academic Press.

Cipriano, F. W. (1992). *Behavior and occurrence patterns, feeding ecology, and life history of dusky dolphins (Lagenorhynchus obscurus) off Kaikoura, New Zealand.* (Ph.D.), University of Arizona.

Citta, J. J., R. S. Suydam, L. T. Quakenbush, K. J. Frost, and G. M. O'Corry-Crowe. (2013). Dive Behavior of Eastern Chukchi Beluga Whales (*Delphinapterus leucas*), 1998 – 2008. Arctic*,* 66(4), 389-406.

Clapham, P. J. (2009). Humpback whale (*Megaptera novaeangliae*). In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammalss* (pp. 582-585): Academic Press.

Clapham, P. J., L. S. Baraff, C. A. Carloson, M. A. Christian, D. K. Matilla, C. A. Mayo, M. A. Murphy, and S. Pittman. (1993). Seasonal occurrence and annual return of humpback whales, *Megaptera novaeangliae*, in the southern Gulf of Maine. Canadian Journal of Zoology*,* 71, 440-443.

Clapham, P. J., and D. K. Mattila. (1990). Humpback whale songs as indicators of migration routes. Marine Mammal Science*,* 6(2), 155-160.

Clark, C. W. (1980). A real-time direction finding device for determining the bearing to the underwater sounds of Southern Right Wales, *Eubalaena australis*. Journal of the Acoustical Society of America*,* 68(2), 508-511.

Clark, C. W. (1982). The acoustic repertoire of the Southern right whale, a quantitative analysis. Animal Behaviour*,* 30(4), 1060-1071.

Clark, C. W. (1983). Acoustic Communication and Behavior of the Southern Right Whale (*Eubalaena australis*). In R. Payne (Ed.), *Communication and Behavior of Whales* (pp. 163-198). Boulder, Colorado: Westview Press.

Clark, C. W. (1990). Acoustic behavior of mysticete whales. In J. Thomas and R. Kastelein (Eds.), *Sensory abilities of cetaceans* (pp. 580-583): Plenum Press.

Clark, C. W., J. F. Borsani, and G. Notarbartolo di Sciara. (2002). Vocal activity of fin whales, *Balaenoptera physalus*, in the Ligurian Sea. Marine Mammal Science, 18(1), 286-295.

Clark, C. W., and P. J. Clapham. (2004). Acoustic monitoring on a humpback whale (*Megaptera novaeangliae*) feeding ground shows continual singing into late spring. Proc R Soc Lond B Biol Sci, 271(1543), 1051-1057.

Clark, C. W., and W. T. Ellison. (2004). Potential use of low-frequency sounds by baleen whales for probing the environment: evidence from models and empirical measurements. In J. A. Thomas, C. F. Moss, and M. Vater (Eds.), *Advances in the study of echolocation in bats and dolphins* (pp. 564-589): University of Chicago Press.

Clark, C. W., and K. Fristrup. (1997). Whales '95: A combined visual and acoustic survey of blue and fin whales off southern California. Rep. Int. Whaling Comm., 47, 583-600.

Clark, C. W., M. L. Tasker, M. Ferguson, J. P. Hartley, J. Fletcher, A. Whitehead, A. A. Duff, J. F. Appelbee, C. Pickton, J. Spink, C. MacDuff-Duncan, S. J. Knight, A. H. Walls, A. Onder, J. Urbanus, and I. Buchanan. (1998). *Monitoring the Occurrence of Large Whales off North and West Scotland Using Passive Acoustic Arrays.* Paper presented at the IWC, Oman.

Clark, C. W., P. Tyack, and W. T. Ellison. (1999). Responses of Four Species of Whales to Sounds of SURTASS LFA Sonar Transmissions

Clarke, M. R. (1976). Observations on sperm whale diving. J. Mar. Biol. Assoc. UK, 56, 809-810.

Clarke, S. C., Magnussen, J. E., Abercrombie, D. L., McAllister, M. K., & Shivji, M. S. (2006). Identification of shark species composition and proportion in the Hong Kong shark fin market based on genetics and trade records. *Conservation Biology, 20*, 201-211.

Coffin, A., M. Kelley, G. A. Manley, and A. N. Popper. (2004). Evolution of sensory hair cells. In G. A. Manley, A. N. Popper, and R. R. Fay (Eds.), *Evolution of vertebrate auditory systems*. New York, New York: Springer-Verlag.

Cole, T. V. N., P. Hamilton, A. G. Henry, P. Duley, R. M. Pace, B. N. White, and T. Frasier. (2013). Evidence of a North Atlantic right whale *Eubalaena glacialis* mating ground. Endangered Species Research, 21(1), 55-64. doi:10.3354/esr00507

Coles, W. C., and J. A. Musick. (2000). Satellite Sea Surface Temperature Analysis and Correlation with Sea Turtle Distribution off North Carolina. Copeia, 2000(2), 551-554.

Compagno, L. J. V. (1984). *FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of sharks species known to date. Part 2: Carcharhiniformes.* FAO Fisheries Synopsis (125) Vol. 4, Pt. 2. Food and Agriculture Organization of the United Nations: Rome, Italy. 406 pages.

Compagno, L. A., Dando, M., & Fowler, S. (2005). *Sharks of the world*. Princeton, New Jersey: Princeton University Press.

Conant, T. A., P. H. Dutton, T. Eguchi, S. P. Epperly, C. C. Fahy, M. H. Godfrey, S. L. MacPherson, E. E. Possardt, B. A. Schroeder, J. A. Seminoff, M. L. Snover, C. M. Upite, and B. E. Witherington. (2009). Loggerhead sea turtle (Caretta caretta) 2009 status review under the U.S. Endangered Species Act. Report of the Loggerhead Biological Review Team to the National Marine Fisheries Service, August 2009

Conn, P. B., Ver Hoef, J. M., McClintock, B. T., Moreland, E. E., London, J. M., Cameron, M. F., Dahle, S. P., & Boveng, P. L. (2014). Estimating multispecies abundance using automated detection systems: Ice-associated seals in the Bering Sea. *Methods in Ecology and Evolution 5,* 1280-1293. doi: 10.1111/2041-210X.12127.

Considine, D. M. (Ed.) (1995). *Van Nostrand's scientific encyclopedia.* (8th ed.). New York, New York: Van Nostrand Reinhold.

Cook, M. L. H., C. A. Manire, and D. A. Mann. (2005). Auditory evoked potential (AEP) measurements in stranded rough-toothed dolphins (*Steno bredanensis*). Journal of the Acoustical Society of America, 117(4), 2441.

Cooke, J. G., Weller, D. ., Bradford, A. L., Sychenko, O. A., Burdin, A. M. and Brownell, R. L., Jr. (2013). Population assessment of the Sakhalin gray whale aggregation. (*Paper SC/65a/BRG27 presented to the International Whaling Commission Scientific Committee*). Retrieved from <http://www.iwcoffice.org/>.

Coombs, S., & Popper, A. N. (1979). Hearing differences among Hawaiian squirrelfish (family Holocentridae) related to differences in the peripheral auditory system. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology, 132*(3), 203-207.

Coombs, S., P. Gorner, and H. Munz. (1989). *The mechanosensory lateral line: Neurobiology and evolution*. New York, New York: Springer-Verlag.

Coombs, S., J. Janssen, and J. Montgomery. (1992). Functional and evolutionary implications of peripheral diversity in lateral line systems. In D. B. Webster, R. R. Fay, and A. N. Popper (Eds.), *The Evolutionary Biology of Hearing*. New York: Springer-Verlag.

Coombs, S., and J. C. Montgomery. (1999). The enigmatic lateral line system. In R. R. Fay and A. N. Popper (Eds.), *Comparative hearing: Fish and amphibians* (pp. 319–362). New York, New York:: Springer-Verlag.

Corkeron, P. J., and S. M. Van Parijs. (2001). Vocalizations of eastern Australian Risso's dolphins, *Grampus griseus*. Canadian Journal of Zoology, 79(1), 160-164.

Costa, D., and N. Gales. (2000). Foraging energetics and diving behavior of lactating New Zealand sea lions, *Phocarctos hookeri*. J. Exp. Biol., 203(23), 3655-3665.

Costa, D. P., and N. J. Gales. (2003). Energetics of a benthic diver: Seasonal foraging ecology of the Australian sea lion, *Neophoca cinerea*. Ecological Monographs, 73(1), 27-43.

Courbis, S., Baird, R. W., Cipriano, F., & Duffield, D. 2014. Multiple populations of pantropical spotted dolphins in Hawaiian waters. 2014. *Journal of Heredity, 105*(5), 627-614.

Cribb, N., C. Miller, and L. Seuront. (2013). Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) habitat preference in a heterogeneous, urban, coastal environment. Aquatic Biosystems, 9(3), 1-9.

Crocker, D. E., Gales, N.J., & Costa, D. P. (2001). Swimming speed and foraging strategies of New Zealand sea lions (*Phocarctos hookeri*). *Journal of Zoology, 254*, 267-277.

Croll, D. A., A. Acevedo-Gutierrez, B. R. Tershy, and J. Urban-Ramirez. (2001). The diving behavior of blue and fin whales: is dive duration shorter than expected based on oxygen stores? Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology, 129(4), 797-809.

Croll, D. A., C. W. Clark, A. Acevedo, B. Tershy, S. Floress, J. Gedamke, and J. Urban. (2002). Only male fin whales sing loud songs. Nature*,* 417, 809.

Croll, D. A., C. W. Clark, J. Calambokidis, W. T. Ellison, and B. R. Tershy. (2001). Effect of anthropogenic low-frequency noise on the foraging ecology of *Balaenoptera* whales. Animal Conservation*,* 4(1), 13-27.

Croll, D. A., B. R. Tershy, A. Acevedo, and P. Levin. (1999). Marine vertebrates and low frequency sound

Crowell, S.C. (2016). Measuring in-air and underwater hearing in seabirds. *Advances in Experimental Medicine and Biology, 875*, 1155-1160.

Crowell, S.E., Wells-Berlin, A.M., Carr, C.E., Olsen, G.H., Therrien, R.E., Yannuzzi, S.E., and Ketten, D.R. (2015). A comparison of auditory brainstem responses across diving bird species. *Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology*, doi 10.1007/s00359-00015-01024-00355.

Cruickshank, R. A., and S. G. Brown. (1981). Recent observations and some historical records of southern right-whale dolphins *Lissodelphis peronii*. Fish. Bull. S. Afr.*,* 15, 109-121.

Cummings, W. C. (1985). Bryde's whale *Balaenoptera edeni* Anderson, 1878. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of marine mammals, Vol. 3: The sirenians and baleen whales* (pp. 137-154). London: Academic Press.

Cummings, W. C., J. F. Fish, and P. O. Thompson. (1972). Sound production and other behavior of southern right whales, *Eubalena glacialis*. San Diego Soc. Nat. Hist., Trans.*,* 17(1), 1-14.

Cummings, W. C., Holliday, D. V., and Graham, B. J. (1981) *Measurements and localization of underwater sounds from the Prudhoe Region, Alaska, March, 1981; A report to OCSEAP, Arctic Project Office, and the Alaska Eskimo Whaling Commission*. Tracer Document T-82-SD-001. 50 pages.

Cummings, W. C., Holliday, D. V., and Lee, B. J. (1984). Potential impacts of manmade noise on ringed seals: Vocalizations and reactions. Outer Continental Shelf Environmental Assessment Program, Final Report. OCS Study MMS 86-0021; NTIS PB87-107546. Anchorage, AK: NOAA.

Cummings, W. C., and D. V. Holliday. (1987). Sounds and source levels from bowhead whales off Pt. Barrow, Alaska. Journal of the Acoustical Society of America*,* 82(3), 814-821.

Cummings, W. C., and P. O. Thompson. (1971). Underwater sounds from the blue whale, *Balaenoptera musculus*. Journal of the Acoustical Society of America*,* 50(4 (Part 2)), 1193-1198.

Cunningham, K. A., B. L. Southall, and C. Reichmuth. (2014). Auditory sensitivity of seals and sea lions in complex listening scenarios. The Journal of the Acoustical Society of America*,* 136(6), 3410. doi:10.1121/1.4900568

D'Vincent, C. G., R. M. Nilson, & R. E. Hanna. (1985). Vocalization and coordinated feeding behavior of the humpback whale *Megaptera novaeangliae* in southeastern Alaska USA. *Scientific Reports to the Whales Research Instititue of Tokyo, 0*(36), 41-48.

Dahlheim, M. E., and D. K. Ljungblad. (1990). Preliminary hearing study on gray whales *Eschrichtius robustus* in the field. In J. Thomas and R. Kastelein (Eds.), *Sensory Abilities of Cetaceans* (pp. 335-346). New York: Plenum Press.

Dahlheim, M. E., A. Schulman-Janiger, N. Black, R. Ternullo, D. Ellifritt, and K. C. Balcomb, III. (2008). Eastern temperate North Pacific offshore killer whales (*Orcinus orca*): Occurrence, movements, and insights into feeding ecology. Marine Mammal Science*,* 24(3), 719-729.

Dale, J. J., M. D. Gray, A. N. Popper, P. H. Rogers, and B. A. Block. (2015). Hearing thresholds of swimming Pacific bluefin tuna *Thunnus orientalis*. Journal of comparative physiology. A, Neuroethology, sensory, neural, and behavioral physiology*,* 201(5), 441-454. doi:10.1007/s00359-015-0991-x.

Dalebout, M. L., Robertson, K. M., Frantzis, A., Engelhaupt, D. A. N., Mignucci-Giannoni, A. A., Rosario-Delestre, R. J., & Baker, C. S. (2005). Worldwide structure of mtDNA diversity among Cuvier's beaked whales (*Ziphius cavirostris*): Implications for threatened populations. *Molecular Ecology, 14*, (11), 3353-3371.

Dalebout, M. L., Baker, C. S., Steel, D., Thompson, K., Robertson, K. M., Chivers, S. J., Perrin, W. F., Goonatilake, M., Anderson, R. C., Mead, J. G., Potter, C. W., Thompson, L., Jupiter, D., and Yamada, T. K. (2014). Resurrection of *Mesoplodon hotaula* Deraniyagala 1963: A new species of beaked whale in the tropical Indo-Pacific. *Marine Mammal Science, 30*(3), 1081-1108.

Davis, R. W. (2010, 1 December). [Personal communication via email between Dr. Randall W. Davis, Texas A&M University at Galveston, Galveston, Texas, and Ms. Cheryl Schroeder, Marine Acoustics, Inc., Arlington, Virginia,].

Davis, R. W., N. Jaquet, D. Gendron, U. Markaida, G. Bazzino, and W. Gilly. (2007). Diving behavior of sperm whales in relation to behavior of a major prey species, the jumbo squid, in the Gulf of California, Mexico. Marine Ecology Progress Series*,* 333, 291-302.

Dawbin, W. H., and D. H. Cato. (1992). Sounds of a pygmy right whale *Caperea marginata*. Mar Mamm Sci*,* 8(3), 213-219.

Dawson, S., J. Barlow, and D. Ljungblad. (1998). Sounds recorded from Baird's beaked whale, *Berardius bairdii*. Marine Mammal Science*,* 14(2), 335-344.

Dawson, S. M. (2009). Cephalorhynchus Dolphins *C. heavisidii, C. eutropia, C. hectori,* and *C. commersonii*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 191-196): Academic Press.

De Boer, M. N. (2000). A note on cetacean observations in the Indian Ocean Sanctuary and the South China Sea, Mauritius to the Philippines, April 1999. Journal of Cetacean Research and Management*,* 2(3), 197-200.

de Freitas, M., F. H. Jensen, J. Tyne, L. Bejder, and P. T. Madsen. (2015). Echolocation parameters of Australian humpback dolphins (*Sousa sahulensis*) and Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in the wild. The Journal of the Acoustical Society of America*,* 137(6), 3033. doi:10.1121/1.4921277.

de Moura, J. F., B. P. S. di Dario, L. M. Lima, and S. Siciliano. (2010). A stranded pygmy killer whale on the coast of Rio de Janeiro State, Brazil. Marine Biodiversity Records*,* 3(e11).

de Vos, A., F. Christiansen, R. G. Harcourt, and C. B. Pattiaratchi. (2013). Surfacing characteristics and diving behaviour of blue whales in Sri Lankan waters. Journal of Experimental Marine Biology and Ecology*,* 449, 149-153. doi:10.1016/j.jembe.2013.09.010.

de Vos, A., C. Pattiaratchi, and R. Harcourt. (2014). Inter-Annual Variability in Blue Whale Distribution off Southern Sri Lanka between 2011 and 2012. Journal of Marine Science and Engineering*,* 2(3), 534-550. doi:10.3390/jmse2030534

Delarue, J., M. Laurinolli, and B. Martin. (2009). Bowhead whale (*Balaena mysticetus*) songs in the Chukchi Sea between October 2007 and May 2008. Journal of the Acoustical Society of America*,* 126(6), 3319-3328.

Delarue, J., B. Martin, and D. Hannay. (2013). Minke whale boing sound detections in the northeastern Chukchi Sea. Marine Mammal Science*,* 29(3), E333-E341. doi:10.1111/j.1748-7692.2012.00611.x.

Dendrinos, P., A. A. Karamanlidis, E. Androukaki, and B. J. McConnell. (2007). Diving development and behavior of a rehabilitated Mediterranean monk seal (*Monachus monachus*). Marine Mammal Science*,* 23(2), 387-397. doi:10.1111/j.1748-7692.2007.00115.x.

Deng, X., H. J. Wagner, and A. N. Popper. (2013). Interspecific variations of inner ear structure in the deep-sea fish family Melamphaidae. *Anatomical Record, 296*(7), 1064-1082. doi:10.1002/ar.22703.

Department of Fisheries and Oceans Canada (DFO). (2011). Recovery potential assessment for northern bottlenose whales (*Hyperoodon ampullatus*) in Canada. *Canadian Science Advisory Secretariat Science Advisory Report 2011/031*.

DFO. (2014). Status of northwest Atlantic harp seals, *Pagophilus groenlandicus*. *Canadian Science Advisory Secretariat Science Advisory Report 2014/011.*

Department of the Interior (DoI). (2014.) Endangered and threatened wildlife and plants; Designation of critical habitat for the northwest Atlantic Ocean distinct population segment of the loggerhead sea turtle; Final rule. U.S. Fish and Wildlife Service, Department of the Interior. *Federal Register 79*(132), 39756-39854.

Department of the Navy (DoN). (2001). *Final overseas environmental impact statement and environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, DC: Chief of Naval Operations, Department of the Navy.*

DoN. (2005). *Marine resource assessment for the Northeast Operating Areas: Atlantic City, Narragansett Bay, and Boston*. Norfolk, VA: Naval Facilities Command Atlantic.

DoN. (2007). *Final supplemental environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar.* Washington, D.C.: Chief of Naval Operations, Department of the Navy. http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS.pdf; <http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS_V2.pdf>.

DoN. (2007). *Marine resources assessment for the Charleston/Jacksonville operating areas*. (Contract #N62470-02-D-9997). Norfolk, VA: Naval Facilities Command Atlantic.

DoN. (2012). *Final supplemental environmental impact statement/supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar.* Washington, D.C.: Chief of Naval Operations, Department of the Navy. <http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS-SOEIS.pdf>.

DoN. (2013). *Request for letter of authorization for the incidental harassment of marine mammals resulting from Navy training activities in the Mariana Islands training and testing areas.* Pearl Harbor, Hawaii: Commander, United States Pacific Fleet.

DoN. (2014). *Final sea turtle marine resources survey report in support of the Commonwealth of the Northern Mariana Islands Joint Military Training environmental impact statement/overseas environmental impact statement*. Prepared for Naval Facilities Engineering Command, Pacific, Honolulu, HI. Prepared by Tetra Tech, Inc., Oakland, CA.

DoN. (2015). *Final supplemental environmental impact statement/supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar*. Washington, D.C.: Chief of Naval Operations, Department of the Navy.

DoN. (2016). Navy marine species density database. Geospatial global database. Accessed March, April, May, 2016. Chief of Naval Operations, DoN.

Doyle, T. K., Houghton, J. D. R., O'Súilleabháin, P. F., Hobson, V. J., Marnell, F., Davenport, J., & Hays, G. C. (2008). Leatherback turtles satellite-tagged in European waters. *Endangered Species Research, 4*, 23-31. doi:doi: 10.3354/esr00076.

Díaz López, B. (2011). Whistle characteristics in free-ranging bottlenose dolphins (*Tursiops truncatus*) in the Mediterranean Sea: Influence of behaviour. *Mammalian Biology-Zeitschrift fur Saugetierkunde, 76*(2), 180-189. doi:10.1016/j.mambio.2010.06.006.

Diercks, K. J., R. T. Trochta, and W. E. Evans. (1973). Delphinid sonar: measurement and analysis. Journal of the Acoustical Society of America*,* 54(1), 200-204.

Diercks, K. J., R. T. Trochta, C. F. Greenlaw, and W. E. Evans. (1971). Recording and analysis of dolphin echolocation signals. Journal of the Acoustical Society of America*,* 49(6), 1729-1732.

Dodd, C. K. (1988). Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeus 1758). U.S. Fish and Wildlife Service Biological Report*,* 88(14), 1-110.

Dodd, C. K., Jr, and R. Byles. (2003). Post-Nesting Movements and Behavior of Loggerhead Sea Turtles (*Caretta caretta*) Departing from East-Central Florida Nesting Beaches. Chelonian Conservation and Biology*,* 4(3).

Dohl, T. P., R. C. Guess, M. L. Duman, and R. C. Helm. (1983). Cetaceans of central and northern California, 1980-1983: Status, abundance, and distribution. Santa Cruz, California

Dolar, M. L. L., W. A. Walker, G. L. Kooyman, and W. F. Perrin. (2003). Comparative feeding ecology of spinner dolphins (*Stenella longirostris*) and Fraser's dolphins (*Lagenodelphis hosei*) in the Sulu Sea. *Marine Mammal Science, 19*(1), 1-19.

Dolar, M. L. (2005). *Cetaceans of American Samoa*. Pago Pago, American Samoa: Department of Marine and Wildlife Resources, Government of American Samoa.

Dolar, M. L. L., W. F. Perrin, B. L. Taylor, G. L. Kooyman, & M. N. R. Alava. (2006). Abundance and distributional ecology of cetaceans in the central Philippines. *Journal of Cetacean Research and Management, 8*(1), 93-111.

Dolar, M. L. L. (2009). Fraser's dolphin *Lagenodelphis hosei*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals, 2nd Ed,* (pp. 469-471). San Diego, CA: Academic Press.

Dolphin, W. F. (1987). Dive behavior and estimated energy expenditure of foraging humpback whales in southeast Alaska. *Canadian Journal of Zoology, 65*(2), 354-362.

Donahue, M., & Perryman, W. L. . (2009). Pygmy killer whale *Feresa attenuata*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals, 2nd Ed* (pp. 938-939). San Diego, CA: Academic Press.

Doney, S. C., W. M. Balch, V. J. Fabry, & R. A. Feely. (2009). Ocean acidification: A critical emerging problem for the ocean sciences. Oceanography*,* 22, 16-25.

Donovan, G. P. (1991). A review of IWC stock boundaries. *Report of the International Whaling Commission, 0*(0), 39-68.

Dorsey, E. M., S. J. Stern, A. R. Hoelzel, & J. Jacobsen. (1990). Minke whales (*Balaenoptera acutorostrata*) from the west coast of North America: Individual recognition and small-scale site fidelity. *Special Report of the International Whaling Commission Special Issue 12* (Vol. 12, pp. 357-368.).

dos Santos, M. E., G. Caporin, H. Moreira, A. J. Ferreira, and J. L. B. Coelho. (1990). Acoustic behavior in a local population of bottlenose dolphins. In J. Thomas and R. Kastelein (Eds.), *Sensory abilities of cetaceans* (pp. 585- 598). New York, NY.: Plenum Press.

Double, M. C., V. Andrews-Goff, C. Jenner, M.-N. Jenner, S. M. Laverick, T. A. Branch, and N. J. Gales. (2014). Migratory Movements of Pygmy Blue Whales (*Balaenoptera musculus brevicauda*) between Australia and Indonesia as Revealed by Satellite Telemetry. PloS one*,* 9(4). doi:10.1371/journal.pone.0093578.t001

Dow Piniak, W. E., S. A. Eckert, C. A. Harms, and E. M. Stringer. (2012). Underwater hearing sensitivity of the leatherback sea turtle (*Dermochelys coriacea*): Assessing the potential effect of anthropogenic noise

Dow Piniak, W. E., D. A. Mann, S. A. Eckert, and C. A. Harms. (2012). Amphibious Hearing in Sea Turtles. In A. N. a. A. H. Popper (Ed.), *The Effects of Noise on Aquatic Life* (Vol. Advances in Experimental Medicine and Biology Vol. 730, pp. 83- 87). New York, NY: Springer.

Dragon, A. C., A. Bar-Hen, P. Monestiez, and C. Guinet. (2012). Horizontal and vertical movements as predictors of foraging success in a marine predator. Marine Ecology Progress Series*,* 447, 243-257. doi:10.3354/meps09498

Dunlop, R. A., D. H. Cato, and M. J. Noad. (2014). Evidence of a Lombard response in migrating humpback whales (*Megaptera novaeangliae*). *The Journal of the Acoustical Society of America, 136*(1), 430. doi:10.1121/1.4883598

Dunlop, R. A., D. H. Cato, M. J. Noad, and D. M. Stokes. (2013). Source levels of social sounds in migrating humpback whales (*Megaptera novaeangliae*). *The Journal of the Acoustical Society of America, 134*(1), 706-714. doi:10.1121/1.4807828

Dunlop, R. A., M. J. Noad, D. H. Cato, and D. Stokes. (2007). The social vocalization repertoire of east Australian migrating humpback whales (*Megaptera novaeangliae*). The Journal of the Acoustical Society of America, 122(5), 2893-2905.

Durban, J. W., and R. L. Pitman. (2012). Antarctic killer whales make rapid, round-trip movements to subtropical waters: evidence for physiological maintenance migrations? Biology letters, 8(2), 274-277. doi:10.1098/rsbl.2011.0875

Durban, J., Weller, D., Lang, A., & Perryman, W. (2013). Estimating gray whale abundance from shore-based counts using a multilevel Bayesian model. *Paper SC/65a/BRG02 presented to the IWC Scientific Committee*.

Dziedzic, A., and V. De Bufrenil. (1989). Acoustic signals of the commerson's dolphin, *Cephalorhynchus commersonii*, in the Kerguelen islands. Journal of Mammalogy, 70(2), 449-452.

Eckert, K. L., B. P. Wallace, J. G. Frazier, S. A. Eckert, and P. C. H. Pritchard. (2012). Synopsis of the biological data on the leatherback sea turtle (*Dermochelys coriacea*). Washington, D.C.

Eckert, S. A. (1998). Perspectives on the use of satellite telemetry and electronic technologies for the study of marine turtles, with reference to the first year long tracking of leatherback sea turtles (NOAA Tech. Memo. NMFS-SEFSC-415)

Eckert, S. A. (1999). Habitats and migratory pathways of the Pacific leatherback sea turtle. Final Report to the National Marine Fisheries Service, Office of Protected Resources. San Diego, California

Eckert, S. A. (2002). Swim speed and movement patterns of gravid leatherback sea turtles (*Dermochelys coriacea*) at St Croix, US Virgin Islands. Journal Of Experimental Biology, 205(23), 3689-3697.

Edds, P. L. (1982). Vocalizations of the blue whale, *Balaenoptera musculus*, in the St. Lawrence River. Journal of Mammology, 63(2), 345-347.

Edds, P. L. (1988). Characteristics of finback *Balaenoptera physalus* vocalizations in the St. Lawrence Estuary. Bioacoustics, 1, 131-149.

Edds, P. L., D. K. Odell, and B. R. Tershy. (1993). Vocalizations of a captive juvenile and free-ranging adult-calf pairs of Bryde's whales, *Balaenoptera edeni*. Marine Mammal Science, 9(3), 269-284.

Edds-Walton, P. L. (1997). Acoustic communication signals of mysticete whales. Bioacoustics, 8(1-2), 47-60.

Edds-Walton, P. L. (2000). Vocalisations of minke whales (*Baleanoptera acutorostrata*) in the St. Lawrence estuary. Bioacoustics, 1, 31-50.

Eguchi, T., T. Gerrodette, R. L. Pitman, J. A. Seminoff, and P. H. Dutton. (2007). At-sea density and abundance estimates of the olive ridley turtle *Lepidochelys olivacea* in the Eastern Tropical Pacific. Endangered Species Research, 3(2), 191-203. doi:10.3354/esr003191.

Eguchi, T., and J. T. Harvey. (2005). Diving behavior of the Pacific harbor seal (*Phoca vitulina richardii*) in Monterey Bay, California. Marine Mammal Science, 21(2), 283-295.

Ehrhart, L. M., D. A. Bagley, and W. E. Redfoot. (2003). Loggerhead turtles in the Atlantic Ocean: Geographic distribution, abundance, and population status. In A. B. Bolten and B. E. Witherington (Eds.), *Loggerhead sea turtles* (pp. 57-174). Washington, D.C.: Smithsonian Institution Press.

Ellison, W. T., C. W. Clark, and G. C. Bishop. (1987). *Potential use of surface reverberation by bowhead whales, Balaena mysticetus, in under-ice navigation: preliminary considerations.* Paper presented at the IWC.

Ellison, W. T., B. L. Southall, W. Clark Christopher, and A. S. Frankel. (2011). A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. Conservation Biology, 26(1), 21-28.

Elwen, S. H., D. Reeb, M. Thornton, and P. B. Best. (2009). A population estimate of Heaviside's dolphins, *Cephalorhynchus heavisidii*, at the southern end of their range. Marine Mammal Science, 25(1), 107-124.

Emek Inanmaz, Ö., Ö. Değirmenci, and A. C. Gücü. (2014). A new sighting of the Mediterranean Monk Seal, *Monachus monachus* (Hermann, 1779), in the Marmara Sea (Turkey). Zoology in the Middle East, 60(3), 278-280. doi:10.1080/09397140.2014.944438

Emmett, R.L., Hinton, S. A., Stone, S. L., & Monaco, M. E. (1991). *Distribution and abundance of fishes and invertebrates in west coast estuaries. Volume II: Species life history summaries.* ELMR Report No. 8. Rockville, Maryland: NOAA/NOS Strategic Environmental Assessments Division. 329 pages.

Erbe, C. (2002). Underwater noise of whale-watching boats and potential effects on Killer whales (*Orcinus orca*), based on an acoustic impact model. *Marine Mammal Science, 18*(2), 394-418.

Eskesen, I. G., M. Wahlberg, M. Simon, and O. N. Larsen. (2011). Comparison of echolocation clicks from geographically sympatric killer whales and long-finned pilot whales (L). The Journal of the Acoustical Society of America, 130(1), 9. doi:10.1121/1.3583499

Evans, P. G. H. (1987). *The natural history of whales and dolphins*. New York: Facts on File Publications.

Evans, P. G. H., and J. A. Raga. (2001). *Marine Mammals: Biology and Conservation*. New York: Kluwer Academic/Plenum Publishers.

Evans, W. E. (1971). Orientation behavior of delphinids: radio telemetric studies. Annals of the New York Academy of Sciences, 188, 142-160.

Evans, W. E. (1973). Echolocation by marine delphinids and one species of fresh-water dolphin. Journal of the Acoustical Society of America, 54(1), 191-199.

Evans, W. E. (1994). Common Dolphin, white bellied porpoise (*Delphnis delphis*, LInnaeus, 1758). In S. Ridgway and R. Harrison (Eds.), *Handbook of Marine Mammals* (Vol. 5, pp. 191-224): Academic Press.

Evans, W. E., and F. T. Awbrey. (1984). High frequency pulses of Commerson's dolphin and Dall's porpoise. American Zoologist, 24, 2A.

Evans, W. E., and P. F. A. Maderson. (1973). Mechanisms of sound production in delphinid cetaceans: a review of some anatomical considerations. American Zoologist, 13, 1205-1213.

Fay, R. (2009). Soundscapes and the sense of hearing of fishes. Integr Zool, 4(1), 26-32.

Fay, R. R. (1969). Behavioral audiogram for the goldfish. Journal of Audiological Research, 9, 112-121.

Fay, R. R. (1988). *Hearing in Vertebrates: a Psychophysics Databook*. Wocester, MA: Heffernan Press Inc.

Fay, C., Bartron, M., Craig, S., Hecht, A., Pruden, J., Saunders, R., Sheehan, T., & Trial, J. (2006). *Status review for anadromous Atlantic salmon (Salmo salar) in the United States.* Report to the National Marine Fisheries Service and U.S. Fish and Wildlife Service. 294 pages.

Fedoseev, G. A. (2000). Population biology of ice-associated forms of seals and their role in the northern Pacific ecosystems. Center for Russian Environmental Policy, Russian Marine Mammal Council, Moscow, Russia. 271 pages (Translated from Russian by I. E. Sidorova, 271 p.).

Fedoseev, G. 2002. Ribbon seal, *Histriophoca fasciata*. Pages 1027-1030 in Perrin, W.F., B. Würsig and J.G.M. Thewissen, editors. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Fedoseev, G. A. (2009). Ribbon seal. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 955-958). San Diego, CA: Academic Press.

Feldkamp, S. D, Delong, R. L., & Antonelis, G. A. (1989). Diving patterns of California sea lions, *Zalophus californianus*. *Canadian Journal of Zoology 67*, 872-883.

Félix, F., Castro, C, Laake, J., Haase, B., and Scheidat, M. (2011). Abundance and survival estimates of the southeastern Pacific humpback whale stock from 1991-2006 photoidentification surveys in Ecuador. *Journal of Cetacean Research and Management (Special issue)*, (3), 301-307.

Ferguson, M. C., & Barlow, J. (2001). *Spatial distribution and density of cetaceans in the eastern tropical Pacific Ocean based on summer/fall research vessel surveys in 1986-1996.* (NMFS-SWFSC Administrative Report LJ-01-04). La Jolla, California: Southwest Fisheries Science Center, National Marine Fisheries Service.

Ferguson, M. C., & Barlow, J. (2003). *Addendum: Spatial distribution and density of cetaceans in the eastern tropical Pacific Ocean based on summer/fall research vessel surveys in 1986-96*. (NMFS-SWFSC Administrative Report LJ-01-04, Addendum). La Jolla, California: Southwest Fisheries Science Center, National Marine Fisheries Service.

Fernández-Juricic, E., C. Campagna, V. Enriquez, and C. L. Ortiz. (1999). Vocal communication and individual variation in breeding South American sea lions. Behaviour*,* 136(4), 495–517.

Ferraroli, S., J. Y. Georges, P. Gaspar, and Y. L. Maho. (2004). Where leatherback turtles meet fisheries. Nature*,* 429, 521-522.

Figueiredo, I., and C. R. Weir. (2014). Blue whales *Balaenoptera musculus* off Angola: recent sightings and evaluation of whaling data. African Journal of Marine Science*,* 36(2), 269-278. doi:10.2989/1814232x.2014.928652

Figueiredo, L. (2014). Bryde's Whale (*Balaenoptera edeni*) Vocalizations from Southeast Brazil. Aquatic Mammals*,* 40(3), 225-231. doi:10.1578/am.40.3.2014.225

Filatova, O. A., J. K. Ford, C. O. Matkin, L. G. Barrett-Lennard, A. M. Burdin, and E. Hoyt. (2012). Ultrasonic whistles of killer whales (*Orcinus orca*) recorded in the North Pacific (L). The Journal of the Acoustical Society of America*,* 132(6), 3618-3621. doi:10.1121/1.4764874

Filatova, O. A., M. A. Guzeev, I. D. Fedutin, A. M. Burdin, and E. Hoyt. (2013). Dependence of killer whale (*Orcinus orca*) acoustic signals on the type of activity and social context. Biology Bulletin*,* 40(9), 790-796. doi:10.1134/s1062359013090045

Finley, K. J., Miller, G. W., Davis, R. A., and Koski, W. R. (1983). A distinctive large breeding population of ringed seals (*Phoca hispida*) inhabiting the Baffin Bay pack ice. *Arctic, 36*, 162-173.

Finneran, J. J., D. S. Houser, B. Mase-Guthrie, R. Y. Ewing, and R. G. Lingenfelser. (2009). Auditory evoked potentials in a stranded Gervais' beaked whale (*Mesoplodon europaeus*). Journal of the Acoustical Society of America, 126(1), 484-490.

Finneran, J. J., C. E. Schlundt, R. Dear, D. A. Carder, and S. H. Ridgway. (2002). Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. Journal of the Acoustical Society of America, 111(6), 2929-2940.

Fish, F. E., and C. A. Hui. (1991). Dolphin Swimming a Review. Mammal Review, 21(4), 181-195.

Fish, F. E., A. J. Nicastro, and D. Weihs. (2006). Dynamics of the aerial maneuvers of spinner dolphins. *The Journal of Experimental Biology,* 209(4), 590-598.

Fish, J. F., and C. W. Turl. (1976). Acoustic source levels of four species of small whales. San Diego, CA

Fitch, J. E., and R. L. Brownell, Jr.,. (1968). Fish Otoliths in Cetacean Stomachs and Their Importance in Interpreting Feeding Habits *Kogia simus Stenella longirostris Stenella graffmani Lagenorhynchus obliquidens Delphinus delphis Lissodelphis borealis*. Journal of the Fisheries Research Board of Canada, 25(12), 2561-2574.

Fletcher, S., B. J. Le Boeuf, D. P. Costa, P. L. Tyack, and S. B. Blackwell. (1996). Onboard acoustic recording from diving northern elephant seals. Journal of the Acoustical Society of America., 100((4 PART 1)), 2531-2539.

Foley, H. J., R. C. Holt, R. E. Hardee, P. B. Nilsson, K. A. Jackson, A. J. Read, D. A. Pabst, and W. A. McLellan. (2011). Observations of a western North Atlantic right whale (*Eubalaena glacialis*) birth offshore of the protected southeast U.S. critical habitat. Marine Mammal Science, 27(3), E234-E240. doi:10.1111/j.1748-7692.2010.00452.x

Folkow, L. P., and A. S. Blix. (1999). Diving behaviour of hooded seals (*Cystophora cristata*) in the Greenland and Norwegian Seas. Polar Biology, 22(1), 61-74.

Folkow, L. P., E. S. Nordøy, and A. S. Blix. (2004). Distribution and diving behaviour of harp seals (*Pagophilus groenlandicus*) from the Greenland Sea stock. Polar Biology, 27(5), 281-298.

Food and Agriculture Organization of the United Nations (FAO). (2005). *Fishery Country Profile: The Socialist Republic of Vietnam*. Food and Agriculture Organization of the United Nations. Accessed February 2016. <http://www.fao.org/fishery/facp/VNM/en>.

FAO. (2010). *Fishery and Aquaculture Country Profiles: The Republic of the Union of Myanmar*. Retrieved January 29, 2016 from <http://www.fao.org/fishery/facp/MMR/en#CountrySector-Overview>.

FAO. (2012a). *Fishery and Aquaculture Country Profiles: The Republic of the Union of Myanmar. Part I Overview and main indicators*. Retrieved January 29, 2016 from <http://www.fao.org/fishery/facp/MMR/en#CountrySector-Overview>.

FAO. (2012b). *Fishery and Aquaculture Statistics*. FAO 2012 yearbook. Accessed January 2016. <http://www.fao.org/3/a-i3740t.pdf>.

FAO. (2015). *FAO global capture production database updated to 2013, Summary information*. Accessed January 29, 2016. <www.fao.org/3/a-i4883e.pdf>.

Forcada, J., & Hammond, P. (1998). Geographical variation in abundance of striped and common dolphins of the western Mediterranean. *Journal of Sea Research, 39*, 313-325.

Forcada, J., Aguilar, A., Hammond, P. S., Pastor, X., & Aguilar, R. (1996). Distribution and abundance of fin whales (*Balaenoptera physalus*) in the western Mediterranean Sea during the summer. *Journal of Zoology, 238*, 23-34.

Ford, J. K. B. (1989). Acoustic behaviour of resident killer whales (*Orcinus orca*) off Vancouver island, British Columbia. Canadian Journal of Zoology, 67(3), 727-745.

Ford, J. K. B. (2009). Killer Whale *Orcincus orca*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 650-657). New York: Academic Press.

Ford, J. K. B., and H. D. Fisher. (1982). Killer Whale (*Orcinus orca*) dialects as an indicator of stocks in British Columbia. Report to the Whaling Commission, 32, 671-679.

Forney, K. (2007). *Preliminary estimates of cetacean abundance along the U.S. west coast and within four National Marine Sanctuaries during 2005.* (NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-406). La Jolla, CA: Southwest Fisheries Science Center, National Marine Fisheries Service.

Forney, K. A., & Wade, P. (2006). Worldwide distribution and abundance of killer whales. In J. A. Estes, R. L. Brownell, D. P. DeMaster, D. F. Doak, & T. M. Williams (Eds.), *Whales, whaling and ocean ecosystems* (pp. 145-162). Berkeley, CA: University of California Press.

Forney, K. A., Barlow, J., & Carretta, J. V. (1995). The abundance of cetaceans in California waters. Part II: Aerial surveys in winter and spring of 1991 and 1992. *Fishery Bulletin, 93*(1), 15-26.

Fournet, M. E., A. Szabo, and D. K. Mellinger. (2015). Repertoire and classification of non-song calls in Southeast Alaskan humpback whales (*Megaptera novaeangliae*). The Journal of the Acoustical Society of America, 137(1), 1. doi:10.1121/1.4904504

Francis, J., D. Boness, and H. Ochoa-Acuña. (1998). Protracted foraging and attendance cycle in female Juan Fernández fur seals. Marine Mammal Science, 14(3), 552-574.

Frankel, A. S. (2005). *Gray whales hear and respond to signals 21 kHz and higher*. Paper presented at the 16th biennial conference on the biology of marine mammals, San Diego.

Frankel, A. S. (2009). Sound Production. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals*: Academic Press.

Frankel, A. S., C. W. Clark, L. M. Herman, and C. M. Gabriele. (1995). Spatial Distribution, Habitat Utilization, and Social Interactions of Humpback Whales, *Megaptera novaeangliae*, off Hawai'i, determined using Acoustic and Visual Techniques. Canadian Journal of Zoology, 73, 1134-1146.

Frankel, A. S., and S. Yin. (2010). A description of sounds recorded from melon-headed whales (*Peponocephala electra*) off Hawai'i. The Journal of the Acoustical Society of America, 127(5), 3248–3255.

Frantzis, A., J. C. Goold, E. K. Skarsoulis, M. I. Taroudakis, and V. Kandia. (2002). Clicks from Cuvier's beaked whales, *Ziphius cavirostris*. The Journal of the Acoustical Society of America, 112(1), 34-37.

Friedel, P., Young, B.A., and van Hemmen, J.L. (2008). Auditory localization of ground-borne vibrations in snakes. *Physical Review Letters, 100*, 048701-1-048701-4. DOI: 10.1103/PhysRevLett.100.048701.

Friedlaender, A. S., J. A. Goldbogen, D. P. Nowacek, A. J. Read, D. Johnston, and N. Gales. (2014). Feeding rates and under-ice foraging strategies of the smallest lunge filter feeder, the Antarctic minke whale (*Balaenoptera bonaerensis*). *The Journal of Experimental Biology,* 217(Pt 16), 2851-2854. doi:10.1242/jeb.106682

Froese, R. and Pauly, D., editors. (2016). FishBase. World Wide Web electronic publication. <www.fishbase.org>, version (01/2016). Accessed May 2016. <http://www.fishbase.org/search.php>.

Fulling, G.L., Thorson, P.H., and Rivers, J. (2011). Distribution and abundance estimates for cetaceans in the waters off Guam and the Commonwealth of the Northern Mariana Islands. *Pacific Science, 65*(3), 321-343.

Gabriele, C. M., and A. S. Frankel. (2002). The occurrence and significance of humpback whale songs in Glacier Bay, Southeastern Alaska. Arctic Research of the United States, 16, 42-47.

Gabriele, C. M., J. M. Straley, L. M. Herman, and R. J. Coleman. (1996). Fastest documented migration of a North Pacific humpback whale. Marine Mammal Science, 12(3), 457-464.

Gales, N. J. (2009). New Zealand Sea Lion *Phocarctos hookeri*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals*. New York: Academic Press.

Gallo Reynosa, J. P. (1994). *Factors affecting the population status of Guadalupe fur seal, Arctocephalus townsendi (Merriam, 1897), at Isla de Guadalupe, Baja California, Mexico*. (Doctoral dissertation). University of California, Santa Cruz. Retrieved from <https://www.researchgate.net/publication/261795932_Factors_affecting_the_population_status_of_Guadalupe_Fur_Seal_Arctocephalus_townsendi_Merriam_1897_at_Isla_de_Guadalupe_Baja_California_Mexico>.

Gambell, R. (1985). Sei Whale (*Balaenoptera borealis)* Lesson, 1828 *Handbook of Marine Mammals* (Vol. 3, pp. 155-170). London: Academic Press Inc.

Gaos, A. R., R. R. Lewison, B. P. Wallace, I. L. Yañez, M. J. Liles, A. Baquero, and J. A. Seminoff. (2012). Dive behaviour of adult hawksbills (*Eretmochelys imbricata*, Linnaeus 1766) in the eastern Pacific Ocean highlights shallow depth use by the species. Journal of Experimental Marine Biology and Ecology, 432-433, 171-178. doi:10.1016/j.jembe.2012.07.006

Gaskin, D. E. (1992). Status of the harbour porpoise, *Phocoena phocoena*, in Canada. Canadian Field-Naturalist, 106, 36-54.

Gaskin, D. E., P. W. Arnold, and B. A. Blair. (1974). *(Phocoena phocoena)*. Mammalian Species, 1-8.

Gassmann, M., E. E. Henderson, S. M. Wiggins, M. A. Roch, and J. A. Hildebrand. (2013). Offshore killer whale tracking using multiple hydrophone arrays. The Journal of the Acoustical Society of America, 134(5), 3513-3521. doi:10.1121/1.4824162

Gazo, M., and A. Aguilar. (2005). Maternal attendance and diving behavior of a lactating Mediterranean monk seal. Marine Mammal Science, 21(2), 340-345.

Gedamke, J., D. P. Costa, and A. Dunstan. (2001). Localization and visual verification of a complex minke whale vocalization. Journal of the Acoustical Society of America*,* 109(6), 3038-3047.

Gelatt, T., & Sweeney, K. (2016). *Eumetopias jubatus*. The IUCN Red List of Threatened Species 2016: e.T8239A45225749. Retrieved from <http://www.iucnredlist.org/details/8239/0>.

Gelatt, T., Ream, R., & Johnson, D. (2015). *Callorhinus ursinus*. The IUCN red list of threatened species 2015, (e.T3590A45224953). Accessed March 2016 from <http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T3590A45224953.en>.

Gentry, R. (2009a). Eared seals. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 339-348). New York: Academic Press.

Gentry, R. (2009b). Northern Fur Seal *Callorhinus ursinus*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 788-791). New York: Academic Press.

Gentry, R. L. (1998). *Behavior and ecology of the northern fur seal.* Princeton, New Jersey: Princeton University Press.

George, J. C., C. Clark, G. M. Carroll, and W. T. Ellison. (1989). Observations on the ice-breaking and ice navigation behavior of migrating bowhead whales (*Balaena mysticetus*) near Point Barrow, Alaska, Spring 1985. Arctic*,* 42(1), 24-30.

Gerrodette, T., and Forcada, J. (2005). Non-recovery of two spotted and spinner dolphin populations in the eastern tropical Pacific Ocean. *Marine Ecology Progress Series, 291*, 1-21.

Gerrodette, T., Watters, G., Perryman, W., & Balance, L. (2008). Estimates of 2006 dolphin abundance in the Eastern Tropical Pacific, with revised estimates from 1996-2003. (NOAA-TM-NMFS-SWFSC-422). La Jolla, CA: Southwest Fisheries Science Center, National Marine Fisheries Service.

Gewalt, W. (1990). The Jacobita, or Commerson's Dolphin (*Cephalorhynchus commersoni*). Aquatic Mammals.

Gjertz, I., K. M. Kovacs, C. Lydersen, and O. Wiig. (2000a). Movements and diving of adult ringed seals (*Phoca hispida*) in Svalbard. *Polar Biology, 23*(9), 651-656.

Gjertz, I., K. M. Kovacs, C. Lydersen, and O. Wiig. (2000b). Movements and diving of bearded seal (*Erignathus barbatus*) mothers and pups during lactation and post-weaning. *Polar Biology, 23*(8), 559-566.

Giles, J. C., J. A. Davis, R. D. McCauley, and G. Kuchling. (2009). Voice of the turtle: The underwater acoustic repertoire of the long-necked freshwater turtle, *Chelodina oblonga*. Journal of the Acoustical Society of America*,* 126(1), 434-443.

Gilmartin, W. G., and J. Forcada. (2009). Monk seals *Monachus monachus*, *M. tropicalis*, and *M. schauinslandi* In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 741-744): Academic Press.

Gitschlag, G. R. (1996). Migration and diving behavior of Kemp's ridley (Garman) sea turtles along the U.S. southeastern Atlantic coast. Journal of Experimental Marine Biology and Ecology*,* 205(1-2), 115-135.

Godley, B. J., A. C. Broderick, F. Glen, and G. C. Hays. (2003). Post-nesting movements and submergence patterns of loggerhead marine turtles in the Mediterranean assessed by satellite tracking. Journal of Experimental Marine Biology and Ecology, 287(1), 119-134.

Godley, B. J., S. Richardson, A. C. Broderick, M. S. Coyne, F. Glen, and G. C. Hays. (2002). Long-term satellite telemetry of the movements and habitat utilisation by green turtles in the Mediterranean. Ecography, 25, 352-362.

Goebel, M. E. (1998). Female foraging behavior: Inter-and intraannual variation in individuals. In R. L. Gentry (Ed.), *Behaviour and ecology of the northern fur seal*. Princeton, New Jersey: Princeton University Press.

Goldbogen, J. A., B. L. Southall, S. L. Deruiter, J. Calambokidis, A. S. Friedlaender, E. L. Hazen, E. A. Falcone, G. S. Schorr, A. Douglas, D. J. Moretti, C. Kyburg, M. F. McKenna, and P. L. Tyack. (2013). Blue whales respond to simulated mid-frequency military sonar. Proc Biol Sci B. Biol Sci, 280(1765), 20130657. doi:10.1098/rspb.2013.0657

Gómez de Segura, A., Crespo, E. A., Pedraza, S. N., Hammond, P. S., & Raga, J. A. (2006). Abundance of small cetaceans in waters of the central Spanish Mediterranean. *Marine Biology, 150*(1), 149-160. doi 10.1007/s00227-006-0334-0.

Good, T. P., Waples, R. S., & Adams, P., eds. (2005). *Updated status of federally listed ESUs of West Coast salmon and steelhead.* NOAA Techical Memorandum NMFS-NWFSC-66. National Marine Fisheries Service; National Oceanic and Atmospheric Administration. 598 pages.

Goodall, R. N. P. (1994a). Chilean dolphin *Cephalorhynchus eutropia* (Gray, 1846). In S. H. Ridgeway and R. Harrison (Eds.), *Handbook of marine mammals, Volume 5: The first book of dolphins.* (pp. 269-287). New York, New York: Academic Press.

Goodall, R. N. P. (1994b). Commerson's dolphin *Cephalorhynchus commersonii* (Lacepede, 1804). In S. H. Ridgeway and R. Harrison (Eds.), *Handbook of marine mammals, Volume 5: The first book of dolphins.* (pp. 241-267). New York, New York: Academic Press.

Goodall, R. N. P. (2009a). Hourglass Dolphin *Lagenorhynchus cruciger*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), (pp. 573-576): Elsevier.

Goodall, R. N. P. (2009b). Peale's Dolphin *Lagenorhynchus australis*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 844-847). New York: Academic Press.

Goodall, R. N. P. (2009c). Spectacled Porpoise *Phocoena dioptrica*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 1087-1091): Academic Press.

Goodall, R. N. P., A. R. Galeazzi, S. Leatherwood, K. W. Miller, I. S. Cameron, R. K. Kastelein, and A. P. Sobral. (1988). Studies of Commerson's Dolphins, *Cephalorhynchus Commersonii*, Off Tierra Del Fuego, 1976-1984, With a Review of Information On the Species in the South Atlantic *Biology of the genus Cephalorhynchus* (pp. 3-70). Cambridge, UK: International Whaling Commission.

Goold, J. C., and S. E. Jones. (1995). Time and frequency domain characteristics of sperm whale clicks. Journal of the Acoustical Society of America, 98(3), 1279-1291.

Gordon, J., D. Gillespie, L. E. Rendell, and R. Leaper. (1996). Draft Report on playback of ATOC like sound to Sperm whales (*Physeter macrocephalus*) off the Azores

Gordon, J. C. D., J. N. Matthews, S. Panigada, A. Gannier, J. F. Borsani, and G. N. di Sciara. (2000). Distribution and relative abundance of striped dolphins, and distribution of sperm whales in the Ligurian Sea cetacean sanctuary: Results from a collaboration using acoustic monitoring techniques. Journal of Cetacean Research and Management, 2(1), 27-36.

Götz, T., R. Antunes, and S. Heinrich. (2010). Echolocation clicks of free-ranging Chilean dolphins (Cephalorhynchus eutropia). The Journal of the Acoustical Society of America, 128(2), 563. doi:10.1121/1.3353078

Gowans, S. (2009). Bottlenose Whales *Hyperoodon ampullatus* and *H. planifrons*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 129-131): Academic Press.

Greenhow, D. R., M. C. Brodsky, R. G. Lingenfelser, and D. A. Mann. (2014). Hearing threshold measurements of five stranded short-finned pilot whales (*Globicephala macrorhynchus*). The Journal of the Acoustical Society of America, 135(1), 531-536. doi:10.1121/1.4829662

Gregr, E. J. (2011). Insights into North Pacific right whale *Eubalaena japonica* habitat from historic whaling records. Endangered Species Research, 15(3), 223-239. doi:10.3354/esr00381

Gridley, T., P. Berggren, V. G. Cockcroft, and V. M. Janik. (2012). Whistle vocalizations of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) inhabiting the south-west Indian Ocean. The Journal of the Acoustical Society of America, 132(6), 4032-4040. doi:10.1121/1.4763990

Gridley, T., V. G. Cockcroft, E. R. Hawkins, M. L. Blewitt, T. Morisaka, and V. M. Janik. (2014). Signature whistles in free-ranging populations of Indo-Pacific bottlenose dolphins,Tursiops aduncus. Marine Mammal Science, 30(2), 512-527. doi:10.1111/mms.12054

Gridley, T., A. Nastasi, H. J. Kriesell, & S. H. Elwen. (2015). The acoustic repertoire of wild common bottlenose dolphins (*Tursiops truncatus*) in Walvis Bay, Namibia. Bioacoustics, 24(2), 153-174. doi:10.1080/09524622.2015.1014851

Groch, K., J. J. T. Palazzo, P. A. C. Flores, F. R. Adler, & M. E. Fabian. (2005). Recent rapid increases in the right whale (*Eubalaena australis*) population off southern Brazil. LAJAM, 4(1), 41-47.

Gunnlaugsson, T., & Sigurjonsson, J. 1990. NASS-87: Estimation of whale abundance based on observations made onboard Icelandic and Faroese survey vessels. *Report of the International Whaling Commission, 40*, 571-580.

Guzman, H. M., R. Condit, B. Pérez-Ortega, J. J. Capella, & P. T. Stevick. (2015). Population size and migratory connectivity of humpback whales wintering in Las Perlas Archipelago, Panama. Marine Mammal Science, 31(1), 90-105. doi:10.1111/mms.12136

Gustafson, F.G., Wainwright, T.C., Winans, G. A., Waknitz, F. W., Parker, L. T., & Waples, R. S. (1997). *Status review of sockeye salmon from Washington and Oregon.* NOAA Technical Memorandum NMFS-NWFSC-33. National Marine Fisheries Service; National Oceanic and Atmospheric Administration. 282 pages.

Hain, J. H. W., J. D. Hampp, S. A. McKenney, J. A. Albert, & R. D. Kenney. (2013). Swim Speed, Behavior, and Movement of North Atlantic Right Whales (*Eubalaena glacialis*) in Coastal Waters of Northeastern Florida, USA. PloS one, 8(1). doi:10.1371/journal.pone.0054340.g00210.1371/journal.pone.0054340.g001

Hall, A., & D. Thompson. (2009). Gray Seal *Halichoerus grypus*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), (pp. 500-503): Elsevier.

Hall, J. D., & C. S. Johnson. (1972). Auditory threshold of a killer whale (*Orcinus orca*) Linnaeus. Journal of the Acoustical Society of America, 51, 515-517.

Hamilton, P. K., G. S. Stone, & S. M. Martin. (1997). Note on a deep humpback whale *Megaptera novaeangliae* dive near Bermuda. Bulletin of Marine Science, 61(2), 491-494.

Hammond, P. S., Berggren, P., Benke, H., Borchers, D. L., Collet, A., Heide-Jørgensen, M. P., Heimlich, S., Hiby, A. R., Leopold, M. F. & Øien, N. (2002). Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology, 39*, 361-376.

Hammond, P. S., Macleod, K., Gillespie, D., Swift, R., Winship, A., Burt, M. L., Cañadas, A., Vázquez, J. A., Ridoux, V., Certain, G., Van Canneyt, O., Lens, S., Santos, B., Rogan, E., Uriarte, A., Hernandez, C., & Castro, R. (2009). *Cetacean offshore distribution and abundance in the European Atlantic (CODA)*. (Final report). Retrieved from <http://biology.st-andrews.ac.uk/coda/documents/CODA_Final_Report_11-2-09.pdf>.

Hammond, P. S., Macleod, K., Berggren, P., Borchers, D. L., Burt, L., Cañadas, A., Desportes, G., Donovan, G. P., Gilles, A., Gillespie, D., Gordon, J., Hiby, L., Kuklik, I., Leaper, R., Lehnert, K., Leopold, M., Lovell, P., Øien, N., Paxton, C. G. M., Ridoux, V., Rogan, E., Samarra, F., Scheidat, M., Sequeira, M., Siebert, U., Skov, H., Swift, R., Tasker, M. L., Teilmann, J., Van Canney, O., & Vázquez, J. A. (2013). Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. *Biological Conservation, 164*, 107-122.

Han, J.-B., Sun, F.-Y., Gao, X.-G., He, C.-B., Wang, P. L., Ma, Z.-Q., & Wang, Z.-H. (2010). Low microsatellite variation in spotted seal (*Phoca largha*) shows a decrease in population size in the Liaodong Gulf colony. *Annales Zoologici Fennici, 47*, 15-27.

Hanggi, E. B., & R. J. Schusterman. (1994). Underwater acoustic displays and individual variation in male harbour seals *Phoca vitulina*. Animal Behaviour, 48(6), 1275-1283.

Hansen, D. J., & J. D. Hubbard. (1999). Distribution of Cook Inlet beluga whales (*Delphinapterus leucas*) in winter

Hanson, M. B., R.W. Baird, & R. L. DeLong. (1998, 22-24 January 1998). *Short-term movements and dive behavior of tagged Dall's porpoise in Haro Strait, Washington.* Paper presented at the World Marine Mammal Science Conference, Monaco.

Harcourt, R. G., Bradshaw, C. J. A., Dickson, K., & Davis, L. S. (2002). Foraging ecology of a generalist predator, the female New Zealand fur seal. *Marine Ecology Progress Series 227*, 11-24.

Harris, D. E., B. Lelli, & G. Jakush. (2002). Harp seal records from the southern Gulf of Maine: 1997-2001. Northeastern Naturalist, 9(3), 331-340.

Hatakeyama, Y., K. Ishii, & T. Akamatsu. (1994). A review of studies on attempts to reduce the entanglement of the Dall's porpoise, Phocoenoides dalli, in the Japanese salmon gillnet fishery. Rep. Int. Whal. Commn(Special Issue 15), 549-550 (Incomplete).

Hatakeyama, Y., & H. Soeda. (1990). Studies on Echolocation of Porpoises Taken in Salmon Gillnet Fisheries. In J. Thomas and R. Kastelien (Eds.), *Sensory Abilities of Cetaceans* (pp. 269-281). New York: Plenum Press.

Haug, T., Nilssen, K. T., & Oigard, T-A. (2007). Report from surveys to assess hooded and harp seal pup production in the Greenland Sea pack-ice in March-April 2007. *(Toktrapport/Havforskninginstituttet/ISSN 1503-6294/Nr. 9_2007).*

Hawkes, L., A. Broderick, M. Coyne, & M. Godfrey. (2007). Only Some Like it Hot - Quantifying the environmental niche of the loggerhead sea turtle. Diversity and Distributions, 13, 447-457.

Hawkes, L. A., J. Tomás, O. Revuelta, Y. M. León, J. M. Blumenthal, A. C. Broderick, M. Fish, J. A. Raga, M. J. Witt, & B. J. Godley. (2012). Migratory patterns in hawksbill turtles described by satellite tracking. Marine Ecology Progress Series, 461, 223-232. doi:10.3354/meps09778

Hawkins, E. R. (2010). Geographic variations in the whistles of bottlenose dolphins (*Tursiops aduncus*) along the east and west coasts of Australia. The Journal of the Acoustical Society of America, 128(2), 924. doi:10.1121/1.3459837

Hay, D., & McCarter, P. B. (2000). Status of the euchalon *Thaleichthys pacificus* in Canada. Research Document 2000/145. Ottawa, Canada: Canadian Stock Assessment Secretariat. <http://www.dfo-mpo.gc.ca/csas/>.

Hays, G. C., S. Hochscheid, A. C. Broderick, B. J. Godley, & J. D. Metcalfe. (2000). Diving behaviour of green turtles: dive depth, dive duration and activity levels. Marine Ecology Progress Series, 208, 297-298.

Hays, G. C., J. D. R. Houghton, & A. E. Myers. (2004). Pan-Atlantic leatherback turtle movements. Nature, 429(6991), 522-522.

Heath, C. B., and W. F. Perrin. (2009). California, Galapagos, and Japanese Sea Lions *Zalophus californianus, Z. wollebaeki,* and *Z. japonicus*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 170-176): Academic Press.

Heatwole, H. (1999). *Sea snakes. Second edition*. Malabar, Florida: Krieger Publishing Company.

Heatwole, H. (1997). Marine snakes: Are they a sustainable resource? *Wildlife Society Bulletin*, *25*, 766-772.

Heatwole, H., & Seymour, R. (1975). Diving physiology. *The biology of sea snakes*, Dunstan, W.A., ed., Chapter 15. Baltimore, MD: University Park Press.

Heide-Jørgensen, M.-P., K. L. Laidre, M. V. Jensen, L. Dueck, & L. D. Postma. (2006). Dissolving stock discreteness with satellite tracking: Bowhead whales in Baffin Bay. Marine Mammal Science, 22(1), 34-45.

Heide-Jørgensen, M. P., K. L. Laidre, D. Litovka, M. Villum Jensen, J. M. Grebmeier, & B. I. Sirenko. (2012). Identifying gray whale (*Eschrichtius robustus*) foraging grounds along the Chukotka Peninsula, Russia, using satellite telemetry. Polar Biology, 35(7), 1035-1045. doi:10.1007/s00300-011-1151-6

Heide-Jørgensen, M. P., K. L. Laidre, N. H. Nielsen, R. G. Hansen, & A. Røstad. (2013). Winter and spring diving behavior of bowhead whales relative to prey. Animal Biotelemetry, 1, 15.

Heide-Jørgensen, M. P., K. L. Laidre, Ø. Wiig, M. V. Jensen, L. Dueck, L. Maiers, H. Schmidt, & R. Hobbs. (2003). From Greenland to Canada in Ten Days: Tracks of Bowhead Whales, *Balaena mysticetus*, across Baffin Bay. Arctic, 56(1), 21-31.

Heimlich-Boarn, J. R., P. G. H. Evans, J. B. Reid, & S. Northridge. (1998, 22-24 January 1998). *Cetaceans in northwest European waters: using diverse sightings to study ecological distribution and related abundance.* Paper presented at the Proceedings of The World Marine Mammal Science Conference, Monaco.

Heise, R. J., Slack, W. T., Ross, S. T., & Dugo, M. A. (2004). Spawning and associated movement patterns of Gulf sturgeon in the Pascagoula River drainage, Mississippi. *Transactions of the American Fisheries Society 133*:221-230.

Hendrix, A. N., J. Straley, C. M. Gabriele, S. M. Gende, & Y. Chen. (2012). Bayesian estimation of humpback whale (*Megaptera novaeangliae*) population abundance and movement patterns in southeastern Alaska. Canadian Journal of Fisheries and Aquatic Sciences, 69(11), 1783-1797. doi:10.1139/f2012-101

Herberholz, J., & B. Schmitz. (2001). Signaling via water currents in behavioral interactions of snapping shrimp (*Alpheus heterochaelis*). The Biological Bulletin, 201(1), 6-16.

Herzing, D. L. (1996). Vocalizations and associated underwater behavior of free-ranging Atlantic spotted dolphins, *Stenella frontalis* and bottlenose dolphins, *Tursiops truncatus*. Aquatic Mammals, 22(2), 61-79.

Hester, K.C., Peltzer, E.T., Kirkwood, W.J., & Brewer, P.G. (2008). Unanticipated consequences of ocean acidification: A noisier ocean at lower pH. *Geophysical Research Letters, 35*(19). doi:10.1029/2008gl034913.

Heupel, M. R., & McCauley, R. B. (2007). *Sharks and rays (Chondrichthyans) in the north-west marine region.* Report to the Department of the Environment and Water Resources, National Ocean Office Branch, Hobart, Tasmania.

Heyning, J. E. (1989). Cuvier's beaked whale—*Ziphius cavirostris* (G. Cuvier, 1823). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of marine mammals. Volume 4: River dolphins and the larger toothed whales.* (pp. 289-308). San Diego, California: Academic Press.

Heyning, J. E., & J. G. Mead. (2009). Cuvier's Beaked Whale *Ziphius cavirostris*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 294-296): Academic Press.

Higgs, D. M., & C. A. Radford. (2016). The Potential Overlapping Roles of the Ear and Lateral Line in Driving "Acoustic" Responses. In J. A. Sisneros (Ed.), *Fish Hearing and Bioacoustics* (Vol. 877, pp. 255-270).

Hildebrand, J.A. (2009). Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology Progress Series, 395*, 5-20. doi:10.3354/meps08353.

Hill, R. D. (1985). Investigation of lightning strikes to water surfaces. Journal of the Acoustical Society of America, 78(6), 2096-2099. doi:10.1121/1.392668.

Hill, R. J. (2005). *Standardizing the auditory evoked potential technique: Ground-truthing against behavioral conditioning in the goldfish Carassius auratus.* (Ph.D.), University of South Florida.

Hindell, M. A., and D. Pemberton. (1997). Successful use of a translocation program to investigate diving behavior in a male Australian fur seal, *Arctocephalus pusillus doriferus*. Marine Mammal Science, 13(2), 219-228.

Hindell, M. A., and W. F. Perrin. (2009). Elephant Seals *Mirounga angustirostris* and *M. leonina*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 364-368): Academic Press.

Hobbs, R. C., & Waite, J. M. (2010). Abundance of harbor porpoise (*Phocoena phocoena*) in three Alaskan regions, corrected for observer errors due to perception bias and species misidentification, and corrected for animals submerged from view. *Fishery Bulletin, 108*, 251–267.

Hobson, R. P., and A. R. Martin. (1996). Behaviour and dive times of Arnoux's beaked whales, *Berardius arnuxii*, at narrow leads in fast ice. Canadian Journal of Zoology*,* 74(2), 388-393.

Hochscheid, S., F. Bentivegna, and G. C. Hays. (2005). First records of dive durations for a hibernating sea turtle. Biol Lett*,* 1(1), 82-86. doi:10.1098/rsbl.2004.0250

Hochscheid, S., B. J. Godley, A. C. Broderick, and R. P. Wilson. (1999). Reptilian diving: Highly variable dive patterns in the green turtle *Chelonia mydas*. Marine Ecology Progress Series*,* 185, 101-112.

Hofmeyr, G. J. G. (2015). *Arctocephalus pusillus. The IUCN Red List of Threatened Species 2015*. T2060A45224212. <http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T2060A45224212.en>.

Hooker, S. K., and R. W. Baird. (1999). Deep-diving behaviour of the northern bottlenose whale, *Hyperoodon ampullatus* (Cetacea: Ziphiidae). Proceedings of the Royal Society of Biological Sciences: Series B.*,* 266(1420), 671-676.

Hooker, S. K., and H. Whitehead. (1998). *Echolocation of northern bottlenose whales—an analysis of click characteristics and their implications for foraging.* Paper presented at the World Marine Mammal Science Conference, Monaco.

Hoos, L. (2013). Resting habitat suitability for spinner dolphins (*Stenella longirostris*) in the northwestern Hawaiian Islands. (Masters of Environmental Management project). Duke University, Durham, NC.

Horton, T. W., R. N. Holdaway, A. N. Zerbini, N. Hauser, C. Garrigue, A. Andriolo, and P. J. Clapham. (2011). Straight as an arrow: humpback whales swim constant course tracks during long-distance migration. Biology letters*,* 7(5), 674-679. doi:10.1098/rsbl.2011.0279

Horwood, J. (2009). Sei whale (*Balaenoptera borealis*). . In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 1001-1003): Academic Press.

Houghton, J. D. R., A. C. Broderick, B. J. Godley, J. D. Metcalfe, and G. C. Hays. (2002). Diving behaviour during the internesting interval for loggerhead turtles *Caretta caretta* nesting in Cyprus. Marine Ecology Progress Series*,* 227, 63-70.

Houser, D. S., and J. J. Finneran. (2006). A comparison of underwater hearing sensitivity in bottlenose dolphins (*Tursiops truncatus*) determined by electrophysiological and behavioral methods. The Journal of the Acoustical Society of America*,* 120(3), 1713-1722.

Houser, D. S., D. A. Helweg, and P. W. Moore. (1999). Classification of dolphin echolocation clicks by energy and frequency distributions. Journal of the Acoustical Society of America*,* 106(3), 1579-1585.

Houser, D. S., D. A. Helweg, and P. W. B. Moore. (2001). A bandpass filter-bank model of auditory sensitivity in the humpback whale. Aquatic Mammals*,* 27(2), 82-91.

Houston, J. (1991). Status of Cuvier's beaked whale, *Ziphius cavirostris*, in Canada. Can. Field Nat., 105(2), 215-218.

Hu, M., H. Y. h. Yan, J. C. Shiao, and P. P. Hwang. (2009). Acoustically evoked potentials in two cephalopods inferred using the auditory brainstem response (ABR) approach. Comp Biochem Physiol A Mol Integr Physiol, abstract on PubMed.

Hui, C. A. (1987). Power and speed of swimming dolphins. Journal of Mammalogy, 68(1), 126-132.

International Council for Exploration of the Sea (ICES). (2013). Report of the working group on harp and hooded seals (WGHARP), 26-30 August 2013, PINRO Murmansk, Russia. ICES CM 2013/ACOM:20. Copenhagen, Denmark: International Council for Exploration of the Sea.

IFAW. (2001). *Report of the Workshop on Right Whale Acoustics: Practical applications in Conservation*.

Ilyina, T., R. E. Zeebe, and P. G. Brewer. (2010). Future ocean increasingly transparent to low-frequency sound owing to carbon dioxide emissions. Nature Geoscience, 3, 18-22.

Insley, S. J. (2000). Long-term vocal recognition in the northern fur seal. Nature, 406, 404-405.

International Union for the Conservation of Nature and Natural Resources (IUCN). (2015). *The IUCN Red List of Threatened Species. Version 2015-4*. Retrieved 22 December 2015 from <http://www.iucnredlist.org>

IWC (International Whaling Commission). 1981. Report of the subcommittee on other baleen whales. *Report of the International Whaling Commission 31*, 122-132.

IWC. (1996). Report of the subcommittee on North Pacific Bryde's whales. *Report of the International Whaling Commission 46*, 147-159.

IWC. (2008). International Whaling Commission: Report of the scientific committee. *Report to the International Whaling Commission 60/Report 1.* Cambridge, U.K.: IWC.

IWC. (2009). Population estimates. Retrieved from IWC website <http.www.iwcoffice.org/conservation/estimate.htm>.

IWC. (2010). *Whale population estimates*. Retrieved from <https://iwc.int/estimate>.

IWC. (2013). Aboriginal whaling catch and catch limits accessed on Thursday March 7, 2013 at: http://iwc.int/catches#aborig. Retrieved from <http://iwc.int/table_aboriginal>.

IWC. (2015). *Whale population estimates*. Retrieved 5 August 2015 from <https://iwc.int/estimate>.

IWC. (2016). *Whale population estimates*. Retrieved January 2016 from <https://iwc.int/estimate>.

IWC. (2016a). *Aboriginal subsistence whaling*. Retrieved February 28, 2016 from <https://iwc.int/aboriginal#>.

IWC. (2016b). *Aboriginal subsistence whaling catches since 1985*. Retrieved February 28, 2016 from <https://iwc.int/table_aboriginal>.

IWC. (2016c). *Aboriginal subsistence whaling sub-committee*. Retrieved February 28, 2016 from <https://iwc.int/aboriginal-subsistence-whaling-sub-committee>.

IWC. (2016d). *Aboriginal subsistence whaling: Expert workshop begins in Greenland*. Retrieved February 28, 2016 from <https://iwc.int/aboriginal-subsistence-whaling-expert-workshop-beg>.

IWC. (2016e). *Whalewatching: Providing an international focus for the whalewatching sector*. Retrieved February 28, 2016 from <https://iwc.int/whalewatching>.

Irvine, L. M., B. R. Mate, M. H. Winsor, D. M. Palacios, S. J. Bograd, D. P. Costa, and H. Bailey. (2014). Spatial and temporal occurrence of blue whales off the U.S. West Coast, with implications for management. PloS one, 9(7), e102959. doi:10.1371/journal.pone.0102959

Ivashchenko, Y., & Clapham, P. (2010). Bowhead whales *Balaena mysticetus* in the Okhotsk Sea. *Mammal Review, 40*(1), 65-89. doi:10.1111/j.1365-2907.2009.00152.x.

Iverson, R. T. B. (1967). Response to yellow fin tuna to underwater sound. Pages 105-121 in W.N. Tavolga, ed. *Marine bioacoustics*. Oxford, England: Pergamon Press.

James, M. C., J. Davenport, and G. C. Hays. (2006). Expanded thermal niche for a diving vertebrate: A leatherback turtle diving into near-freezing water. Journal of Experimental Marine Biology and Ecology, 335(2), 221-226. doi:10.1016/j.jembe.2006.03.013

James, M. C., S. A. Eckert, and R. A. Myers. (2005). Migratory and reproductive movements of male leatherback turtles (*Dermochelys coriacea*). Marine Biology, 147(4), 845-853.

Janik, V. M., S. L. King, L. S. Sayigh, and R. S. Wells. (2013). Identifying signature whistles from recordings of groups of unrestrained bottlenose dolphins (*Tursiops truncatus*). Marine Mammal Science, 29(1), 109-122. doi:10.1111/j.1748-7692.2011.00549.x

Jaquet, N., S. Dawson, and L. Douglas. (2001). Vocal behavior of male sperm whales: why do they click? Journal of the Acoustical Society of America, 109(5), 2254-2259.

Jefferson, T., Leatherwood, S., Webber, M. (1993). *FAO species identificaion guide: Marine Mammals of the World*. Rome, Italy: FAO UNEP.

Jefferson, T. A. (2009a). Dall's Porpoise *Phocoenoides dalli*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 296-298): Academic Press.

Jefferson, T. A. (2009b). Rough-Toothed Dolphin *Steno bredanensis*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 990-992). New York: Academic Press.

Jefferson, T. A., and N. B. Barros. (1997). *Peponocephala electra*. Mammalian Species, 553, 1-6.

Jefferson, T. A., M. A. Webber, and R. L. Pitman. (2008). *Marine mammals of the world a comprehensive guide to their identification*. San Diego, California: Elsevier.

Jefferson, T. A., M. A. Webber, and R. L. Pitman. (2015). *Marine mammals of the world a comprehensive guide to their identification* (Second ed.). San Diego, California: Elsevier.

Jérémie, S., A. Gannier, S. Bourreau, and J. C. Nicolas. (2006). *Acoustic monitoring of cetaceans in territorial waters off La Martinique (FWI), Lesser Antilles: global abundance and first description of Kogia simus vocalisations (November December 2004).*

Johnson, C. S. (1967). Sound detection thresholds in marine mammals. In W. N. Tavolga (Ed.), *Marine bio-acoustics* (Vol. 2, pp. 247-260). New York: Pergamon Press.

Johnson, C. S., M. W. McManus, and D. Skaar. (1989). Masked tonal hearing thresholds in the beluga whale. *Journal of the Acoustical Society of America, 85*(6), 2651-2654.

Johnson, H. D., K. M. Stafford, J. C. George, W. G. Ambrose, & C. W. Clark. (2014). Song sharing and diversity in the Bering-Chukchi-Beaufort population of bowhead whales (*Balaena mysticetus*), spring 2011. *Marine Mammal Science, 31*(3), 902-922. doi:10.1111/mms.12196.

Johnson, M., P. T. Madsen, W. M. X. Zimmer, N. Aguilar de Soto, & P. L. Tyack. (2004). Beaked whales echolocate on prey. *Proceedings of the Royal Society of London Series B, 271*, S383-S386.

Johnson, M., P. T. Madsen, W. M. X. Zimmer, N. Aguilar de Soto, & P. L. Tyack. (2006). Foraging Blainville's beaked whales (*Mesoplodon densirostris*) produce distinct click types matched to different phases of echolocation. *The Journal of Experimental Biology, 209*(24), 5038-5050.

Johnston, C.E., & Phillips, C.T. (2003). Sound production in sturgeon *Scaphirhynchus albus* and *S. platyrynchus* (Acipenseridae). *Environmental Biology of Fishes 68*, 59-64.

Jones, G. J., & L. S. Sayigh. (2002). Geographic variation in rates of vocal production of free-ranging bottlenose dolphins. Marine Mammal Science, 18(2), 374-393.

Jones, M. L., & S. L. Swartz. (2009). Gray Whale *Eschrichtius robustus*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), (pp. 503-511): Elsevier.

Jones, J. M., Thayre, B. J., Roth, E. H., Mahoney, M., Sia, I., Merculief, K., Jackson, C., Zeller, C., Clare, M., Bacon, A. et al. (2014). Ringed, bearded, and ribbon seal vocalizations north of Barrow, Alaska: Seasonal presence and relationship with sea ice. *Arctic, 67,* 203-222.

Jorgensen, S. J., Klimley, A. P., & Muhlia-Melo, A. F. (2009). Scalloped hammerhead shark *Sphyrna lewini*, utilizes deep-water, hypoxic in the Gulf of California. Journal of Fish Biology 74:1682-1687.

Joseph, J.E., & Chiu, C.S. (2010). A computational assessment of the sensitivity of ambient noise level to ocean acidification. *The Journal of the Acoustical Society of America, 128*(3), EL144-149. doi:10.1121/1.3425738.

Kamezaki, N., Y. Matsuzawa, O. Abe, H. Asakawa, T. Fujii, K. Goto, S. Hagino, M. Hayami, T. I. M. Ishii, T. Kamata, H. Kato, J. Kodama, Y. Kondo, I. Miyawaki, K. Mizobuchi, Y. Nakamura, Y. Nakashima, H. Naruse, K. Omuta, M. Samejima, H. Suganuma, H. Takeshita, T. Tanaka, T. Toji, M. Uematsu, A. Yamamoto, T. Yamato, & I. Wakabayashi. (2003). Loggerhead turtles nesting in Japan. In A. B. Bolten and B. E. Witherington (Eds.), *Loggerhead sea turtles* (pp. 210-217). Washington, D.C.: Smithsonian Institution Press.

Jenner, C., Jenner, M., Burton, C., Sturrock, V., Salgado Kent, C., Morrice, M., Attard, C., Moller, L. & Double, M.C. (2008). Mark recapture analysis of pygmy blue whales from the Perth Canyon, Western Australia 2000-2005. *Paper submitted for consideration by the International Whaling Commission Scientific Committee SC/60/SH16*.

Johnston, C.E., & Phillips, C.T. (2003). Sound production in sturgeon *Scaphirhynchus albus* and *S. platyrynchus* (Acipenseridae). *Environmental Biology of Fishes, 68*, 59-64.

Johnston, S. E., Zerbini, A. N., & Butterworth, D. S. (2011). A Bayesian approach to assess the status of Southern Hemisphere humpback whales (*Megaptera novaeangliae*) with an application to breeding stock G. *Journal of Cetacean Research and Management, (Special issue, 3*, 309-18.

Jones, E. L., McConnell, B. J., Smout, S., Hammond, P. S., Duck, C. D., Morris, C. D., Thompson, D., Russell, D. J. F., Vincent, C., Cronin, M., Sharples, R. J., & Matthiopoulos, J. (2015). Patterns of space use in sympatric marine colonial predators reveal scales of spatial partitioning. *Marine Ecology Progress Series, 534*, 235-249.

Jorgensen, S. J., Klimley, A. P., & Muhlia-Melo, A. F. (2009). Scalloped hammerhead shark *Sphyrna lewini*, utilizes deep-water, hypoxic in the Gulf of California. *Journal of Fish Biology, 74,* 1682-1687.

Kamminga, C., & J. G. Van Velden. (1987). Investigations on Cetacean Sonar VIII: Sonar signals of *Pseudorca crassidens* in comparison with *Tursiops truncatus*. *Aquatic Mammals, 13*(2), 43-50.

Kanaji, Y., Miyashita, T., Yoshida, H., Okazaki, M., & Kishiro, T. (2015). Abundance estimates of dalli-type and truei-type of Dall's porpoise *Phocoenoides dalli* in the western central part of the Sea of Okhotsk, July–September between 1990 and 2010. *Fisheries Science, 81,* 611-619.

Karamanlidis, A. A., P. Dendrinos, P. F. de Larrinoa, A. C. Gücü, W. M. Johnson, C. O. Kiraç, and R. Pires. (2015). The Mediterranean monk seal *Monachus monachus*: status, biology, threats, and conservation priorities. Mammal Review, n/a-n/a. doi:10.1111/mam.12053

Karlsen, H. E. (1992a). Infrasound sensitivity in the plaice (*Pleuronectes platessa*). Journal Of Experimental Biology*,* 171(1), 173-187.

Karlsen, H. E. (1992b). The inner ear is responsible for detection of infrasound in the perch (*Perca fluviatilis*). Journal Of Experimental Biology*,* 171(1), 163-172.

Karlsen, J. D., A. Bisther, C. Lydersen, T. Haug, and K. M. Kovacs. (2002). Summer vocalisations of adult male white whales (*Delphinapterus leucas*) in Svalbard, Norway. Polar Biology*,* 25(11), 808-817.

Kasamatsu, F., & Joyce, G. G. (1995). Current status of odontocetes in the Antarctic. *Antarctic Science, 7*(4), 365-379.

Kaschner, K. (2006). Mapping world-wide distributions of marine mammal species using a relative environmental suitability (RES) model. *Marine Ecology Progress Series, 316*, 285-310.

Kastak, D., and R. J. Schusterman. (1996). Temporary threshold shift in a harbor seal (*Phoca vitulina*). Journal of the Acoustical Society of America*,* 100(3), 1905-1908.

Kastak, D., and R. J. Schusterman. (1998). Low-frequency amphibious hearing in pinnipeds: Methods, measurements, noise, and ecology. Journal of the Acoustical Society of America*,* 103(4), 2216-2228.

Kastak, D., and R. J. Schusterman. (1999). In-air and underwater hearing sensitivity of a northern elephant seal (*Mirounga angustirostris*). Canadian Journal of Zoology*,* 77(11), 1751-1758.

Kastak, D., B. L. Southall, R. J. Schusterman, and C. R. Kastak. (2005). Underwater temporary threshold shift in pinnipeds: Effects of noise level and duration. Journal of the Acoustical Society of America*,* 118(5), 3154-3163.

Kastelein, R. A., P. Bunskoek, M. Hagedoorn, W. W. L. Au, and D. de Haan. (2002). Audiogram of a harbor porpoise (*Phocoena phocoena*) measured with narrow-band frequency-modulated signals. Journal of the Acoustical Society of America*,* 112(1), 334-344.

Kastelein, R. A., and N. M. Gerrits. (1991). Swimming, diving, and respiration patterns of a Northern bottlenose whale (*Hyperoodon ampullatus*, Forster, 1770). Aquatic Mammals*,* 17(1), 20-30.

Kastelein, R. A., M. Hagedoorn, W. W. L. Au, and D. de Haan. (2003). Audiogram of a striped dolphin (*Stenella coeruleoalba*). Journal of the Acoustical Society of America, 113(2), 1130-1137.

Kastelein, R. A., S. v. d. Heul, W. C. Verboom, N. Jennings, J. v. d. Veen, and D. d. Haan. (2008). Startle response of captive North Sea fish species to underwater tones between 0.1 and 64 kHz. Marine Environmental Research, 65(5), 369-377.

Kastelein, R. A., L. Hoek, and C. A. F. de Jong. (2011). Hearing thresholds of a harbor porpoise (*Phocoena phocoena*) for sweeps (1–2 kHz and 6–7 kHz bands) mimicking naval sonar signals. The Journal of the Acoustical Society of America, 129(5), 3393. doi:10.1121/1.3569739

Kastelein, R. A., L. Hoek, P. J. Wensveen, J. M. Terhune, and C. A. F. de Jong. (2010). The effect of signal duration on the underwater hearing thresholds of two harbor seals (*Phoca vitulina*) for single tonal signals between 0.2 and 40 kHz. Journal of the Acoustical Society of America, 127(2), 1135-1145.

Kastelein, R. A., J. Schop, L. Hoek, and J. Covi. (2015). Hearing thresholds of a harbor porpoise (*Phocoena phocoena*) for narrow-band sweeps. The Journal of the Acoustical Society of America, 138(4), 2508. doi:10.1121/1.4932024

Kastelein, R. A., R. van Schie, W. C. Verboom, and D. de Haan. (2005). Underwater hearing sensitivity of a male and a female Steller sea lion (*Eumetopias jubatus*). The Journal of the Acoustical Society of America, 118(3), 1820-1829.

Kastelein, R. A., P. J. Wensveen, L. Hoek, W. C. Verboom, and J. M. Terhune. (2009). Underwater detection of tonal signals between 0.125 and 100 kHz by harbor seals (*Phoca vitulina*). Journal of the Acoustical Society of America, 125(2), 1222-1229.

Kasuya, T. (1986). Distribution and behavior of Baird's beaked whales off the Pacific coast of Japan. *Scientific Report of the Whales Research Institute, 37*, 61-83.

Kasuya, T. (2009a). Giant Beaked Whales *Berardius bairdii* and *B. arnuxii*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), (pp. 498-500): Elsevier.

Kasuya, T. (2009b). Giant Beaked Whales *Berardius bairdii* and *B. arnuxii*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 498-500). New York: Academic Press.

Kato, H., & Miyashita,T. (1998). Current status of North Pacific sperm whales and its preliminary abundance estimates. *Report SC/50/CAWS/52 submitted to the International Whaling Commission.*

Kato, H., and W. F. Perrin. (2009). Bryde's whale (*Balaenoptera edeni*). In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 158-163): Academic Press.

Kelly, J. C., and D. R. Nelson. (1975). Hearing thresholds of the horn shark, *Heterodontus francisci*. Journal of the Acoustical Society of America, 58(4), 905-909.

Kelly, B. P., Bengtson, J. L., Boveng, P. L., Cameron, M. F., Dahle, S. P., Jansen, J. K., Logerwell, E. A., Overland, J. E., Sabine, C. L., Waring, G. T., & Wilder, J. M. (2010). *Status review of the ringed seal (Phoca hispida).* (NOAA Technical Memorandum NMFS-AFSC-212). Seattle, WA: Alaska Fisheries Science Center, National Marine Fisheries Service.

Kemper, C. M. (2009). Pygmy Right Whale *Caperea marginata*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 939-941). New York: Academic Press.

Kenney, R. D. (2009). Right Whales *Eubalaena glacialis, E. japonica,* and *E. australis*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 962-972). New York: Academic Press.

Kerosky, S. M., A. Širović, L. K. Roche, S. Baumann-Pickering, S. M. Wiggins, and J. A. Hildebrand. (2012). Bryde's whale seasonal range expansion and increasing presence in the Southern California Bight from 2000 to 2010. Deep Sea Research Part I: Oceanographic Research Papers*,* 65, 125-132. doi:10.1016/j.dsr.2012.03.013

Ketten, D.R. (2013). *Acoustic fatheads: Parallel adaptations for underwater hearing in whales, turtles, and sea birds*. Paper presented at the Zurich Center for Integrative Human Physiology (ZIHP) Special Seminar, University Hospital Zurich, Germany.

Ketten, D. (1998). Marine Mammal Auditory Systems: A summary of audiometric and anatomical data and its implications for underwater acoustic impacts (NOAA-TM-NMFS-SWFSC-256). San Diego

Ketten, D., and S. M. Bartol. (2006). Functional measures of sea turtle hearing. ONR Final Project Report, ONR Award N00014-02-1-0510. Boston, Massachusetts

Ketten, D. R. (1994). Functional Analyses of Whale Ears: Adaptations for Underwater Hearing. IEEE, 264-270.

Ketten, D. R. (2000). Cetacean Ears. In W. W. L. Au, A. N. Popper, and R. R. Fay (Eds.), *Hearing by Whales and Dolphins* (pp. 43-108). New York: Springer-Verlag.

Ketten, D. R. (2008). Underwater Ears and the Physiology of Impacts: Comparative Liability for Hearing Loss in Sea Turtles, Birds, and Mammals. Bioacoustics*,* 17(1-3), 312-315. doi:10.1080/09524622.2008.9753860

King, J., K, and M. M. Bryden. (1981). Southern elephant seal *Mirounga leonina* Linnaeus, 1758. In S. H. Ridgway and R. J. Harrison (Eds.), *Handbook of marine mammals. Volume 2: Seals* (pp. 297-327). New York, New York: Academic Press.

King, J. E. (1983). *Seals of the world*. 2nd edition. London, UK: British Museum (Natural History) and Oxford University Press. 240 pages.

Kinze, C. C. (2009). White-Beaked Dolphin *Lagenorhynchus albirostris*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 1255-1258). New York: Academic Press.

Kiraç, C. O., Y. Savas, H. Güçlüsoy, and N. O. Veryeri. (2002). Observations on diving behaviour of free ranging Mediterranean monk seals Monachus monachus on Turkish coasts. Monachus Guardian 5(1):1-8.*,* 5(1), 1-8.

Kirkwood, R., M. Lynch, N. Gales, P. Dann, and M. Sumner. (2006). At-sea movements and habitat use of adult male Australian fur seals (*Arctocephalus pusillus doriferus*). Canadian Journal of Zoology*,* 94(12), 1781-1788. doi:doi:10.1139/Z06-164

Kirkman, S. P., Yemane, D., Oosthuizen, W. H., Meyer, M. A., Kotze, P. G. H., Skrypzeck, H., Vaz Velho, F. and Underhill, L. G. (2013). Spatio-temporal shifts of the dynamic Cape fur seal population in southern Africa, based on aerial censuses (1972-2009). *Marine Mammal Science 29*: 497-524.

Klimley, A. P., and A. A. Myrberg. (1979). Acoustic Stimuli Underlying Withdrawal from a Sound Source by Adult Lemon Sharks, *Negaprion brevirostris* (Poey). Bulletin of Marine Science*,* 29(4), 447-458.

Knudsen, F. R., P. S. Enger, and O. Sand. (1992). Awareness Reactions and Avoidance Response to Sound in Juvenile Atlantic *Salmon Salmo salar* L. Journal of Fish Biology*,* 40(4), 523-534.

Kooyman, G. L., and R. L. Gentry. (1986). Diving behavior of South African fur seals. In R. L. Gentry and G. L. Kooyman (Eds.), *Fur seals: Maternal strategies on land and sea*. Princeton, New Jersey: Princeton University Press.

Kovacs, K., Lowry, L., and Harkonen, T. (2008a). *Pusa hispida. The IUCN Red List of Threatened Species 2008*: e.T41672A10505155. IUCN SSC Pinniped Specialist Group. <http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T41672A10505155.en>.

Kovacs, K. & Lowry, L. (IUCN SSC Pinniped Specialist Group). (2008b). *Erignathus barbatus. The IUCN Red List of Threatened Species 2008*: e.T8010A12882802. <http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T8010A12882802.en>.

Kovacs, K. M. (2009). Hooded Seal *Cystophora cristata*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), (pp. 569-573): Elsevier.

Kraght, P. E. (1995). Fronts and storms. In D. M. Considine (Ed.), *Van Nostrand's Scientific Encyclopedia* (8th ed.). New York, New York: Van Nostrand Reinhold.

Kritzler, H., and L. Wood. (1961). Provisional audiogram for the shark, *Carcharhinus leucas*. Science*,* 133, 1480-1482.

Kruse, S.,Caldwell,D. K.,& Caldwell,M.C. (1999). Risso'sdolphin *Grampus griseus* (G. Cuvier, 1812). Pages 183–212 in Ridgway, S. H., & Harrison, R. (Eds.). *Handbook of marine mammals, vol.6, The second book of dolphins and porpoises*. San Diego, CA: Academic Press.

Krutzikowsky, G. K., and B. R. Mate. (2000). Dive and surfacing characteristics of bowhead whales (*Balaena mysticetus*) in the Beaufort and Chukchi seas. Canadian Journal of Zoology*,* 78(7), 1182-1198.

Kuczaj, S. A., H. C. Eskelinen, B. L. Jones, and J. L. Borger-Turner. (2015). Dolphin (*Tursiops truncatus*) Mothers Use Individually Distinctive Acoustic Signals To Call Their Calves. doi:10.12966/abc.02.07.2015

Kuningas, S., Similä, T., & Hammond, P. S. (2014). Population size, survival and reproductive rates of northern Norwegian killer whales (*Orcinus orca*) in 1986-2003. *Journal of the Marine Biological Association of the United Kingdom, 9,* 1277-1291.

Kuzin, A. E. (2014). New data on the abundance of the northern fur seal (*Callorhinus ursinus*), Steller sea lion (*Eumetopias jubatus*), and spotted seal (*Phoca largha*) on Tyuleniy Island, Sea of Okhotsk. *Russian Journal of Marine Biology, 40*(7), 532-538.

Kvadsheim, P. H., E. M. Sevaldsen, L. P. Folkow, and A. S. Blix. (2010). Behavioural and physiological responses of hooded seals (*Cystophora cristata*) to 1 to 7 kHz Sonar Signals. *Aquatic Mammals, 36*(3), 239-247. doi:10.1578/am.36.3.2010.239.

Kyhn, L. A., F. H. Jensen, K. Beedholm, J. Tougaard, M. Hansen, and P. T. Madsen. (2010). Echolocation in sympatric Peale's dolphins (*Lagenorhynchus australis*) and Commerson's dolphins (*Cephalorhynchus commersonii*) producing narrow-band high-frequency clicks. Journal Of Experimental Biology, 213(11), 1940-1949. doi:10.1242/jeb.042440.

Kyhn, L. A., J. Tougaard, K. Beedholm, F. H. Jensen, E. Ashe, R. Williams, and P. T. Madsen. (2013). Clicking in a killer whale habitat: narrow-band, high-frequency biosonar clicks of harbour porpoise (*Phocoena phocoena*) and Dall's porpoise (*Phocoenoides dalli*). PloS one, 8(5), e63763. doi:10.1371/journal.pone.0063763.

Kyhn, L. A., J. Tougaard, F. Jensen, M. Wahlberg, G. Stone, A. Yoshinaga, K. Beedholm, and P. T. Madsen. (2009). Feeding at a high pitch: Source parameters of narrow band, high-frequency clicks from echolocating off-shore hourglass dolphins and coastal Hector's dolphins. Journal of the Acoustical Society of America, 125(3), 1783-1791.

Lacsamana, J. K. M, Ventolero, M. F. H., Blatchley, D., & Santos, M.D. (2015). First record of a rare beaked whale *Mesoplodon hotaula* in the Philippines. *Marine Biodiversity Records, 8,* e77. doi:10.1017/S1755267215000457.

Ladich, F. (2014). Fish bioacoustics. *Current Opinion in Neurobiology, 28*, 121-127. doi:10.1016/j.conb.2014.06.013.

Ladich, F., and A. N. Popper. (2004). Parallel evolution in fish hearing organs. In E. G. Manley, A. N. Popper, and R. R. Fay (Eds.), *Evolution of the Vertebrate Auditory System* (pp. 95 - 227). New York: Springer-Verlag.

Laidre, K. L., H. Stern, K. M. Kovacs, L. Lowry, S. E. Moore, E. V. Regehr, S. H. Ferguson, Ø. Wiig, P. Boveng, R. P. Angliss, E. W. Born, D. Litovka, L. Quakenbush, C. Lydersen, D. Vongraven, and F. Ugarte. (2015). Arctic marine mammal population status, sea ice habitat loss, and conservation recommendations for the 21st century. *Conservation Biology, 29*(3), 724-737. doi:10.1111/cobi.12474.

Lammers, M. O., W. W. L. Au, and D. L. Herzing. (2003). The broadband social acoustic signaling behavior of spinner and spotted dolphins. The Journal of the Acoustical Society of America, 114(3), 1629-1639.

Lang, T. G. (1966). Hydrodynamic analysis of cetacean performance. In K. S. Norris (Ed.), *Whales, dolphins, and porpoises.* Berkeley, California: University of California Press.

Laran, S., Joiris, C., Gannier, A. & Kenney, R. D. (2010). Seasonal estimates of densities and predation rates of cetaceans in the Ligurian Sea, northwestern Mediterranean Sea: An initial examination. *Journal of Cetacean Research and Management, 11*, 31-40.

Latha, G., S. Senthilvadivu, R. Venkatesan, and V. Rajendran. (2005). Sound of shallow and deep water lobsters: Measurements, analysis, and characterization (L). The Journal of the Acoustical Society of America, 117(5), 2720. doi:10.1121/1.1893525.

Lauriano, G., Pierantonio, N., Donovan, G., & Panigada, S. (2014). Abundance and distribution of *Tursiops truncatus* in the Western Mediterranean Sea: An assessment towards the Marine Strategy Framework Directive requirements. *Marine Environmental Research 100*, 86-93. <http://dx.doi.org/10.1016/j.marenvres.2014.04.001>.

Lavender, A.L., Bartol, S.M., and Bartoll, K. (2011). A two-method approach for investigating the hearing capabilities of loggerhead sea turtles (*Caretta caretta*). Proceedings of 31st Annual Symposium on Sea Turtle Biology and Conservation, San Diego, CA. <http://iconferences.seaturtle.org/preview.shtml?event_id=18&abstract_id=4003>. Accessed August 2011.

Lavender, A., Bartol, S. and Bartol, I. (2012). Hearing Capabilities of Loggerhead Sea Turtles (*Caretta caretta*) Throughout ontogeny. Pages 89-92 in Popper, A., and Hawkins, A., editors. *The Effects of Noise on Aquatic Life. Advances in Experimental Medicine and Biolog*y. Volume 730. Springer: New York.

Lavender, A.L., Bartol, S.M., and Bartol, I.K. 2014. Ontogenetic investigation of underwater hearing capabilities in loggerhead sea turtles (*Caretta caretta*) using a dual testing approach. *The Journal of Experimental Biology 217*(14):2580-2589.

Laws, R. M. (1994). History and present status of southern elephant seal populations *Elephant seals: population ecology, behavior, and physiology* (pp. 49-65). Berkeley: University of CA Press.

Lawson, J. W., and Gosselin, J.-F. (2009). Distribution and preliminary abundance estimates for cetaceans seen during Canada's Marine Megafauna Survey-A component of the 2007 TNASS. *(Canadian Scientific Advisory Secretariat Research Document 2009/031).*

Lawson, J. W., & Gosselin, J.-F-. (2011). Fully-corrected cetacean abundance estimates from the Canadian TNASS survey. *(Working Paper 10, National Marine Mammal Peer Review Meeting. Ottawa, Canada).*

Lawson, J. W., & Stevens, T. S. 2014. Historic and current distribution patterns, and minimum abundance of killer whales (*Orcinus orca*) in the north-west Atlantic. *Journal of the Marine Biological Association of the United Kingdom, 9,* 1253-1265.

Lazell, J. D. (1980). New England waters: Critical habitat for marine turtles. Copeia, 1980, 290-295.

Le Boeuf, B. J., and R. M. Laws (Eds.). (1994). *Elephant Seals: Populations Ecology, Behavior, and Physiology*. London: Universtiy of California Press.

Le Boeuf, B. J., Y. Naito, A. C. Huntley, and T. Asaga. (1989). Prolonged, continuous, deep diving by northern elephant seals. Canadian Journal of Zoology, 67, 2514-2519.

Le Boeuf, B. J., and R. S. Peterson. (1969). Dialects in elephant seals. Science, 166, 1654-1656.

Le Boeuf, B. J., and L. F. Petrinovich. (1974). Dialects of northern elephant seals, *Mirounga angustirostris*: origin and reliability. Animal Behaviour, 22, 656-663.

Leatherwood, J. S., and M. E. Dalheim. (1978). Worldwide distribution of pilot whales and killer whales. San Diego, California

Leatherwood, S., W. F. Perrin, V. L. Kirby, C. L. Hubbs, and M. Dahlheim. (1980). Distribution and Movements of Risso's Dolphin *Grampus griseus* in the Eastern North Pacific. Fishery Bulletin Washington D C, 77(4), 951-964.

Leatherwood, S., and R. R. Reeves. (1983). *The Sierra Club Handbook of Whales and Dolphins*. San Francisco: Sierra Club Books.

Leatherwood, S., R. R. Reeves, W. F. Perrin, and W. E. Evans. (1988). *Whales, dolphins and porpoises of the eastern North Pacific and adjacent Arctic waters*. New York, NY: Dover Publication.

Leatherwood, S., and W. A. Walker. (1979). The northern right whale dolphin *Lissodelphis borealis* Peale in the eastern north pacific. In H. E. Winn and B. L. Olla (Eds.), *Behavior of Marine animals: Current perspectives in research* (Vol. 3, pp. 85-141). Plenum.

LeDuc, R. G. (2009). Delphinids, overview. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals*: Academic Press.

Lee, O., R. D. Andrews, V. N. Burkanov, and R. W. Davis. (2014). Ontogeny of early diving and foraging behavior of northern fur seal (*Callorhinus ursinus*) pups from Bering Island, Russia. Marine Biology, 161(5), 1165-1178. doi:10.1007/s00227-014-2408-8

Lenfant, C. (1969). Physiological properties of blood of marine mammals. In H. T. Andersen (Ed.), *The biology of marine mammals* (pp. 95-116). New York: Academic Press.

LGL (LGL Limited, Environmental Research Associates). (2008). Environmental assessment of a marine geophysical survey by the R/V *Marcus G. Langseth* in Southeast Asia, March–July 2009.

LGL. (2011). Environmental assessment of a low-energy marine geophysical survey by the R/V *Thompson* in the western tropical Pacific Ocean, November–December 2011.

LGL. (2015). Environmental assessment of HMDC's 2D/3D/4D seismic projects 2013-Life of Field, Newfoundland offshore area, revised. LGL Rep. SA1207 (May 2013 revised February 2015). Prepared by LGL Limited for Hibernia Management and Development Company Ltd., St. John's, Newfoundland. St. John's, Newfoundland: LGL.

Lima, I. M. S. d., L. G. de Andrade, R. Ramos de Carvalho, J. Lailson-Brito, and A. de Freitas Azevedo. (2012). Characteristics of whistles from rough-toothed dolphins (*Steno bredanensis*) in Rio de Janeiro coast, southeastern Brazil. The Journal of the Acoustical Society of America, 131(5), 4173-4181. doi:10.1121/1.3701878

Limpus, C. J. (2007). A biological review of Australian marine turtle species. 5. Flatback turtle, *Natator depressus* (Garman)

Limpus, C. J., and D. J. Limpus. (2003). Loggerhead turtles in the Equatorial and Southern Pacific Ocean. In A. B. Bolten and B. E. Witherington (Eds.), *Loggerhead sea turtles* (pp. 199-209). Washington, D.C.: Smithsonian Institution Press.

Limpus, C. J., C. J. Parmenter, V. Baker, and A. Fleay. (1983). The flatback turtle, *Chelonia depressa*, in Queensland: Post-nesting migration and feedling ground distribution. Australian Wildlife Research, 10(3), 557-561.

Ling, J. K. (2009). Australian Sea Lion *Neophoca cinerea*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 58-61): Academic Press.

Linnenschmidt, M., J. Teilmann, T. Akamatsu, R. Dietz, and L. A. Miller. (2013). Biosonar, dive, and foraging activity of satellite tracked harbor porpoises (*Phocoena phocoena*). Marine Mammal Science, 29(2), E77-E97. doi:10.1111/j.1748-7692.2012.00592.x

Lipsky, J. D. (2009). Right whale dolphins (*Lissodelphis borealis* and *L. peronii*). . In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 958-962): Academic Press.

Ljungblad, D. K., P. D. Scoggins, and W. G. Gilmartin. (1982). Auditory thresholds of a captive Eastern Pacific bottlenose dolphin, *Tursiops spp.* Journal of the Acoustical Society of America, 72(6), 1726-1729.

Lockyer, C. (1984). Review of baleen whale (*Mysteceti*) reproduction and implications for management. In W. F. Perrin, R. L. J. Brownell, and D. P. DeMaster (Eds.), *Reproduction in whales, dolphins, and porpoises* (Special Issue 6 ed., pp. 27-50). Cambridge, England: International Whaling Commission Special Issue 6.

López-Mendilaharsua, M., C. F. D. Rocha, A. Domingo, B. P. Wallace, & P. Miller. (2009). Prolonged deep dives by the leatherback turtle Dermochelys coriacea: pushing their aerobic dive limits. *Marine Biodiversity Records, 2*, e35.

Loughlin, T. R. (2009). Steller's sea lion (*Eumetopias jubatus*). In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 1107-1110): Academic Press.

Lovell, J. M., Findlay, M. M., Moate, R. M., Nedwell, J. R., & Pegg, M. A. (2005). The inner ear morphology and hearing abilities of the paddlefish (*Polyodon spathula*) and the lake sturgeon (*Acipenser fulvescens*). *Comparative Biochemistry and Physiology A-Molecular & Integrative Physiology, 142*(3), 286-296.

Lovell, J., Findlay, M., Moate, R., & Yan, H. (2005). The hearing abilities of the prawn *Palaemon serratus*. *Comparative Biochemistry and Physiology, Part A, 140*(1), 89-100.

Lowry, L. F., Frost, K. J., Davis, R., DeMaster, D. P., & Suydam, R. S. (1998). Movements and behavior of satellite-tagged spotted seals (*Phoca largha*) in the Bering and Chukchi Seas. *Polar Biology, 19*(4), 221-230.

Lowry, M.S., Condit, R., Hatfield, B., Allen, S. G., Berger, R., Morris, P. A., Le Boeuf, B. J. & Reiter, J. (2014). Abundance, distribution, and population growth of the northern elephant seal (*Mirounga angustirostris*) in the United States from 1991 to 2010. *Aquatic Mammals, 40*(1):20-31.

LTD, S.T. (2015). Revealed: *The world's top 100 dive sites*. Retrieved from <http://www.scubatravel.co.uk/topdiveslong.html>.

Lutcavage, M. E., & P. L. Lutz. (1997). Diving physiology. In P. L. Lutz and J. A. Musick (Eds.), *The biology of sea turtles*. Boca Raton, FL: CRC Press.

Lydersen, C. (1991). Monitoring ringed seal (*Phoca hispida*) activity by means of acoustic telemetry. *Canadian Journal of Zoology, 69*(5), 1178-1182.

Lydersen, C., & K. M. Kovacs. (1993). Diving behaviour of lactating harp seal, *Phoca groenlandica*, females from the Gulf of St. Lawrence, Canada. *Animal Behaviour, 46*, 1213-1221.

Lynn, S. K., & D. L. Reiss. (1992). Pulse sequence and whistle production by two captive beaked whales, Mesoplodon species. *Marine Mammal Science, 8*(3), 299-305.

Maclean, S. A. (2002). Occurrence, behavior and genetic diversity of bowhead whales in the western Sea of Okhotsk, Russia. (Unpublished Master's thesis). Texas A&M University, College Station, TX.

Madsen, P. T., I. Kerr, & R. Payne. (2004a). Echolocation clicks of two free-ranging, oceanic delphinids with different food preferences: false killer whales *Pseudorca crassidens* and Risso's dolphins *Grampus griseus*. *The Journal of Experimental Biology, 207*(11), 1811-1823.

Madsen, P. T., I. Kerr, and R. Payne. (2004b). Source parameter estimates of echolocation clicks from wild pygmy killer whales (*Feresa attenuata*) (L). *The Journal of the Acoustical Society of America, 116*(4), 1909-1912.

Madsen, P. T., R. Payne, N. U. Kristiansen, M. Wahlberg, I. Kerr, & B. Mohl. (2002). Sperm whale sound production studied with ultrasound time/depth-recording tags. *Journal of Experimental Biology, 205*(13), 1899-1906.

Madsen, P. T., M. Wahlberg, and B. Møhl. (2002). Male sperm whale (*Physeter macrocephalus*) acoustics in a high- latitude habitat: implications for echolocation and communication. Behavioral Ecology and Sociobiology*,* 53(1), 31-41.

Magnúsdóttir, E. E., M. H. Rasmussen, M. O. Lammers, & J. Svavarsson. (2014). Humpback whale songs during winter in subarctic waters. Polar Biology*,* 37(3), 427-433. doi:10.1007/s00300-014-1448-3

Masaki, Y. (1977). The separation of the stock units of sei whales in the North Pacific. *Report of the International Whaling Commission Special Issue, 1*, 71-79.

Malme, C. I., P. R. Miles, C. W. Clark, P. L. Tyack, & J. E. Bird. (1983). Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior (5366 (NTIS PB86-174474))

Malme, C. I., P. R. Miles, C. W. Clark, P. L. Tyack, & J. E. Bird. (1984). Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior, Phase II. (5586, for US MMS (NTIS PB86-218377))

Malme, C. I., P. R. Miles, P. L. Tyack, C. W. Clark, & J. E. Bird. (1985). Investigation of the Potential Effects of underwater noise form petroleum industry activities on feeding humpback whale behavior (5851 (NTIS PB86-218385))

Malme, C. I., B. Würsig, J. E. Bird, & P. Tyack. (1988). Observations of feeding gray whale responses to controlled industrial noise exposure. In W. M. Sackinger and M. O. Jeffries (Eds.), *Port and Ocean Engineering under Arctic Conditions* (pp. 55-73). Fairbanks, AK: The Geophysical Institute.

Mann, D. A., B. M. Casper, K. S. Boyle, & T. C. Tricas. (2007). On the attraction of larval fishes to reef sounds. *Marine Ecology Progress Series, 338,* 307-310. doi:10.3354/meps338307.

Mann, D. A., D. M. Higgs, W. N. Tavolga, M. J. Souza, & A. N. Popper. (2001). Ultrasound detection by clupeiform fishes. *The Journal of the Acoustical Society of America, 109*(6), 3048. doi:10.1121/1.1368406.

Mann, D. A., & S. M. Jarvis. (2004). Potential sound production by a deep-sea fish. *The Journal of the Acoustical Society of America, 115*(5), 2331-2333.

Mann, D. A., Z. Lu, & A. N. Popper. (1997). A clupeid fish can detect ultrasound. *Nature, 389*, 341.

Margaritoulis, D., R. Argano, I. Baran, F. Bentivegna, M. N. Bradai, J. A. Camiñas, P. Casale, G. D. Metrio, G. G. A. Demetropoulos, B. J. Godley, D. A. Haddoud, J. Houghton, L. Laurent, & B. Lazar. (2003). Loggerhead turtles in the Mediterranean Sea: Present knowledge and conservation perspectives. In A. B. Bolten and B. E. Witherington (Eds.), *Loggerhead sea turtles* (pp. 175-198). Washington, D.C.: Smithsonian Institution Press.

Maguire, J.-J., Sissenwine, M., Csirke, J., Grainger, R., & Garcia, S. (2006). *The state of world highly migratory, straddling and other high seas fishery resources and associated species.* FAO Fisheries Technical Paper No. 495. Rome, Italy: Food and Agriculture Organization of the United Nations.

Marquez-M., R. (1994). Synopsis of biological data on the Kemp's ridley turtle, *Lepidochelys kempi* (Garman, 1880).

Marsh, H., Penrose, H., Eros, C., & Hugues, J. (2002). *Dugong: Status reports and action plans for countries and territories.* UNEP/DEWA/RS.02-1. Early Warning and Assessment Report Series. Nairobi, Kenya: United Nations Environment Programme. 172 pages.

Martin, K. J., S. C. Alessi, J. C. Gaspard, A. D. Tucker, G. B. Bauer, & D. A. Mann. (2012). Underwater hearing in the loggerhead turtle (*Caretta caretta*): a comparison of behavioral and auditory evoked potential audiograms. *The Journal of Experimental Biology,* 215(Pt 17), 3001-3009. doi:10.1242/jeb.066324

Martin Lopez, L. M., P. J. Miller, N. Aguilar de Soto, and M. Johnson. (2015). Gait switches in deep-diving beaked whales: biomechanical strategies for long-duration dives. The Journal of experimental biology*,* 218(Pt 9), 1325-1338. doi:10.1242/jeb.106013

Martin, S. W., C. R. Martin, B. M. Matsuyama, and E. E. Henderson. (2015). Minke whales (*Balaenoptera acutorostrata*) respond to navy training. The Journal of the Acoustical Society of America*,* 137(5), 2533. doi:10.1121/1.4919319

Maruska, K. P., and J. A. Sisneros. (2016). Comparison of Electrophysiological Auditory Measures in Fishes. In J. A. Sisneros (Ed.), *Fish Hearing and Bioacoustics* (Vol. 877, pp. 227-254).

Mate, B. R., V. Y. Ilyashenko, A. L. Bradford, V. V. Vertyankin, G. A. Tsidulko, V. V. Rozhnov, and L. M. Irvine. (2015). Critically endangered western gray whales migrate to the eastern North Pacific. Biol Lett*,* 11(4), 20150071. doi:10.1098/rsbl.2015.0071

Mate, B. R., G. K. Krutzikowsky, and M. H. Winsor. (2000). Satellite-monitored movements of radio-tagged bowhead whales in the Beaufort and Chukchi seas during the late-summer feeding season and fall migration. Canadian Journal of Zoology*,* 78(7), 1168-1181.

Mate, B. R., B. A. Lagerquist, and J. Calambokidis. (1999). Movements of North Pacific blue whales during the feeding season off southern California and their southern fall migration. Marine Mammal Science*,* 15(4), 1246-1257.

Mate, B. R., S. Nieukirk, R. Mesecar, and T. Martin. (1992). Application of remote sensing methods for tracking large cetaceans: North Atlantic right whales (*Eubalaena glacialis*). Herndon, Virginia

Mate, B. R., S. L. Nieukirk, and S. D. Kraus. (1997). Satellite-monitored movements of the northern right whale. Journal of Wildlife Management*,* 61(4), 1393-1405.

Mate, B. R., K. A. Rossbach, S. L. Nieukirk, R. S. Wells, A. B. Irvine, M. D. Scott, and A. J. Read. (1995). Satellite-monitored movements and dive behaviour of a bottlenose dolphin (*Tursiops truncatus*) in Tampa Bay, Florida. Marine Mammal Science*,* 11(4), 452-463.

Mate, B. R., K. M. Stafford, R. Nawojchik, and J. L. Dunn. (1994). Movements and dive behavior of a satellite-monitored Atlantic white-sided dolphin (*Lagenorhynchus acutus*) in the Gulf of Maine. Marine Mammal Science*,* 10(1), 116-121.

Matthews, C. J. D., S. P. Luque, S. D. Petersen, R. D. Andrews, and S. H. Ferguson. (2011). Satellite tracking of a killer whale (*Orcinus orca*) in the eastern Canadian Arctic documents ice avoidance and rapid, long-distance movement into the North Atlantic. Polar Biology, 34(7), 1091-1096. doi:10.1007/s00300-010-0958-x.

Matthews, J. N., S. Brown, D. Gillespie, M. Johnson, R. McLanaghan, A. Moscrop, D. Nowacek, R. Leaper, T. Lewis, and P. Tyack. (2001). Vocalisation rates of the North Atlantic right whale (*Eubalaena glacialis*). *Journal of Cetacean Research and Management, 3*(3), 271-282.

McAlpine, D. F. (2009). Pygmy and Dwarf Sperm Whales *Kogia breviceps* and *K. sima* In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 936-938). New York, NY: Academic Press.

McAlpine, D. F., & R. H. Walker. (1990). Extralimital records of the harp seal, *Phoca groenlandica*, from the western north Atlantic: A review. *Marine Mammal Science, 6*(3), 248-252.

McAlpine, D. F., & R. J. Walker. (1999). Additional extralimital records of the harp seal, *Phoca groenlandica*, from the Bay of Fundy, New Brunswick. Canadian Field-Naturalist, 113, 290-292.

McCauley, R.D., & Jenner, C. (2010). Migratory patterns and estimated population size of pygmy blue whales (*Balaenoptera musculus brevicauda*) traversing the Western Australian coast based on passive acoustics. *Paper SC/62/SH26 presented to the Scientific Committee, International Whaling Commission.*

McCauley , R. D., J. Fewtrel, A. J. Duncan, C. Jener, M. N. Jener, J. D. Penrose, R. I. T. Prince, A. Adhitya, J. Murdoch, & K. McCabe. (2000). *Marine seismic surveys: Analysis of airgun signals, and effects of airgun exposure on humpback whales, sea turtles, fishes and squid.*

McCosker, J.E. (1975). Feeding behaviour of Indo-Australian Hydrophiidae. Pages 217-232 in Dunson, W. A., ed. *The biology of sea snakes*. Baltimore: University Park Press.

McCowan, B., and D. Reiss. (1995). Quantitative Comparison of Whistle Repertoires from Captive Adult Bottlenose Dolphins (Delphinidae, *Tursiops truncatus*): A Re-evaluation of the Signature Whistle Hypothesis. *Ethology, 100*(3), 194-209.

McDonald, B. I., and P. J. Ponganis. (2014). Deep-diving sea lions exhibit extreme bradycardia in long-duration dives. *The Journal of Experimental Biology, 217*(Pt 9), 1525-1534. doi:10.1242/jeb.098558.

McDonald, M. A., J. A. Hildebrand, and S. C. Webb. (1995). Blue and fin whales observed on a seafloor array in the Northeast Pacific. *Journal of the Accoustical Society of America, 98*(2), 712-721.

McDonald, M. A., J. A. Hildebrand, and S. M. Wiggins. (2006). Increases in deep ocean ambient noise in the Northeast Pacific west of San Nicolas Island, California. *The Journal of the Acoustical Society of America, 120*(2), 711-718.

McDonald, M. A., J. A. Hildebrand, S. M. Wiggins, D. Thiele, D. Glasgow, and S. E. Moore. (2005). Sei whale sounds recorded in the Antarctic. *The Journal of the Acoustical Society of America, 118*(6), 3941-3945. doi:10.1121/1.2130944

McDonald, M. A., and S. E. Moore. (2002). Calls recorded from North Pacific right whales (*Eubalaena japonica*) in the eastern Bering Sea. *Journal of Cetacean Research and Management, 4*(3), 261-266.

Mcleod, P. (1986). Observations during the stranding of one individual from a pod of pilot whales, *Globicephala melaena*, in Newfoundland. *Canadian Field-Naturalist, 100*(1), 137-139.

McMahon, C. R., C. J. A. Bradshaw, and G. C. Hays. (2007). Satellite tracking reveals unusual diving characteristics for a marine reptile, the olive ridley turtle *Lepidochelys olivacea*. Marine Ecology Progress Series, 329, 239-252.

Mead, J. G. (2009a). Beaked Whales, Overview *Ziphiidae*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 94-97): Academic Press.

Mead, J. G. (2009b). Shepherd's Beaked Whale *Tasmacetus shepherdi*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 1011-1014).

Meadows, D., & Coll, H. (2013). *Status Review Report of five foreign sturgeon*. Report to the National Marine Fisheries Service, Office of Protected Resources. October 2013. 78 pages.

Melcón, M. L., A. J. Cummins, S. M. Kerosky, L. K. Roche, S. M. Wiggins, and J. A. Hildebrand. (2012). Blue Whales Respond to Anthropogenic Noise. PloS one, 7(2), 1-6. doi:10.1371/journal.pone.0032681.t00110.1371/journal.pone.0032681.g001.

Mellinger, D. K., C. D. Carson, and C. W. Clark. (2000). Characteristics of minke whale (*Balaenoptera acutorostrata*) pulse trains recorded near Puerto Rico. Marine Mammal Science, 16(4), 739-756.

Mellinger, D. K., and C. W. Clark. (2003). Blue whale (*Balaenoptera musculus*) sounds from the North Atlantic. The Journal of the Acoustical Society of America, 114(2), 1108-1119.

Meyer, M., and Popper, A. N. (2002). Hearing in "primitive" fish: brainstem responses to pure tone stimuli in the lake sturgeon, *Acipenser fulvescens*. Pages 11-12 in *Abstracts of the Association for Research in Otolaryngology*.

Mignucci-Giannoni, A. A., and D. K. Odell. (2001). Tropical and subtropical records of hooded seals (*Cystophora cristata*) dispel the myth of extant Caribbean monk seals (*Monachus tropicalis*). Bulletin of Marine Science, 68(1), 47-58.

Miller, B. S., K. Collins, J. Barlow, S. Calderan, R. Leaper, M. McDonald, P. Ensor, P. A. Olson, C. Olavarria, and M. C. Double. (2014). Blue whale vocalizations recorded around New Zealand: 1964-2013. The Journal of the Acoustical Society of America, 135(3), 1616-1623. doi:10.1121/1.4863647.

Miller, E. H., and D. A. Job. (1992). Airborne acoustic communication in the Hawaiian monk seal, *Monachus schauinslandi*. In J. A. Thomas, R. A. Kastelein, and A. Y. Supin (Eds.), *Marine Mammal Sensory Systems* (pp. 485-531). New York: Plenum.

Miller, P. J. O., and D. E. Bain. (2000). Within-pod variation in the sound production of a pod of killer whales, *Orcinus orca*. Animal Behaviour, 60(5), 617-628.

Miller, P. J. O. M., A. D. Shapiro, and V. B. Deecke. (2010). The diving behaviour of mammal-eating killer whales (*Orcinus orca*): variations with ecological not physiological factors. Canadian Journal of Zoology, 88(11), 1103-1112. doi:10.1139/z10-080.

Milton, S. L., and P. L. Lutz. (2003). Physiological and genetic responses to environmental stress. In P. L. Lutz, J. A. Musick, and J. Wyneken (Eds.), *The biology of sea turtles, Volume 2* (pp. 163-198). Boca Raton, Florida: CRC Press.

Miksis-Olds, J.L., Bradley, D.L., and Niu, X.M. (2013). Decadal trends in Indian Ocean ambient sound. *The Journal of the Acoustical Society of America, 134*(5), 3464-3475. doi:10.1121/1.4821537.

Miksis-Olds, J.L., and Nichols, S.M. (2016). Is low frequency ocean sound increasing globally? The *Journal of the Acoustical Society of America, 139*(1), 501-511. doi:10.1121/1.4938237.

Minamikawa, S., T. Iwasaki, and T. Kishiro. (2007). Diving behaviour of a Baird's beaked whale, *Berardius bairdii*, in the slope water region of the western North Pacific: first dive records using a data logger. Fisheries Oceanography, 16(6), 573-577. doi:10.1111/j.1365-2419.2007.00456.x.

Minamikawa, S., H. Watanabe, and T. Iwasaki. (2013). Diving behavior of a false killer whale, *Pseudorca crassidens*, in the Kuroshio-Oyashio transition region and the Kuroshio front region of the western North Pacific. Marine Mammal Science, 29(1), 177-185. doi:10.1111/j.1748-7692.2011.00532.x.

Minton, G., Collins, T. J. Q., Pomilla, C., Findlay, K. P., Rosenbaum, H. C., Baldwin, R. & Brownell, Jr., R. L. (2008). *Megaptera novaeangliae*, Arabian Sea subpopulation. *IUCN Red List of Threatened Species.* <http://www.iucnredlist.org/details/132835>.

Minton, G., Collins, T. J. Q., Findlay, K. P., Ersts, P. J., Rosenbaum, H. C., Berggren, P., & Baldwin, R. M. (2011). Seasonal distribution, abundance, habitat use and population identity of humpback whales in Oman. *Journal of Cetacean Research and Management,* Special Issue on Southern Hemisphere Humpback Whales**,** 185–198.

Miralles, R., G. Lara, J. Antonio Esteban, and A. Rodriguez. (2012). The pulsed to tonal strength parameter and its importance in characterizing and classifying Beluga whale sounds. The Journal of the Acoustical Society of America, 131(3), 2173-2179. doi:10.1121/1.3682056.

Mitchell, E. D. (1975). Review of biology and fisheries for smaller cetaceans. Report of the meeting on smaller cetaceans in Montreal, April 1-11, 1974. Journal of the Fisheries Research Board of Canada, 32, 889-983.

Mitchell, E. D. (1977). Initial population size of bowhead whale *Balaena mysticetus* stocks: cumulative estimates. Internationl Whaling Commission Scientific Committee, Paper SC/29/33.

Mitchell, E., & Chapman, D. G. (1977). Preliminary assessment of stocks of northwest Atlantic sei whales (*Balaenoptera borealis*). *Report of the International Whaling Commission (Special Issue 1*), 117-120.

Miyashita, T. (1993). Abundance of dolphin stocks in the western North Pacific taken by the Japanese drive fishery. *International Whaling Commission, 43*, 417-437.

Miyashita, T. (1986). Population estimates of dolphins using research vessels data. In T. Tamura, S. Ohsumi, & S. Arai (Eds.), *Report of the investigation in search of resolution of the dolphin-fishery conflict in the Iki Island area* (pages 202-213). Tokyo, Japan: The Investigating Committee.

Miyashita, T., & Kato, H. (1998). Recent data on the status of right whales in the NW Pacific Ocean. *IWC Working Document SC/M98/RW11 presented to the IWC Special Meeting of the Scientific Committee towards a Comprehensive Assessment of Right Whales Worldwide. 16-25 March. Cape Town, South Africa*.

Miyashita, T., V. L. Vladimirov, and H. Kato. (2005, September 29–October 9, 2005). *Current status of cetaceans in the Sea of Okhotsk, Japanese and Russian survey results. (S3-2489).* Paper presented at the North Pacific Marine Science Organization (PICES) fourteen annual meeting, , Valdivostock, Russia.

Miyazaki, N. (2002). Ringed, Caspian, and Baikal seals *Pusa hispida*, *P. caspica*, and *P. sibirica*. Pages 1033-1037 in Perrin, W. F., Wursig, B., and Thewissen, J. G. M. (eds). *Encyclopedia of marine mammals*. San Diego, CA: Academic Press.

Miyazaki, N., and W. F. Perrin. (1994). Rough-toothed dolphin *Steno bredanensis* (Lesson, 1828). In S. H. Ridgway and R. Harrison (Eds.), *Handbook of marine mammals, Volume 5: The first book of dolphins* (pp. 1-21). London: Academic Press.

Mizroch, S. A., Rice, D. W., Zwiefelhofer, D., Waite, J. M., & Perryman, W. L. (2009). Distribution and movements of fin whales in the North Pacific Ocean. *Mammal Review, 39*(3), 193-227.

Mizroch, S.A., Conn, P.B., & Rice, D.W. (2015). The mysterious sei whale: Its distribution, movements and population decline in the North Pacific revealed by whaling data and recoveries of Discovery-type marks. [Presentation]. *Paper SC/66a/IA/14 presented at the 66a IWC Scientific Committee Meeting in San Diego, CA, 22 May to 3 June 2015*.

Mizuno, A. W., A. Wada, T. Ishinazaka, K. Hattori, Y. Watanabe, and N. Ohtaishi. (2002). Distribution and abundance of spotted seals *Phoca largha* and ribbon seals *Phoca fasciata* in the southern Sea of Okhotsk. *Ecological Research, 17*, 79-96.

Møhl, B. (1968a). Auditory senstivity of the common seal in air and water. *Journal of Auditory Research, 8,* 27-38.

Møhl, B. (1968b). Hearing in seals. In R. J. Harrison, R. C. Hubbard, S. B. Peterson, C. E. Rice, and R. J. Schusterman (Eds.), *The behavior and physiology of pinnipeds*. New York, New York: Appleton-Century-Crofts.

Møhl, B. (2003). Sperm whale sonar rivals tactical sonar with source levels at 235 dB. In P. G. H. Evans and L. Miller (Eds.), *Proceedings of the workshop on Active sonar and cetaceans* (pp. 41-42).

Møhl, B., M. Wahlberg, P. T. Madsen, L. A. Miller, and A. Surlykke. (2000). Sperm whale clicks: Directionality and source level revisited. *Journal of the Acoustical Society of America, 107*(1), 638-648.

Montgomery, J., S. Coombs, and M. Halstead. (1995). Biology of the mechanosensory lateral line in fishes. Reviews in Fish Biology and Fisheries*,* 5(4), 399-416.

Montie, E. W., C. A. Manire, and D. A. Mann. (2011). Live CT imaging of sound reception anatomy and hearing measurements in the pygmy killer whale, *Feresa attenuata*. *The Journal of Experimental Biology,* 214(Pt 6), 945-955. doi:10.1242/jeb.051599.

Mooney, T. A., P. E. Nachtigall, M. Castellote, K. A. Taylor, A. F. Pacini, and J.-A. Esteban. (2008). Hearing pathways and directional sensitivity of the beluga whale, *Delphinapterus leucas*. Journal of Experimental Marine Biology and Ecology*,* 362, 108-116.

Mooney, T. A., R. T. Hanlon, J. Christensen-Dalsgaard, P. T. Madsen, D. R. Ketten, and P. E. Nachtigall. (2010). Sound detection by the longfin squid (*Loligo pealeii*) studied with auditory evoked potentials: sensitivity to low-frequency particle motion and not pressure. *The Journal of Experimental Biology,* 213(Pt 21), 3748-3759. doi:10.1242/jeb.048348.

Mooney, T. A., Tyack, P., Baird, R. W., & Nachtigall, P. E. (2012*). Acoustic behavior, baseline ecology and habitat use of pelagic odontocete species of concern.* Annual progress report to the Office of Naval Research, FY 2013. Award Number: N000141110612. Arlington, VA: Office of Naval Research. Retrieved from <http://www.onr.navy.mil/reports/FY13/mbmoone1.pdf>.

Mooney, T. A., W. C. Yang, H. Y. Yu, D. R. Ketten, and I. F. Jen. (2015). Hearing abilities and sound reception of broadband sounds in an adult Risso's dolphin (*Grampus griseus*). Journal of comparative physiology. A, Neuroethology, sensory, neural, and behavioral physiology*,* 201(8), 751-761. doi:10.1007/s00359-015-1011-x.

Moore, J. E., & Barlow, J. (2011). Bayesian state-space model of fin whale abundance trends from a 1991-2008 time series of line-transect surveys in the California Current. *Journal of Applied Ecology, 48*, 1195-1205.

Moore, J. E., & Barlow, J. P. (2013). Declining abundance of beaked whales (family Ziphiidae) in the California Current large marine ecosystem. *PLoS ONE, 8*(1), e52770. doi:10.1371/journal.pone.0052770.

Moore J. E., & Barlow, J. P. (2014). Improved abundance and trend estimates for sperm whales in the eastern North Pacific from Bayesian hierarchical modeling. *Endangered Species Research, 25,* 141-150.

Moore, J. E., and J. P. Barlow. (2014). Improved abundance and trend estimates for sperm whales in the eastern North Pacific from Bayesian hierarchical modeling. Endangered Species Research*,* 25(2), 141-150. doi:10.3354/esr00633.

Moore, P. W. B., and R. J. Schusterman. (1987). Audiometric assessment of northern fur seals *Callorhinus ursinus*. Mar Mamm Sci*,* 3(1), 31-53.

Moore, S., and J. T. Clarke. (2002). Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). Journal of Cetacean Research and Management*,* 4(1), 19-25.

Moore, S. E., M. E. Dahlheim, K. M. Stafford, C. G. Fox, H. W. Braham, M. A. McDonald, and J. Thomason. (1999). Acoustic and visual detection of large whales in the eastern North Pacific Ocean. Seattle, WA.

Moore, S. E., and R. R. Reeves. (1993). Distribution and movement. In J. J. Burns, J. J. Montague, and C. J. Cowles (Eds.), *The bowhead whale* (pp. 313-386). Lawrence, Kansas: Society for Marine Mammalogy.

Moore, S. E., and S. H. Ridgway. (1995). Whistles produced by common dolphins from the Southern California Bight. Aquatic Mammals*,* 21(1), 55-63.

Morano, J. L., D. P. Salisbury, A. N. Rice, K. L. Conklin, K. L. Falk, and C. W. Clark. (2012). Seasonal and geographical patterns of fin whale song in the western North Atlantic Ocean. The Journal of the Acoustical Society of America*,* 132(2), 1207-1212. doi:10.1121/1.4730890.

Moreland, E., Cameron, M., & Boveng, P. (2012). Bering Okhotsk Seal Surveys (BOSS): Joint U.S.-Russian aerial surveys. *Alaska Fisheries Science Center Quarterly Report, April-May-June 2012*.

Mori, M., & Butterworth, D. S. (2006). A first step towards modelling the krill-predator dynamics of the Antarctic ecosystem. *CCAMLR Science, 13*, 217-277.

Morisaka, T., L. Karczmarski, T. Akamatsu, M. Sakai, S. Dawson, and M. Thornton. (2011). Echolocation signals of Heaviside's dolphins (*Cephalorhynchus heavisidii*). The Journal of the Acoustical Society of America, 129(1), 449-457. doi:10.1121/1.3519401.

Morisaka, T., M. Shinohara, F. Nakahara, and T. Akamatsu. (2005a). Effects of ambient noise on the whistles of Indo-Pacific bottlenose dolphin populations. Journal of Mammalogy, 86(3), 541-546.

Morisaka, T., M. Shinohara, F. Nakahara, and T. Akamatsu. (2005b). Geographic variations in the whistles among three Indo-Pacific bottlenose dolphin *Tursiops aduncus* populations in Japan. Fisheries Science, 71(3), 568-576.

Morreale, S. J., E. A. Standora, J. R. Spotila, and F. V. Paladino. (1996). Migration corridor for sea turtles. Nature, 384(6607), 319-320.

Mortimer, J. A. (1982). Feeding Ecology of Sea Turtles. In K. A. Bjorndal (Ed.), *Biology and Conservation of Sea Turtles* (pp. 103-109). Washington, D.C.

Moyle, P. B. (2002). *Inland Fishes of California*, 2nd ed. Davis, CA: University of California Press.

Mrosovsky, N. (1972). Spectrographs of the sounds of leatherback turtles. Herpetologica 28, 256-258.

Mullin, K. D., & Fulling, G. L. (2003). Abundance of cetaceans in the southern U.S. North Atlantic Ocean during summer 1998. *Fishery Bulletin, 101*, 603-613.

Mullin, K. D., L. V. Higgins, T. A. Jefferson, and L. J. Hansen. (1994). Sightings of the Clymene dolphin (*Stenella clymene*) in the Gulf of Mexico. Marine Mammal Science, 10(4), 464-470.

Mulsow, J., D. S. Houser, and J. J. Finneran. (2012). Underwater psychophysical audiogram of a young male California sea lion (Zalophus californianus). The Journal of the Acoustical Society of America, 131(5), 4182-4187. doi:10.1121/1.3699195.

Munger, L. M., S. M. Wiggins, and J. A. Hildebrand. (2011). North Pacific right whale up-call source levels and propagation distance on the southeastern Bering Sea shelf. The Journal of the Acoustical Society of America, 129(6), 4047. doi:10.1121/1.3557060.

Mugue, N. (2010). *Acipenser mikadoi*. The IUCN eed list of threatened species. Version 2014.3. Retrieved from <www.iucnredlist.org>.

Murray, A., A. N. Rice, and C. W. Clark. (2013). Extended seasonal occurrence of humpback whales in Massachusetts Bay. Journal of the Marine Biological Association of the United Kingdom, 94(06), 1117-1125. doi:10.1017/s0025315412001968.

Murray, S. O., E. Mercado, and H. L. Roitblat. (1998). Characterizing the graded structure of false killer whale (*Pseudorca crassidens*) vocalizations. Journal of the Acoustical Society of America, 104(3), 1679-1688.

Myrberg, A. A. (1978a). Ocean noise and the behavior of marine animals: Relationships and Implications. In J. L. Fletcher and R. G. Bushell (Eds.), *Effects of Noise on Wildlife* (pp. 169-208). Saint Louis, MO: Academic Press.

Myrberg, A. A. (1978b). Underwater sound—its effect on the behavior of sharks. In E. S. Hodgson and R. Mathewson (Eds.), *Sensory biology of sharks, skates, and rays* (pp. 391-417). Arlington, Virgina: Department of the Navy, Office of Naval Research.

Myrberg, A. A. (1981). Sound communication and interception in fishes. In W. N. Tavolga, A. N. Popper, and R. R. Fay (Eds.), *Hearing and sound communications in fishes* (pp. 395-425). New York: Springer-Verlag.

Myrberg, A.A., Jr. (2001). The acoustical biology of elasmobranchs. *Environmental Biology of Fishes, 60*, 31-45.

Myrberg, A. A., C. R. Gordon, and A. P. Klimley. (1976). Attraction of free ranging sharks by low frequency sound, with comments on its biological significance *Sound reception in fishes* (pp. 205-227). Amsterdam: Elsevier Scientific Publishing Company.

Myrberg, A. A., Jr.,, C. R. Gordon, and A. P. Klimley. (1978). Rapid withdrawal from a sound source by open-ocean sharks. Journal of the Acoustical Society of America*,* 64, 1289-1297.

Nachtigall, P. E., W. W. L. Au, J. L. Pawloski, and P. W. B. Moore. (1995). Risso's dolphin (*Grampus griseus*) hearing thresholds in Kaneohe Bay, Hawaii *Sensory systems of aquatic mammals* (pp. 49-53). Woerden, Netherlands: . De Spil Publication.

Nachtigall, P. E., D. W. Lemonds, and H. L. Roitblat. (2000). Psychoacoustic studies of dolphin and whale hearing *Hearing by whales and dolphins*. New York, New York: Springer-Verlag.

Nachtigall, P. E., T. A. Mooney, K. A. Taylor, L. A. Miller, M. H. Rasmussen, T. Akamatsu, J. Teilmann, M. Linnenschmidt, and G. A. Vikingsson. (2008). Shipboard measurements of the hearing of the white-beaked dolphin *Lagenorhynchus albirostris*. Journal Of Experimental Biology*,* 211(4), 642-647. doi:10.1242/jeb.014118.

Nachtigall, P. E., and A. Y. Supin. (2008). A false killer whale adjusts its hearing when it echolocates. Journal Of Experimental Biology*,* 211(11), 1714-1718.

Nachtigall, P. E., & A. Y. Supin. (2013). A false killer whale reduces its hearing sensitivity when a loud sound is preceded by a warning. *The Journal of Experimental Biology,* 216(Pt 16), 3062-3070. doi:10.1242/jeb.085068.

Nachtigall, P. E., &d A. Y. Supin. (2015). Conditioned frequency-dependent hearing sensitivity reduction in the bottlenose dolphin (*Tursiops truncatus*). *The Journal of Experimental Biology,* 218(Pt 7), 999-1005. doi:10.1242/jeb.114066.

Nachtigall, P. E., M. M. L. Yuen, T. A. Mooney, & K. A. Taylor. (2005). Hearing measurements from a stranded infant Risso's dolphin, *Grampus griseus*. Journal Of Experimental Biology*,* 208(21), 4181-4188.

Nakamoto, R. J., Kisanuki, T. T., & G.H. Goldsmith. (1995). *Age and growth of Klamath River green sturgeon (Acipenser medirostris).* U.S. Fish and Wildlife Service Project #93-FP-13. 20 pages.

NMFS (National Marine Fisheries Service). 2005. Green sturgeon (*Acipenser medirostris*) status review update. Biological Review Team, National Marine Fisheries Service. 35 pages. <http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/greensturgeon_update.pdf>.

NMFS. (2010). Species of concern: Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). Retrieved from <http://www.nmfs.noaa.gov/pr/pdfs/species/atlanticsturgeon_highlights.pdf>.

NMFS. (2013). Status review of the Eastern Distinct Population segment of Steller sea lion (*Eumetopias jubatus*).

NMFS. (2014). U.S. distributions of the 15 ESA-listed Indo-Pacific coral species. Retrieved from <http://www.fpir.noaa.gov/Library/PRD/Coral/us_indo-pacific_corals_distribution.pdf>.

NMFS. (2015). NOAA lists 20 new corals as threatened under the Endangered Species Act. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. Retrieved from <http://sero.nmfs.noaa.gov/protected_resources/coral/documents/2014_corals_esa_listing.pdf>.

NMFS and USFWS (National Marine Fisheries Service and U.S. Fish and Wildlife Service). (2007b). *Kemp's ridley sea turtle (Lepidochelys kempii), 5-year review: Summary and evaluation.* National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD and U.S. Fish and Wildlife Service, Southwest Region, Albuquerque, NM. 50 pp.

NMFS and USFWS. (2007c). *Loggerhead sea turtle (Caretta caretta), 5-year review: Summary and evaluation.* National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD and U.S. Fish and Wildlife Service, Southeast Region, Jacksonville, FL. 67 pp.

National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS). (2013). Leatherback sea turtle (*Dermochelys coriacea*) 5-year review: Summary and evaluation.

NMFS and USFWS. (2011). Endangered and threatened species; Determination of nine distinct population segments of loggerhead sea turtles as endangered or threatened, Final rule. National Marine Fisheries Service and the U.S. Fish and Wildlife Service. *Federal Register, 76*(184), 58868-58952.

NMFS and USFWS. (2013). *Hawksbill sea turtle (Eretmochelys imbricata) 5-year review: Summary and evaluation.* Office of Protected Resources, NMFS, Silver Spring, MD, and Southeast Region, USFWS, Jacksonville Ecological Services Office, Jacksonville, FL.

NMFS and USFWS. (2014). Olive ridley sea turtle (*Lepidochelys olivacea*) 5-year review: Summary and evaluation.

NMFS and USFWS. (2015). Kemp's ridley sea turtle (*Lepidochelys kempii*) 5-year review: Summary and evaluation.

National Marine Sanctuary Program (NMSP). (2006). *Gerry E. Studds Stellwagen Bank National Marine Sanctuary condition report 2006.* Office of the National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://sanctuaries.noaa.gov/science/condition/>.

NMSP. (2007). *Fagetele Bay National Marine Sanctuary condition report 2007*. Office of the National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://americansamoa.noaa.gov/pdfs/fb_condition.pdf>.

NMSP. (2008). *Monitor National Marine Sanctuary condition report 2008*. Office of the National Marine Sanctuaries, National Oceanic and Atmospheric Administration. <http://sanctuaries.noaa.gov/science/condition/pdfs/mnms_condition_report.pdf>.

National Oceanic and Atmospheric Administration (NOAA). (1979). Determination of critical habitat for the leatherback sea turtle. *Federal Register, 44*(58), 17710-17712.

NOAA. (1993). Designated critical habitat; Snake River sockeye salmon, Snake River spring/summer Chinook salmon, and Snake River fall Chinook salmon; Final rule. National Marine Fisheries Service; National Oceanic and Atmospheric Administration. *Federal Register, 58*(247), 68543-68554.

NOAA. (1994). Designated critical habitat; northern right whale. *Federal Register, 59*(106), 28793-28808.

NOAA. (1997). Endangered and threatened species: Listing of several evolutionary significant units (ESUs) of west coast steelhead; Final rule. National Marine Fisheries Service; National Oceanic and Atmospheric Administration. *Federal Register, 62*(159), 43937-43954.

NOAA. (1998). Designated critical habitat; green and hawksbill sea turtles; Final rule. *Federal Register, 63*(170), 46693-46701.

NOAA. (1999). Designated critical habitat; Central California coast and southern Oregon/northern California coasts soho salmon; Final rule and correction. National Marine Fisheries Service; National Oceanic and Atmospheric Administration. *Federal Register, 64*(86), 24049-24062.

NOAA. (2000). *Tortugas ecological Reserve final supplemental environmental impact statement/final supplemental management plan.* Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://floridakeys.noaa.gov/mgmtplans/FinalFSEIS.pdf>.

NOAA. (2005). Endangered and threatened wildlife and plants: Endangered status for Southern Resident Killer whales; Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register, 70*(222), 69903-69912.

NOAA. (2006). Endangered and threatened species; Designation of critical habitat for southern resident killer whale. Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register, 71*(229), 69054-69070.

NOAA. (2006a). Endangered and threatened species: final listing determinations for 10 Distinct Population Segments of west coast steelhead; Final rule. National Marine Fisheries Service; National Oceanic and Atmospheric Administration. *Federal Register, 71*(3), 834-861.

NOAA. (2007a). Endangered and threatened species: final listing determination for Puget Sound steelhead; Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register, 72*(91), 26722-26735.

NOAA. (2007b). *Florida Keys National Marine Sanctuary revised management plan.* Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://floridakeys.noaa.gov/mgmtplans/2007_man_plan.pdf>.

NOAA. (2008). Endangered and threatened species: Final threatened listing determination, final protective regulations, and final designation of critical habitat for the Oregon Coast evolutionarily significant unit of coho salmon; Final rule. National Marine Fisheries Service; National Oceanic and Atmospheric Administration. *Federal Register, 73*(28), 7816-7873.

NOAA. (2008a). Monterey Bay National Marine Sanctuary final management plan. Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://montereybay.noaa.gov/intro/mp/mp.html>.

NOAA. (2008b). Cordell Bank, Gulf of the Farallones, and Monterey Bay National Marine Sanctuaries final environmental impact statement. Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://montereybay.noaa.gov/intro/mp/feis.html>.

NOAA. (2008c). *Gray's Reef National Marine Sanctuary condition report 2008.* Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://graysreef.noaa.gov/science/publications/pdfs/grnms_condition_report08.pdf>.

NOAA. (2009). *Channel Islands National Marine Sanctuary management plan/final environmental impact statement.* Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://channelislands.noaa.gov/management/manplan/cinms_fmp_2009.pdf>.

NOAA. (2009a). Endangered and threatened wildlife and plants: Final rulemaking to designate critical habitat for the threatened southern distinct population segment of North American green sturgeon; Final rule. National Marine Fisheries Service; National Oceanic and Atmospheric Administration. *Federal Register, 74*(195), 52300-52351.

NOAA. (2010). *Stellwagen Bank national marine sanctuary final management plan and environmental assessment*. Silver Spring, MD: Office of the National Marine Sanctuaries, NOAA. Retrieved from <http://stellwagen.noaa.gov/management/fmp/pdfs/sbnms_fmp2010_lo.pdf>.

NOAA. (2010a). Endangered and threatened wildlife and plants: Threatened status for Southern Distinct Population Segment of eulachon; Final rule. National Marine Fisheries Service; National Oceanic and Atmospheric Administration. *Federal Register, 75*(52), 13012-13024.

NOAA. (2011). *Olympic Coast National Marine Sanctuary final management plan and environmental assessment.* Silver Spring, MD: Office of National Marine Sanctuaries, NOAA. Retrieved from <http://olympiccoast.noaa.gov/management/managementplan/mgmtplan_complete.pdf>.

NOAA. (2012). Endangered and threatened species: final rule to revise the critical habitat designation for the endangered leatherback sea turtle; Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration and U.S. Fish and Wildlife Service. *Federal Register, 77*(17), 4170-4201.

NOAA. (2012a). Endangered and threatened species: Fnal rule to revise the critical habitat designation for the endangered leatherback sea turtle; Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration and U.S. Fish and Wildlife Service. *Federal Register, 77*(17), 4170-4201.

NOAA. (2012b). Endangered and threatened wildlife and plants; Endangered status for the Main Hawaiian Islands Insular false killer whale distinct population segment; Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register, 77*(229), 70915-70939.

NOAA. (2012c). Expansion of Fagatele Bay National Marine Sanctuary, regulatory changes, and sanctuary name change; Final rule. Office of National Marine Sanctuaries and National Ocean Service, National Oceanic and Atmospheric Administration. *Federal Register, 77*(144), 43942-43966.

NOAA. (2012d). *Fagatele Bay National Marine Sanctuary final management plan / Final environmental impact statement.* Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://americansamoa.noaa.gov/management/pdfs/fbnms_mp_eis.pdf>.

NOAA. (2012e). *Gray's Reef National Marine Sanctuary condition report 2012, addendum.* Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://graysreef.noaa.gov/science/publications/pdfs/grnms_condition_add_2012.pdf>.

NOAA. (2012f). Flower Garden Banks National Marine Sanctuary final environmental assessment. Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://flowergarden.noaa.gov/document_library/mgmtdocs/fmp2012/ea2012lores.pdf>.

NOAA. (2012g). Flower Garden Banks National Marine Sanctuary final environmental assessment. Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://flowergarden.noaa.gov/document_library/mgmtdocs/fmp2012/fmp2012lores.pdf>.

NOAA. (2013). *Monitor National Marine Sanctuary, Final management plan and environmental assessment.* Silver Spring, MD: Office of the National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://monitor.noaa.gov/management/final_mp.pdf>.

NOAA. (2014). Endangered and threatened species: Critical habitat for the Northwest Atlantic Ocean loggerhead sea turtle distinct population segment (DPS) and determination regarding critical habitat for the North Pacific Ocean Loggerhead DPS; Final rule. *Federal Register, 79*(132), 39856-39912.

NOAA. (2014a). Map of critical habitat for the Northwest Atlantic Ocean loggerhead sea turtle distinct population segment (DPS). Retrieved from <http://www.nmfs.noaa.gov/pr/species/turtles/criticalhabitat_loggerhead.htm>.

NOAA. (2014b). *Gray's Reef National Marine Sanctuary final environmental assessment for the implementation of the management plan and new regulations.* Silver Spring, MD: Office of the National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://graysreef.noaa.gov/management/mgmtplan/pdfs/grnms_enviro_assess_07092014.pdf>.

NOAA. (2014c). *Cordell Bank and Gulf of the Farallones National Marine Sanctuaries expansion final environmental impact statement.* Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://farallones.noaa.gov/manage/pdf/expansion/CBNMS_GFNMS_FEIS_Expansion122014.pdf>.

NOAA. (2014d). *Cordell Bank National Marine Sanctuary final management plan.* Silver Spring, MD: Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://cordellbank.noaa.gov/management/cbnms_fmp_december_2014.pdf>.

NOAA. (2014e). *Gulf of the Farallones National Marine Sanctuary final management plan.* Silver Spring, MD: Office of National Marine Sanctuaries, NOAA. Retrieved from <http://farallones.noaa.gov/manage/pdf/expansion/GFNMS_FMP_12_04_14.pdf>.

NOAA. (2015a). Endangered and threatened species: Final rulemaking to revise critical habitat for Hawaiian monk seals. *Federal Register, 80*(162), 50926-50988.

NOAA. (2015b). Endangered and threatened species; Identification of 14 distinct population segments of the humpback whale (*Megaptera novaeangliae*) and proposed revision of species-wide listing; Proposed rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register 80*(76):22304-22356.

NOAA. (2015c). *Hawaiian Islands Humpback Whale National Marine Sanctuary draft management plan and draft environmental impact statement*. Silver Spring, MD: Office of National Marine Sanctuaries, NOAA. Retrieved from <http://hawaiihumpbackwhale.noaa.gov/management/pdfs/mp2015_dmp_deis.pdf>.

NOAA. (2016a). *Document containing proposed changes to: NOAA draft guidance for assessing the effects of anthropogenic sound on marine mammal hearing; Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts.* Silver Spring, MD: NOAA. Retrieved from <http://www.nmfs.noaa.gov/pr/acoustics/draft_guidance_march_2016_.pdf>.

NOAA. (2016b). Endangered and threatened wildlife and plant species: Final rule to list eleven Distinct Population Segments of the green sea turtle *(Chelonia mydas)* as endangered or threatened and revision of current listings under the Endangered Species Act; Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration and U.S. Fish and Wildlife Service. *Federal Register, 81*(66), 20058-20090.

NOAA. (2016c). Notice of Intent to review *Monitor* National Marine Sanctuary boundary; Notice of intent to review boundaries; intent to prepare environmental impact statement; hold scoping meetings. Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. *Federal Register, 81*(5), 879-881.

NOAA. (2016d). Endangered and threatened species; Critical habitat for endangered North Atlantic right whale; Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register, 81*(17), 4838-4874.

NOAA. (2016e). Endangered and threatened species; Critical habitat for the endangered Carolina and South Atlantic distinct population segments of Atlantic sturgeon; Proposed rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register, 81*(107), 36078-36123.

NOAA. (2016f). Endangered and threatened species; Designation of critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay distinct population segments of Atlantic sturgeon; Proposed rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register, 81*(107), 35701-35731.

NOAA. (2016g). Endangered and threatened species; Critical habitat for the endangered Carolina and South Atlantic distinct population segments of Atlantic sturgeon; Proposed rule, correction. National Marine Fisheries Service, National Oceanic and Atmospheric Administration. *Federal Register, 81*(124), 41926-41927.

NOAA and USFWS (U.S. Fish and Wildlife Service). (2011). Endangered and threatened species; Determination of nine distinct population segments of loggerhead sea turtles as endangered or threatened; Final rule. National Marine Fisheries Service, National Oceanic and Atmospheric Administration and U.S. Fish and Wildlife Service. *Federal Register, 76*(184), 58868-58952.

Nelson, D., and J. Lien. (1996). The status of the long-finned pilot whale, *Globicephala melas*, in Canada. *Canadian Field Naturalist, 110*(3), 511-524.

Nelson, D. R. (1967). Hearing thresholds, frequency discrimination, and acoustic orientation in the lemon shark, *Negaprion brevirostris* (Poey). Bulletin of Marine Science, 17, 741-768.

Nelson, D. R., and S. H. Gruber. (1963). Sharks: Attraction by low-frequency sounds. Science, 142(3594), 975-977.

Nelson, D. R., & Johnson, R. H. (1972). Acoustic attraction of Pacific reef sharks: Effects of pulse intermittency and variability. *Comparative Biochemistry and Physiology, Part A: Physiology, 42*(1), 85-95.

Nelson, D. R., and R. H. Johnson. (1976). Some recent observations on acoustic attraction of Pacific reef sharks. In A. Schuij and A. D. Hawkins (Eds.), *Sound reception in fish. Developments in aquaculture and fisheries science*. Amsterdam: Elsevier.

Nelson, J. S. (2006). *Fishes of the World*: John Wiley & Sons, Inc.

Nemiroff, L., and H. Whitehead. (2009). Structural Characteristics of Pulsed Calls of Long-Finned Pilot Whales *Globicephala melas*. Bioacoustics, 19(1-2), 67-92.

Nesterenko, V. A., & Katin, I. O. (2008). The spotted seal (*Phoca largha*) in the south of the range: The results and problems of research. *Marine mammals of the Holoarctic—Collection of Scientific Papers after the 5th International Conference, Odessa, Ukraine, 2008*, (pp. 386 to 389).

Niño-Torres, C. A., R. Jorge Urbán, T. Olavarrieta, M. d. P. Blanco-Parra, & K. A. Hobson. (2014). Dietary preferences of Bryde's whales (Balaenoptera edeni) from the Gulf of California: Aδ13C,δ15N analysis. Marine Mammal Science, 30(3), 1140-1148. doi:10.1111/mms.12081

Nishiwaki, M. (1972). General biology. In S. H. Ridgway (Ed.), *Mammals of the sea: Biology and medicine* (pp. 3-204): Charles C. Thomas.

Noad, M.J., Dunlop, R.A., Paton, D., & Cato, D.H. (2011). Absolute and relative abundance estimates of Australian east coast humpback whales (*Megaptera novaeangliae*) *Journal of Cetacean Research and Management* (Special issue, 3, 243–252.

Norberg, B. (2013). Personal communication between Brent Norberg (NMFS), Steve Stone (NMFS) & Andrea Balla-Holden (Navy) via email during March 5-8, 2013 regarding gray whale aboriginal historical catches reported in the Stock Assessment Report.

Norris, J. C., & S. Leatherwood. (1981). Hearing in the bowhead whale (*Balaena mysticetus*) as estimated by cochlear morphology. In T. F. Albert (Ed.), *Tissue structural studies and other investigations on the biology of endangered whales in the Beaufort Sea. Volume II.* (pp. 745-787). College Park, Maryland,: University of Maryland, Research unit 1580.

Norris, K. S. (1969). The echolocation of marine mammals. In H. T. Andersen (Ed.), *The biology of marine mammals* (pp. 391-423). New York, NY: Academic Press.

Norris, K. S., & W. E. Evans. (1967). Directionality of echolocation clicks in the rough-tooth porpoise, *Steno bredanensis* (Lesson) *Marine Bioacoustics* (Vol. 2, pp. 305-316). Oxford and New York: Pergamon Press.

Norris, K. S., & Prescott, J. H. (1961). Observations on Pacific cetaceans of Californian and Mexican waters. *University of California Publications in Zoology, 63*, 291-402.

Norris, K. S., & Watkins, W. A. (1971). Underwater sounds of (*Arctocephalus philippii*), the Juan Fernandez fur seal. In W. H. Burt (Ed.), *Antarctic pinnipedia* (pp. 169-171). Washington, D.C.: American Geophysical Union.

Norris, K. S., Würsig, B., Wells, R. S., & Würsig, M. (1994). *The Hawaiian spinner dolphin*. Berkeley, CA: University of California Press.

North Atlantic Marine Mammal Commission (NAMMCO). (2016). *Long-finned pilot whale: Current abundance and trends.* Retrieved March 2016 from <http://www.nammco.no/marine-mammals/whales-and-dolphins-cetaceans/new-long-finned-pilot-whale/current-abundance-and-trends/>.

Nummela, S. (2009). Hearing. In W. F. Perrin, Würsig, B., & Thewissen, J. G. M. (Eds.), *Encyclopedia of marine mammals* (pp. 553-562). San Diego, CA: Academic Press.

O'Corry-Crowe, G. M. (2009). Beluga whale *Delphinapterus leucas*. In Perrin, W. F., Würsig, B., & Thewissen, J. G. M. (Eds.). *Encyclopedia of marine mammals* (pp. 108-112). San Diego, CA: Academic Press.

Office of National Marine Sanctuaries (ONMS). (2006). *Gerry E. Studds Stellwagen Bank national marine sanctuary condition report 2006*. Silver Spring, MD: National Oceanic and Atmospheric Administration, National Marine Sanctuary Program. 39 pp.

ONMS. (2008a). *Olympic Coast National Marine Sanctuary condition report 2008*. Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://sanctuaries.noaa.gov/science/ condition/pdfs/oc_conditionreport08.pdf>.

ONMS. (2008b). *Flower Garden National Marine Sanctuary condition report 2008*. Office of the National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://flowergarden.noaa.gov/document_library/scidocs/fgbnmsconditionreport.pdf>.

ONMS. (2009a). *Channel Islands National Marine Sanctuary condition report 2009*. Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from: <http://sanctuaries.noaa.gov/science/condition/pdfs/cinms_conditionreport09.pdf>.

ONMS. (2009b). *Cordell Bank National Marine Sanctuary condition report 2009.* Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://cordellbank.noaa.gov/science/cb_conditionreport.pdf>.

ONMS. 2010. *Gulf of the Farallones National Marine Sanctuary condition report 2010*. Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://sanctuaries.noaa.gov/science/condition/gfnms/welcome.html>.

ONMS. (2010). *Hawaiian Islands Humpback Whale NMS condition report 2010*. Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://sanctuaries.noaa.gov/science/condition/pdfs/hihw_condition_report_low.pdf>.

ONMS. (2011). *Florida Keys National Marine Sanctuary condition report 2011*. Office of the National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://sanctuaries.noaa.gov/science/condition/pdfs/fknms_lowres.pdf>.

ONMS. (2015). *Monterey Bay NMS condition report partial update: a new assessment of the state of the sanctuary resources*. Office of National Marine Sanctuaries, National Oceanic and Atmospheric Administration. Retrieved from <http://sanctuaries.noaa.gov/science/condition/monterey-bay-2015/mbnms-cr-2015-lowres.pdf>.

O'Hara, J., & Wilcox, J. R. (1990). Avoidance responses of loggerhead turtles, *Caretta caretta*, to low frequency sound. *Copeia, 1990*, 564-567.

Odell, D. K., & K. M. McClune. (1999). False killer whale. In S. H. RIdgway and R. Harrison (Eds.), *Handbook of Marine Mammals, Volume 6: The Second book of dolphins and the porpoises* (pp. 213-243): Academic Press.

Ogren, L., & C. McVea, Jr. (1995). Apparent hibernation in turtles in North American waters. In K. A. Bjorndal (Ed.), *Biology and conservation of sea turtles* (pp. 127-132). Washington, D.C.: Smithsonian Press.

Ohizumi, H., T. Isoda, T. Kishiro, and H. Kato. (2003). Feeding habits of Baird's beaked whale *Berardius bairdii*, in the western North Pacific and Sea of Okhotsk off Japan. Fisheries Science Tokyo*,* 69(1), 11-20.

Ohsumi, S. (1977). Bryde's whales in the pelagic whaling ground of the North Pacific. *Report of the International Whaling Commission Special Issue, 1*, 140-149.

Ohsumi, S. (1980). Population study of the Bryde’s whale in the Southern Hemisphere under scientific permit in the three seasons, 1976/77-1978/79. *Reports of the International Whaling Commission, 30*, 319-331.

Øien, N. (2008). Distribution and abundance of large whales in Norwegian and adjacent waters based on ship surveys 1995-2001. *NAMMCO Scientific Publications, 7*, 31-48.

Oleson, E. M., Boggs, C. H., Forney, K. A., Hanson, M. B., Kobayashi, D. R., Taylor, B. L., Wade, P. R., & Ylitalo, G.M. (2010). *Status review of Hawaiian insular false killer whales (Pseudorca crassidens) under the Endangered Species Act.* (NOAA Technical Memorandum NMFS-PIFSC-22). Honolulu, HI: Pacific Islands Fisheries Science Center, National Marine Fisheries Service.

Oleson, E. M., Baird, R. W., Martien, K. K., & Taylor, B. L. (2013). Island-associated stocks of odontocetes in the main Hawaiian Islands: A synthesis of available information to facilitate evaluation of stock structure. *Document PSRG-2013-16 presented to the Pacific Scientific Review Group, Del Mar, California, April 2013.*

Oliver, G. W. (1978). Navigation in mazes by a gray seal, (*Halichoerus grypus*)(Fabricus). Behavior, 67(1-2), 99-114.

Oliver, M. J., Breece, M. W., Fox, D. A., Haulsee, D. E. Kohut, J. T., Manderson, J., & Savoy, T. (2013). Shrinking the haystack: Using an AUV in an integrated ocean observatory to map Atlantic sturgeon in the coastal ocean. *Fisheries, 38*(5), 210-216.

Olla, B. (1962). *The perception of sound in small hammerhead sharks Sphyrna lewini.* (M.S.), University of Hawaii, Honolulu, Hawaii.

Olson, P. A. (2009). PIlot Whales *Globicephala melas* and *G. macrorhynchus*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 847-852). New York: Academic Press.

Omoto, N., Maebayashi, M., Hara, A., Adachi, S., & Yamauchi, K. (2004). Gonadal maturity in wild sturgeons, *Huso dauricus*, *Acipenser mikadoi* and *A. schrenckii* caught near Hokkaido, Japan. *Environmental Biology of Fishes, 70,* 381-391.

Omura, H. (1959). Bryde's whale from the coast of Japan. Sci.Rep.Whales.Res.Inst*,* 14, 1-33.

Omura, H., K. Fujino, and S. Kimura. (1955). Beaked whale *Berardius bairdi* of Japan, with notes on *Ziphius cavirostris*. Scientific Reports of the Whales Research Institute*,* 10, 89-132.

Oswald, J. N., J. Barlow, and T. F. Norris. (2003). Acoustic identification of nine delphinid species in the eastern tropical Pacific Ocean. Marine Mammal Science*,* 19(1), 20-37.

Oswald, J. N., S. Rankin, and J. Barlow. (2008). To Whistle or Not to Whistle? Geographic Variation in the Whistling Behavior of Small Odontocetes. Aquatic Mammals*,* 34(3), 288-302.

Oswald, J. N., S. Rankin, J. Barlow, and M. O. Lammers. (2007). A tool for real-time acoustic species identification of delphinid whistles. The Journal of the Acoustical Society of America*,* 122(1), 587-595.

Pacific Fishery Management Council (PFMC). (2000). Amendment 14 to the Pacific coast salmon plan (1997). Incorporating the regulatory impact review/initial regulatory flexibility analysis and final supplemental environmental impact statement. Portland, OR: Pacific Fishery Management Council. 420 pages.

Pacini, A. F., P. E. Nachtigall, L. N. Kloepper, M. Linnenschmidt, A. Sogorb, and S. Matias. (2010). Audiogram of a formerly stranded long-finned pilot whale (Globicephala melas) measured using auditory evoked potentials. Journal Of Experimental Biology*,* 213(18), 3138-3143. doi:10.1242/jeb.044636

Pacini, A. F., P. E. Nachtigall, C. T. Quintos, T. D. Schofield, D. A. Look, G. A. Levine, and J. P. Turner. (2011). Audiogram of a stranded Blainville's beaked whale (*Mesoplodon densirostris*) measured using auditory evoked potentials. *The Journal of Experimental Biology,* 214(Pt 14), 2409-2415. doi:10.1242/jeb.054338

Packard, A., H. E. Karlsen, and O. Sand. (1990). Low frequency hearing in cephalopods. Journal of Comparative Physiology A: Neuroethology, Sensory, Neural, and Behavioral Physiology*,* 166(4), 501-505.

Page, B., S. D. Goldsworthy, M. A. Hindell, and J. McKenzie. (2002). Interspecific differences in male vocalizations of three sympatric fur seals (*Arctocephalus* spp.). Journal of Zoology*,* 258, 49-56.

Page, B., J. McKenzie, and S. D. Goldsworthy. (2005). Inter-sexual differences in New Zealand fur seal diving behaviour. Marine Ecology Progress Series*,* 304, 249-264.

Palacios, D.M., Herrera, J.C., Gerrodette, T., Garcia, C., Soler, G. A., Avila, I.C., Bessudo, S., Hernandez, E., Trujillo, F., Florez-Gonzalez, L., & Kerr, I. (2012). Cetacean distribution and relative abundance in Colombia's Pacific EEZ from survey cruises and platforms of opportunity. *Journal of Cetacean Research and Management, 12*(1), 45-60.

Panigada, S., Lauriano, G., Burt, L., Pierantonio, N., & Donovan, G. (2011). Monitoring winter and summer abundance of cetaceans in the Pelagos Sanctuary (Northwestern Mediterranean Sea) through aerial surveys*. PLoS ONE, 6,* e22878. doi:22810.21371/journal.pone.0022878.

Papastavrou, V., S. C. Smith, and H. Whitehead. (1989). Diving behavior of the sperm whale *Physeter macrocephalus* off the Galapagos Islands, Ecuador. Can J Zool*,* 67(4), 839-846.

Paredes, R., Orben, R.A., Roby, D.D., Irons, D.B., Young, R., Renner, H., Tremblay, Y., Will, A., Harding, A.M.A., and Kitaysky, A. S. (2015). Foraging ecology during nesting influences body size in a pursuit-diving seabird. *Marine Ecology Progress Series, 533*, 261-276. doi:10.3354/meps11388

Parks, S. E., P. K. Hamilton, S. D. Kraus, and P. L. Tyack. (2005). The gunshot sound produced by male North Atlantic right whales (*Eubalaena glacialis*) and its potential function in reproductive advertisement. Marine Mammal Science*,* 21(3), 458-475.

Parks, S. E., D. R. Ketten, J. T. O'Malley, and J. Arruda. (2007). Anatomical predictions of hearing in the North Atlantic right whale. The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology*,* 290(6), 734-744.

Parks, S. E., and P. L. Tyack. (2005). Sound production by North Atlantic right whales (*Eubalaena glacialis*) in surface active groups. Journal of the Acoustical Society of America*,* 117(5), 3297-3306.

Parks, S. E., J. D. Warren, K. Stamieszkin, C. A. Mayo, and D. Wiley. (2011). Dangerous dining: surface foraging of North Atlantic right whales increases risk of vessel collisions. Biology letters*,* 8(1), 57-60. doi:10.1098/rsbl.2011.0578

Parrish, F. A., & Abernathy, K. (2006). Movements of monk seals relative to ecological depth zones in the lower Northwestern Hawaiian Islands. *Atoll Research Bulletin, 543*, 115-130.

Parrish, F. A., K. Abernathy, G. J. Marshall, and B. M. Buhleier. (2002). Hawaiian monk seals (*Monachus schauinslandi*) foraging in deep-water coral beds. Marine Mammal Science*,* 18(1), 244-258.

Parsons, K. M., Durban, J. W., Burdin, A. M., Burkanov, V. N., Pitman, R. L., Barlow, J., Barrett-Lennard, L. G., LeDuc, R. G., Robertson, K. M., Matkin, C. O., & Wade, P. R. (2013). Geographic patterns of genetic differentiation among killer whales in the northern North Pacific. *The Journal of Heredity, 104*, 737-754.

Pastene, L.A., and M. Goto. 1998. An estimate of the mixing proportion of 'J' and 'O' stocks minke whales in subarea 11 based on mitochondrial DNA haplotype data. *Report of the International Whaling Commission 48*, 471-474.

Pastene, L. A., Goto, M., & Kishino, H. (1998). An estimate of the mixing proportion of "J" and "O" stocks minke whales in sub-area 11 based on mitochondrial DNA haplotype data. *Report of the International Whaling Commission, 38*,471-474.

Patterson, B., & G. R. Hamilton. (1964). Repetitive 20 cycle per second biological hydroacoustic signals at Bermuda. In W. N. Tavolga (Ed.), *Marine bio-acoustics* (pp. 125-145). Oxford: Pergamon Press.

Pauley, G. B., Bortz, B. M., & Shepard, M. F. (1986). *Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific northwest)—Steelhead trout.* U.S. Fish Wildlife Service Biological Report 82(11.62). U.S. Army Corps of Engineers, TR EL-82-4. 24 pages.

Pavan, G., T. J. Hayward, J. F. Borsani, M. Priano, M. Manghi, C. Fossati, & J. Gordon. (2000). Time patterns of sperm whale codas recorded in the Mediterranean Sea 1985--1996. *The Journal of the Acoustical Society of America, 107*(6), 3487-3495.

Payne, R., & K. Payne. (1971). Underwater sounds of southern right whales. New York Zoological Society: *Zoologica (Winter, 1971),* 159-163.

Payne, R. S., & S. McVay. (1971). Songs of humpback whales. *Science, 173*, 585-597.

Perrin, W. F. (2009a). Atlantic Spotted Dolphin *Stenella frontalis*. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 54-56): Academic Press.

Perrin, W. F. (2009b). Common dolphins *Delphinus delphis* and *D. capensis.* Pages 255-259 in W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.) *Encyclopedia of marine mammals,* 2nd ed. New York: Academic Press.

Perrin, W. F. (2009c). Pantropical Spotted Dolphin *Stenella attenuata*. Pages 819-821 in W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.). *Encyclopedia of marine mammals*, 2nd ed. New York: Academic Press.

Perrin, W. F. (2009d). Spinner Dolphin *Stenella longirostris*. Pages 1100-1103 in W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.). *Encyclopedia of marine mammals*, 2nd ed. New York: Academic Press.

Perry, S. L., DeMaster, D. P., & Silber, G. K. (1999). The great whales: History and status of six species listed as endangered under the U.S. Endangered Species Act of 1973. *Marine Fisheries Review, 61*(1), 1-74.

Peterson, D. L., Bain, M. B., & Haley, N. (2000). Evidence of declining recruitment of Atlantic sturgeon in the Hudson River. *North American Journal of Fisheries Management, 20*, 231-238.

Philips, J. D., P. E. Nachtigall, W. W. L. Au, J. L. Pawloski, & H. L. Roitblat. (2003). Echolocation in the Risso's dolphin, *Grampus griseus*. *Journal of the Acoustical Society of America, 113*(1), 605-616.

Phillips, A. V., & I. Stirling. (2000). Vocal individuality in mother and pup South American fur seals, *Arctocephalus australis*. *Marine Mammal Science, 16*(3), 592-616.

Pierson, M. O. (1987). Breeding Behavior of the Guadalupe fur seal, *Arctocephalus Townsendi*. Pages 83-94 in J. P. Croxall & R. L. Gentry (Eds.). *Status, biology, and ecology of fur seals.* NOAA Technical Report NMFS 51. Seattle, Washington: Northwest Regional Office.

Pike, D. G., Víkingsson, G. A., Gunnlaugsson, Th., & Øien, N. (2009). A note on the distribution and abundance of blue whales (*Balaenoptera musculus*) in the central and northeast North Atlantic. *NAMMCO Scientific Publications, 7,* 19-29.

Pike, D. G., Gunnlaugsson, T., Vikingsson, G. A., Desportes, G., & Mikkelsen, B. (2010). Estimates of the abundance of humpback whales (*Megaptera novaengliae*) from the TNASS Icelandic and Faroese ship surveys conducted in 2007. *International Whaling Commission Scientific Committee, Agadir, Morocco. 15.*

Pitman, R. (2009a). Indo-Pacific beaked whale (*Indopacetus pacificus*). In W. F. Perrin, B. G. Wursig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals, 2nd edition* (pp. 600-602). San Diego, California: Academic Press.

Pitman, R. (2009b). Mesoplodont whales (*Mesoplodon* spp.). In W. F. Perrin, B. G. Wursig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals, 2nd edition* (pp. 721-726). San Diego, California: Academic Press.

Pitman, R. L., D. M. Palacios, P. L. Rodriguez, B. J. Brennan, K. C. Balcomb, and T. Miyashita. (1998, 24-28 January 1998). *Probable sightings of Longman's beaked whale (Indopacetus [Mesoplodon] pacificus) from the equatorial Indian and Pacific oceans.* Paper presented at the World Marine Mammal Science Conference, Monaco.

Plotkin, P. T. (2003). Adult migrations and habitat. In P. L. Lutz, J. A. Musick, and J. Wyneken (Eds.), *The biology of sea turtles, Volume 2* (pp. 225-241). Boca Raton, Florida: CRC Press.

Plotkin, P. T. (2010). Nomadic behaviour of the highly migratory olive ridley sea turtle *Lepidochelys olivacea* in the Eastern Tropical Pacific Ocean. Endangered Species Research*,* 13(1), 33-40. doi:10.3354/esr00314

Polovina, J. J., G. H. Balazs, E. A. Howell, D. M. Parker, M. P. Seki, and P. H. Dutton. (2004). Forage and migration habitat of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific Ocean. Fisheries Oceanography*,* 13(1), 36-51. doi:doi:10.1046/j.1365-2419.2003.00270.x

Polovina, J. J., E. Howell, D. M. Parker, and G. H. Balazs. (2003). Dive-depth distribution of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific: Might deep longline sets catch fewer turtles? . Fish. Bull.*,* 101(1), 189-193.

Pomilla, C., A. R. Amaral, T. Collins, G. Minton, K. Findlay, M. S. Leslie, L. Ponnampalam, R. Baldwin, and H. Rosenbaum. (2014). The World's Most Isolated and Distinct Whale Population? Humpback Whales of the Arabian Sea. PloS one*,* 9(12), e114162. doi:10.1371/journal.pone.0114162

Popper, A. N. (1980a). Scanning electron microscopic study of the sacculus and lagena in several deep-sea fishes. . American Journal of Anatomy*,* 157(2), 115-136.

Popper, A. N. (1980b). Sound Emission and Detection by Delphinids. In L. M. Herman (Ed.), *Cetacean Behavior* (pp. 1-52). New York: John Wiley and Sons.

Popper, A. N. (1980c). Sound emission and detection by delphinids. In L. M. Herman (Ed.), *Cetacean Behavior: Mechanisms and Functions* (pp. 1-52). New York: John Wiley & Sons.

Popper, A. N. (2003). Effects of anthropogenic sound on fishes. Fisheries*,* 28(10), 24-31.

Popper, A. N. (2005). *A review of hearing by sturgeon and lamprey*. Report for the U.S. Army Corps of Engineers, Portland District. Rockville, MD: Environmental BioAcoustics, LLC . 23 pages.

Popper, A. N., & Coombs, S. (1982). The morphology and evolution of the ear in Actinopterygian fishes. *American Zoologist, 22*, 311-328.

Popper, A. N., and R. R. Fay. (1973). Sound detection and processing by teleost fishes: a critical review. Journal of the Acoustical Society of America*,* 53(6), 1515.

Popper, A. N., and R. R. Fay. (1993). Sound detection and processing by fish critical review and major research questions. Brain Behav Evol*,* 41(1), 14-38.

Popper, A. N., and R. R. Fay. (1997). Evolution of the ear and hearing: Issues and questions. Brain Behavior and Evolution*,* 50(4), 213-221.

Popper, A. N., and R. R. Fay. (1999). The auditory periphery in fishes. In R. R. Fay and A. N. Popper (Eds.), *Comparative hearing: fish and amphibians.* (pp. 43-100). New York: Springer-Verlag.

Popper, A. N., and R. R. Fay. (2009). The future of fish bioacoustics. Journal of the Acoustical Society of America*,* 125(4), 2485-2485.

Popper, A., and C. R. Schilt. (2008). Hearing and acoustic behavior: Basic and applied considerations. In J. F. Webb, R. R. Fay, and A. N. Popper (Eds.), *Fish Bioacoustics* (pp. 17-48): Springer.

Popper, A. N., R. R. Fay, C. Platt, and O. Sand. (2003). Sound detection mechanisms and capabilities of teleost fishes. In S. P. Collin and N. J. Marshall (Eds.), *Sensory Processing in Aquatic Environments* (pp. 3-38). New York: Springer-Verlag.

Popper, A. N., A. D. Hawkins, R. R. Fay, D. A. Mann, S. M. Bartol, T. J. Carlson, S. Coombs, W. T. Ellison, R. L. Gentry, M. B. Halvorsen, S. Lokkeborg, P. H. Rogers, B. L. Southall, D. G. Zeddies, & W. N. Tavolga. (2014). *Sound exposure guidelines for fishes and sea turtles: A technical report prepared by the ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI.* Springer briefs in oceanography. New York, NY: ASA Press.

Poulter, T. C. (1968). Underwater Vocalization and Behavior of Pinnipeds. In R. J. Harrison, R. C. Hubbard, R. S. Peterson, C. E. Rice, and R. J. Schusterman (Eds.), *The Behavior and Physiology of Pinnipeds* (pp. 69-84). New York: Appleton-Century-Crofts.

Preen, A. R., Marsh, H., Lawler, I. R., Prince, R. I. T., & Shepherd, R. (1997). Distribution and abundance of dugongs, turtles, dolphins and other megafauna in Shark Bay, Ningaloo Reef and Exmouth Gulf, Western Australia. *Wildlife Research, 24*(2), 185-208.

Prieto, R., Silva, M. A., Waring, G. T., & Gonçalves, J. M. A. (2014). Sei whale movements and behaviour in the North Atlantic inferred from satellite telemetry. *Endangered Species Research, 26*, 101-113. doi: 10.3354/esr00630.

Pritchard, P. C. H. (1997). Evolution, phylogeny, and current status. In P. Lutz and J. A. Musick (Eds.), *The biology of sea turtles* (pp. 1-28). Boca Raton, FL: CRC Press.

Professional Association of Diving Instructors (PADI). (2015). Worldwide Corporate Statistics 2015 Data for 2009-2014. Accessed February 2016. <https://www.padi.com/scuba-diving/about-padi/statistics/PADI-2015-WW-Statistics/.>.

PADI. (2016). *Technical diving course offerings*. Retrieved January 6, 2016 from <http://www.padi.com/scuba-diving/PADI-Courses/Course-Catalog/Go-Beyond-with-PADI-TecRec percentC2 percentAE/>.

Pryor, T., K. Pryor, and K. S. Norris. (1965). Observations on a pygmy killer whale (*Feresa attenuata* Gray) from Hawaii. Journal of Mammalogy*,* 46, 450-461.

Qiwei, W. (2010). *Acipenser sinensis*. The IUCN red list of threatened species. Version 2014.3. Retrieved March 2015 from <www.iucnredlist.org>.

Radford, C. A., J. C. Montgomery, P. Caiger, and D. M. Higgs. (2012). Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. *The Journal of Experimental Biology,* 215(Pt 19), 3429-3435. doi:10.1242/jeb.073320

Radford, C. A., C. T. Tindle, J. C. Montgomery, and A. G. Jeffs. (2011). Modelling a reef as an extended sound source increases the predicted range at which reef noise may be heard by fish larvae. Marine Ecology Progress Series*,* 438, 167-174. doi:10.3354/meps09312

Rankin, S., and J. Barlow. (2005). Source of the North Pacific ``boing'' sound attributed to minke whales. The Journal of the Acoustical Society of America*,* 118(5), 3346-3351.

Rankin, S., and J. Barlow. (2007). Vocalizations of the Sei Whale *Balaenoptera borealis* off the Hawaiian Islands. Bioacoustics*,* 16(2), 137-145. doi:10.1080/09524622.2007.9753572

Rankin, S., S. Baumann-Pickering, T. Yack, and J. Barlow. (2011). Description of sounds recorded from Longman's beaked whale, *Indopacetus pacificus*. The Journal of the Acoustical Society of America*,* 130(5), EL339-344. doi:10.1121/1.3646026

Rankin, S., J. Oswald, J. Barlow, and M. Lammers. (2007). Patterned burst-pulse vocalizations of the northern right whale dolphin, *Lissodelphis borealis*. The Journal of the Acoustical Society of America*,* 121(2), 1213-1218.

Rasmussen, M. H., L. A. Miller, and W. W. L. Au. (2002). Source levels of clicks from free-ranging white-beaked dolphins (*Lagenorhynchus albirostris* Gray 1846) recorded in Icelandic waters. The Journal of the Acoustical Society of America*,* 111(2), 1122-1125.

Rasmussen, M. H., M. Lammers, K. Beedholm, and L. A. Miller. (2006). Source levels and harmonic content of whistles in white-beaked dolphins (*Lagenorhynchus albirostris*). *The Journal of the Acoustical Society of America, 120*(1), 510-517.

Rasmussen, M. H., Akamatsu, T., Teilmann, J., Vikingsson, G., & Miller, L. A. (2013). Biosonar, diving and movements of two tagged white-beaked dolphin in Icelandic waters. *Deep Sea Research II, 88-89*, 97-105. doi.org/10.1016/j.dsr2.2012.07.011.

Raum-Suryan, K. L., Rehberg, M. J., Pendleton, G. W., Pitcher, K. W., Gelatt, T. S. (2004). Development of dispersal, movement patterns, and haul-out use by pup and juvenile Steller sea lions (*Eumetopias jubatus*) in Alaska. *Marine Mammal Science 20*, 823-850.

Read, A. J., and A. J. Westgate. (1997). Monitoring the movements of harbour porpoises (*Phocena phocena*) with satellite telemetry. Mar. Biol., 130, 315-322.

Ream, R. R., J. T. Sterling, and T. R. Loughlin. (2005). Oceanographic features related to northern fur seal migratory movements. Deep Sea Research Part II: Topical Studies in Oceanography, 52(5-6), 823-843.

Recalde-Salas, A., C. P. Salgado Kent, M. J. Parsons, S. A. Marley, and R. D. McCauley. (2014). Non-song vocalizations of pygmy blue whales in Geographe Bay, Western Australia. The Journal of the Acoustical Society of America, 135(5), EL213-218. doi:10.1121/1.4871581.

Reeder, D.B., and Chiu, C.S. (2010). Ocean acidification and its impact on ocean noise: phenomenology and analysis. *The Journal of the Acoustical Society of America, 128*(3), EL137-143. doi:10.1121/1.3431091.

Reeves, R. R., and S. Leatherwood. (1994). Dolphins, Porpoises, and Whales (pp. 1-91). Chicago, IL: IUCN.

Reeves, R. R., and H. Whitehead. (1997). Status of the sperm whale, *Physeter macrocephalus* in Canada. Canadian Field-Naturalist, 111(2), 293-307.

Reeves, R. R. (1998). Distribution, abundance and biology of ringed seals (*Phoca hispida*): An overview. *NAMMCO Scientific Publications, 1*, 9-45.

Rehberg, M. J., R. D. Andrews, U. G. Swain, and D. G. Calkins. (2009). Foraging behavior of adult female Steller sea lions during the breeding season in Southeast Alaska. Marine Mammal Science, 25(3), 588-604.

Reilly, S. B., J. L. Bannister, P. B. Best, M. Brown, R. L. B. Jr., D. S. Butterworth, P. J. Clapham, J. Cooke, G. P. Donovan, J. Urbán, and A. N. Zerbini. (2008). *Balaenoptera omurai. In: IUCN 2013 Red list of threatened species. Version 2015.2* from http://www.iucnredlist.org.

Reilly, S. B., J.L.Bannister, P. B. Best, M. Brown, R. L. Brownell, Jr., , D. S. Butterworth, P. J. Clapham, J. Cooke, G. P. Donovan, J. Urbán, and A. N. Zerbini. (2012). *Balaena mysticetus, Okhotsk Sea subpopulation*. Retrieved 24 July 2015 from http://www.iucnredlist.org/details/2467/0.

Reisinger, R. R., M. Keith, R. D. Andrews, and P. J. N. de Bruyn. (2015). Movement and diving of killer whales (*Orcinus orca*) at a Southern Ocean archipelago. Journal of Experimental Marine Biology and Ecology, 473, 90-102. doi:10.1016/j.jembe.2015.08.008

Renaud, M. L. (1995). Movements and Submergence Patterns of Kemp's Ridley Turtles (*Lepidochelys kempii*). Journal of Herpetology, 29(3), 370-374.

Rendell, L. E., J. Matthews, A. Gill, J. Gordon, and D. W. Macdonald. (1999). Quantitative analysis of the tonal calls of five odontocete species. J. Zool., 249(4), 403-410.

Rendell, L., Simião, S., Brotons, J. M., Airoldi, S., Fasano, D., & Gannier, A. (2014). Abundance and movements of sperm whales in the western Mediterranean basin. *Aquatic Conservation: Marine and Freshwater Ecosystems, 24* (Supplement 1), 31-40. doi: 10.1002/aqc.2426.

Rice, D. (1998). *Marine mammals of the world: Systematics and distribution*. Lawrence, KS: Special Publication Number 4, The Society for Marine Mammalogy,.

Rice, D. W. (1989). Sperm whale *Physeter macrocephalus* Linneaus, 1758. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of marine mammals, Vol. 4: River dolphins and the larger toothed whales* (pp. 177-234). San Diego: Academic Press.

Rice, M. R., and G. H. Balazs. (2008). Diving behavior of the Hawaiian green turtle (*Chelonia mydas*) during oceanic migrations. Journal of Experimental Marine Biology and Ecology, 356(1-2), 121-127. doi:10.1016/j.jembe.2007.12.010

Richardson, W. J., C. R. Greene, C. I. Malme, and D. H. Thomson. (1995). *Marine mammals and noise* (1st ed.). San Diego: Academic Press.

Ridgway, S. H. (1966). Dall porpoise, *Phocoenoides dalli* (True): observations in captivity and at sea. Norsk Hvalfangst-Tidende, 55(5), 97-110.

Ridgway, S. H. (1986). Diving By Cetaceans. In A. O. Brubakk, J. W. Kanwisher, and G. Sundness (Eds.), *Diving in animals and man* (pp. 33-62). Trondheim, Norway: The Royal Norwegian Society of Science and Letters.

Ridgway, S. H., C. A. Bowers, D. Miller, M. L. Schultz, C. A. Jocaobs, and C. A. Dooley. (1984). Diving and blood oxygen in the white whale. Canadian Journal of Zoology, 62, 2349-2351.

Ridgway, S. H., and D. A. Carder. (2001). Assessing hearing and sound production in cetaceans not available for behavioral audiograms: Experiences with sperm, pygmy sperm, and gray whales. Aquatic Mammals, 27(3), 267-276.

Ridgway, S. H., D. A. Carder, T. Kamolnick, R. R. Smith, C. E. Schlundt, and W. R. Elsberry. (2001). Hearing and whistling in the deep sea: Depth influences whistle spectra but does not attenuate hearing by white whales (*Delphinapterus leucas*) (Odontoceti, Cetacea). Journal Of Experimental Biology, 204(22), 3829-3841.

Ridgway, S. H., and P. L. Joyce. (1975). Studies on seal brain by radiotelemetry. Rapp. P.-v. Reun. Cons. int. Explor. Mer., 169, 81-91.

Ridgway, S. H., E. G. Wever, J. G. McCormick, J. Palin, and J. G. Anderson. (1969). Hearing in the giant sea turtle, *Chelonia mydas*. Proceedings of the National Academy of Sciences, 64(3), 884-890.

Riedman, M. (1990). *The Pinnipeds: Seals, Sea Lions and Walruses*: Unviersity of California Press.

Risch, D., C. W. Clark, P. J. Dugan, M. Popescu, U. Siebert, and S. M. Van Parijs. (2013). Minke whale acoustic behavior and multi-year seasonal and diel vocalization patterns in Massachusetts Bay, USA. *Marine Ecology Progress Series, 489*, 279-295. doi:10.3354/meps10426.

Risch, D., N. J. Gales, J. Gedamke, L. Kindermann, D. P. Nowacek, A. J. Read, U. Siebert, I. C. Van Opzeeland, S. M. Van Parijs, and A. S. Friedlaender. (2014). Mysterious bio-duck sound attributed to the Antarctic minke whale (*Balaenoptera bonaerensis*). *Biology Letters, 10*(4), 20140175. doi:10.1098/rsbl.2014.0175.

Risch, D., Sofie M. Van Parijs, and U. Siebert. (2014). Individual calling behaviour and movements of North Atlantic minke whales (*Balaenoptera acutorostrata*). *Behaviour, 151*(9), 1335-1360. doi:10.1163/1568539x-00003187.

Ritter, F. (2002). Behavioural observations of rough-toothed dolphins (*Steno bredanensis*) off La Gomera, Canary Islands (1995-2000), with special reference to their interactions with humans. *Aquatic Mammals, 28*(1), 46-59.

Rivers, J. A. (1997). Blue whale, *Balaenoptera musculus*, vocalizations from the waters off central California. *Marine Mammal Science, 13*(2), 186-195.

Roberts, J. J., Best, B. D., Mannocci, L., Fujioka, E., Halpin, P. N., Palka, D. L., Garrison, L. P., Mullin, K. D., Cole, T. V. N., Khan, C. B., McLellan, W. A., Pabst, D. A., & Lockhart, G. G. (2016). Habitat-based cetacean density models for the U.S. Atlantic and Gulf of Mexico. *Scientific Reports, 6,* 22615.

Rogachev, K. A., E. C. Carmack, and M. G. G. Foreman. (2008). Bowhead whales feed on plankton concentrated by estuarine and tidal currents in Academy Bay, Sea of Okhotsk. *Continental Shelf Research, 28*(14), 1811-1826.

Rogers, P. H., and M. Cox. (1988). Underwater sound as a biological stimulus. In J. Atema, R. R. Fay, A. N. Popper, and W. N. Tavolga (Eds.), *Sensory biology of aquatic animals* (pp. 131-149). New York, New York: Springer-Verlag.

Rogers, T. L., and S. M. Brown. (1999). Acoustic observations of Arnoux's beaked whale (*Berardius arnuxii*) off Kemp Land, Antarctica. *Marine Mammal Science, 15*(1), 192-198.

Rohr, J. J., F. E. Fish, and J. W. Gilpatrick. (2002). Maximum swim speeds of captive and free-ranging delphinids: Critical analysis of extraordinary performance. *Marine Mammal Science, 18*(1), 1-19.

Ronald, K., and P. J. Healey. (1981). Harp seal, *Phoca groenlandica* Erxleben, 1777. In S. H. Ridgway and R. J. Harrison (Eds.), *Handbook of marine mammals. Volume 2: Seals* (pp. 55-87). New York: Academic Press.

Ronconi, R.A., Ryan, P.G., and Ropert-Coudert, Y. (2010). Diving of great shearwaters (*Puffinus gravis*) in cold and warm water regions of the South Atlantic Ocean. *PLoS ONE, 5*(11), e15508. doi:15510.11371/journal.pone.0015508.

Rosenbaum, H. C., Pomilla, C., Mendez, M., Leslie, M. S., Best, P. B., Findlay, K. P., . . . Kiszka, J. (2009). Population structure of humpback whales from their breeding grounds in the South Atlantic and Indian Oceans. *PLoS ONE, 4*(10). e7318. doi:10.1371/journal.pone.0007318.

Ross, D. (1976). *Mechanics of underwater noise*. New York: Pergamon.

Ross, D. (2005). Ship sources of ambient noise. *IEEE Journal of Oceanic Engineering, 30*(2), 257-261. doi:10.1109/JOE.2005.850879.

Ross, G. J. B., P. B. Best, and B. G. Donnelly. (1975). New records of the pygmy right whale *Caperea marginata* new record from South Africa with comments on distribution migration appearance and behavior. *Journal of the Fisheries Research Board of Canada, 32*(7), 1005-1018.

Rossong, M. A., and J. M. Terhune. (2009). Source levels and communication-range models for harp seal (*Pagophilus groenlandicus*) underwater calls in the Gulf of St. Lawrence, Canada. Canadian *Journal of Zoology, 87*(7), 609-617.

Ruegg, K. C., E. C. Anderson, C. S. Baker, M. Vant, J. A. Jackson, and S. R. Palumbi. (2009). Are Antarctic minke whales unusually abundant because of 20th century whaling? *Molecular Ecology, 19*(2), 281-291.

Rugh, D., D. DeMaster, A. Rooney, J. Breiwick, K. Shelden, and S. Moore. (2003). A review of bowhead whale (*Balaena mysticetus*) stock identity. Journal of Cetacean Research and Management, 5(3), 267-279.

Rugh, D. J., K. E. W. Shelden, and B. A. Mahoney. (2000). Distribution of Belugas, Delphinapterus leucas, in Cook Inlet, Alaska, During June/July 1993–2000. Marine Fisheries Review, 62(3), 6-21.

Sala, J. E., F. Quintana, R. P. Wilson, J. Dignani, M. N. Lewis, and C. Campagna. (2011). Pitching a new angle on elephant seal dive patterns. Polar Biology, 34(8), 1197-1209. doi:10.1007/s00300-011-0981-6.

Sale, A., P. Luschi, R. Mencacci, P. Lambardi, G. R. Hughes, G. C. Hays, S. Benvenuti, and F. Papi. (2006). Long-term monitoring of leatherback turtle diving behaviour during oceanic movements. Journal of Experimental Marine Biology and Ecology, 328(2), 197-210. doi:10.1016/j.jembe.2005.07.006.

Samarra, F. I. P., V. B. Deecke, A. E. Simonis, and P. J. O. Miller. (2015). Geographic variation in the time-frequency characteristics of high-frequency whistles produced by killer whales (*Orcinus orca*). Marine Mammal Science, 31(2), 688-706. doi:10.1111/mms.12195.

Samuel, Y., S. J. Morreale, C. W. Clark, C. H. Greene, and M. E. Richmond. (2005). Underwater, low-frequency noise in a coastal sea turtle habitat. The Journal of the Acoustical Society of America, 117(3), 1465-1472.

Sand, O., P. S. Enger, H. E. Karlsen, F. Knudsen, and T. Kvernstuen. (2000). Avoidance responses to infrasound in downstream migrating European silver eels, *Anguilla anguilla*. Environmental Biology Of Fishes, 57(3), 327-336.

Sand, O., and H. Karlsen. (1986). Detection of infrasound by the Atlantic cod. J. Exp. Biol., 125(1), 197-204.

Santoro, A., K. I. Marten, and T. W. Crawford. (1989). *Pygmy sperm whale sound Kogia breviceps.* Paper presented at the 8th Biennial Conference on the Biology of Marine Mammals, Pacific Grove, CA.

Sasaki, T., M. Nikaido, S. Wada, T. K. Yamada, Y. Cao, M. Hasegawa, and N. Okada. (2006). *Balaenoptera omurai* is a newly discovered baleen whale that represents an ancient evolutionary lineage. Molecular Phylogenetics and Evolution, 41(1), 40-52.

Sasso, C. R., and W. N. Witzell. (2006). Diving behaviour of an immature Kemp's ridley turtle (*Lepidochelys kempii*) from Gullivan Bay, Ten Thousand Islands, south-west Florida. Journal of the Marine Biological Association of the UK, 86(04), 919. doi:10.1017/s0025315406013877

Sayigh, L., N. Quick, G. Hastie, and P. Tyack. (2013). Repeated call types in short-finned pilot whales, *Globicephala macrorhynchus*. Marine Mammal Science, 29(2), 312-324. doi:10.1111/j.1748-7692.2012.00577.x.

Scheer, M., B. Hofmann, and P. I. Behr. (1998). *Discrete pod-specific call repertoires among short-finned pilot whales (Globicephala macrorhynchus) off the SW coast of Tenerife, Canary Islands.* Paper presented at the Abstracts of the World Marine Mammal Science Conference, Monaco.

Schellart, N. A. M., and A. N. Popper. (1992). Functional aspects of the evolution of the auditory system of actinopterygian fish. In D. B. Webster, R. R. Fay, and A. N. Popper (Eds.), *The evolutionary biology of hearing* (pp. 295-322). New York: Springer-Verlag.

Schevill, W. E. (1964). Underwater sounds of cetaceans. In W. N. Tavolga (Ed.), *Marine bio-acoustics* (pp. 307-316). New York, NY: Pergamon Press.

Schevill, W. E., and B. Lawrence. (1949). Underwater Listening to the White Porpoise (*Delphinapterus leucas*). *Science, 109,* 143-144.

Schevill, W. E., and W. A. Watkins. (1966). Sound structure and directionality in *Orcinus* (killer whale). *Zoologica, 51*(2), 71-76.

Schevill, W. E., and W. A. Watkins. (1971). Pulsed Sounds of the Porpoise *Lagenorhynchus australis*. *Breviora 366*, 1-10.

Schevill, W. E., and W. A. Watkins. (1972). Intense Low-Frequency Sounds from an Antarctic Minke Whale, (*Balaenoptera acurostrata*). *Breviora 388*, 1-8.

Schlundt, C. E., R. L. Dear, D. S. Houser, A. E. Bowles, T. Reidarson, and J. J. Finneran. (2011). Auditory evoked potentials in two short-finned pilot whales (*Globicephala macrorhynchus*). *The Journal of the Acoustical Society of America, 129*(2), 1111-1116. doi:10.1121/1.3531875.

Schorr, G. S., R. W. Baird, M. B. Hanson, D. L. Webster, D. J. McSweeney, and R. D. Andrews. (2009). Movements of satellite-tagged Blainville's beaked whales off the island of Hawaii. *Endangered Species Research*. doi:10.3354/esr00229.

Schorr, G. S., Falcone, E. A., Moretti, D. J., and Andrews, R. D. (2014). First long-term behavioral records from Cuvier's beaked whales (*Ziphius cavirostris*) reveal record-breaking dives. *PLoS One, 9*(3), 1-10. doi:10.1371/journal.pone.0092633.g001.

Schotten, M., W. W. L. Au, M. O. Lammers, and R. Aubauer. (2004). Echolocation recordings and localization of wild spinner dolphins (*Stenella longirostris*) and pantropical spotted dolphins (*S. attenuata*) using a four-hydrophone array. In J. A. Thomas, C. F. Moss, and M. Vater (Eds.), *Echolocation in bats and dolphins* (pp. 393-400). Chicago, Illinois: University of Chicago Press.

Schreer, J. F., and K. M. Kovacs. (1997). Allometry of diving capacity in air-breathing vertebrates. *Canadian Journal of Zoology, 75*(3), 339-358.

Schultz, K. W., D. H. Cato, P. J. Corkeron, and M. M. Bryden. (1995). Low frequency narrow-band sounds produced by bottlenose dolphins. *Marine Mammal Science, 11*(4), 503-509.

Schusterman, R. J. (1966). Perception and Determinants of Underwater Vocalization in the California Sea Lion. In R. G. Busnel (Ed.), *Symp. of Animal Sonar Systems, Biology and Bionics* (pp. 535-617).

Schusterman, R. J. (1978). Vocal communication in pinnipeds *Behavior of captive wild animals* (pp. 247-308). Chicago: Nelson-Hall.

Scott, M., S. J. Chivers, R. Olson, and R. Lindsay. (1993). *Radio tracking of spotted dolphin associated with tuna in the eastern tropical Pacific.* Paper presented at the 10th biennial conference on the biology of marine mammals, Galveston, TX.

Scott, M. D., and S. J. Chivers. (1990). Distribution and herd structure of bottlenose dolphins in the eastern tropical Pacific Ocean. In S. Leatherwood and R. R. Reeves (Eds.), *The bottlenose dolphin* (pp. 387-402). San Diego: Academic Press.

Scott, M. D., A. A. Hohn, A. J. Westgate, J. R. Nicolas, B. R. Whitaker, and W. B. Campbell. (2001). A note on the release and tracking of a rehabilitated pygmy sperm whale (*Kogia breviceps*). Journal of Cetacean Research and Management, 3(1), 87-94.

Sears, R., and W. F. Perrin. (2009). Blue whale (*Balaenoptera musculus*). In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 120-124): Academic Press.

Sekiguchi, K., N. Klages, K. Findlay, and P. Best. (1993). *Feeding habits and possible movements of southern bottlenose whales (Hyperoodon planifrons).* Paper presented at the Proceedings of the NIPR Symposium on Polar Biology, No. 6, Tokyo.

Sekiguchi, K., M. A. Meyer, P. B. Best, R. Davis, and J. H. M. David. (1998). *Satellite-monitored movements and diving patterns of Heaviside's dolphin (Cephalorhynchus heavisidii) off St. Helena Bay, South Africa.* Paper presented at the Proceedings for World Marine Mammal Science Conference, Monaco.

Sekiguchi, K., H. Onishi, H. Sasaki, S. Haba, Y. Iwahara, D. Mizuguchi, M. Otsuki, D. Saijo, B. Nishizawa, H. Mizuno, N. Hoshi, and T. Kamito. (2014). Sightings of the western stock of North Pacific right whales (Eubalaena japonica) in the far southeast of the Kamchatka Peninsula. Marine Mammal Science*,* 30(3), 1199-1209. doi:10.1111/mms.12105

Seminoff, J. A., Allen, C. D., Balazs, G. H., Dutton, P. H., Eguchi, T., Haas, H. L., Hargrove, S. A., Jensen, M. P., Klemm, D. L., Lauritsen, A. M., MacPherson, S. L., Opay, P., Possardt, E. E., Pultz, S. L., Seney, E. E., Houtan, K. S. V., Waples, R. S. (2015) Status review of the green turtle (*Chelonia mydas*) under the U.S. Endangered Species Act. (NOAA Technical Memorandum NOAA-NMFS-SWFSC-539). La Jolla, California: Southwest Fisheries Science Center.

Sergeant, D. E. (1962). The biology of the pilot or pothead whale, *Globicephala melaena* (Traill), in Newfoundland waters. Bulletin of the Fisheries Research Board of Canada*,* 132, 1-84.

Serrano, A. (2001). New underwater and aerial vocalizations of captive harp seals (*Pagophilus groenlandicus*). Canadian Journal of Zoology*,* 79(1), 75-81.

Serrano, A., and J. M. Terhune. (2001). Within-call repetition may be an anti-masking strategy in underwater calls of harp seals (*Pagophilus groenlandicus*). Canadian Journal of Zoology*,* 79(8), 1410-1413.

Shane, S. H. (1995a). Behavior patterns of pilot whales and Risso's dolphins off Santa Catalina Island, California. Aquatic Mammals*,* 21(3), 195-197.

Shane, S. H. (1995b). Human-pilot whale encounter: an update. Marine Mammal Science*,* 11(1), 115.

Sharpe, F. A., and L. M. Dill. (1997). The behavior of pacific herring schools in response to artificial humpback whale bubbles. Canadian Journal of Zoology*,* 75, 725-730.

Shillinger, G. L., D. M. Palacios, H. Bailey, S. J. Bograd, A. M. Swithenbank, P. Gaspar, B. P. Wallace, J. R. Spotila, F. V. Paladino, R. Piedra, S. A. Eckert, and B. A. Block. (2008). Persistent leatherback turtle migrations present opportunities for conservation. PLoS Biol*,* 6(7), e171. doi:10.1371/journal.pbio.0060171

Shmigirilov, A., Mednikova, A., & Israel, J. (2007). Comparison of biology of the Sakhalin sturgeon, Amur sturgeon and kaluga from the Amur River, Sea of Okhotsk and Sea of Japan biogeographic province. *Environmental Biology of Fishes, 79*, 383-395.

Shpak, O., and Glazov, D. (2013). Review of the recent scientific data on the Okhotsk Sea white whale (*Delphinapterus leucas*) population structure and its application to management. (*Paper SC/65a/SM23 presented to the Scientific Committee at the 2013 International Whaling Commission SC65a Meeting).* Journal of Cetacean Research and Management.

Silber, G. K. (1986). The relationship of social vocalizations to surface behavior and aggression in the Hawaiian humpback whale *Megaptera novaeangliae*. Can J Zool*,* 64(10), 2075-2080.

Sills, J. M., B. L. Southall, and C. Reichmuth. (2014). Amphibious hearing in spotted seals (*Phoca largha*): underwater audiograms, aerial audiograms and critical ratio measurements. *The Journal of Experimental Biology,* 217(Pt 5), 726-734. doi:10.1242/jeb.097469

Sills, J. M., Southall, B. L., and Reichmuth, C. (2015). Amphibious hearing in ringed seals (*Pusa hispida*): Underwater audiograms, aerial audiograms and critical ratio measurements. *The Journal of Experimental Biology, 21*8, 2250-2259, doi:10.1242/jeb.120972.

Simard, P., D. A. Mann, and S. Gowans. (2008). Burst-Pulse Sounds Recorded from White-Beaked Dolphins (*Lagenorhynchus albirostris*). Aquatic Mammals*,* 34(4), 464-470.

Simmonds, M. P., and J. D. Hutchinson. (1996). *The conservation of whales and dolphins: science and practice*. Chichester, United Kingdom: John Wiley and Sons.

Simon, M., F. Ugarte, M. Wahlberg, and L. A. Miller. (2006). Icelandic killer whales *Orcinus orca* use a pulsed call suitable for manipulating the schooling behaviour of herring *Clupea harengus*. Bioacoustics*,* 16, 57-74.

Simonis, A. E., S. Baumann-Pickering, E. Oleson, M. L. Melcon, M. Gassmann, S. M. Wiggins, and J. A. Hildebrand. (2012). High-frequency modulated signals of killer whales (*Orcinus orca*) in the North Pacific. The Journal of the Acoustical Society of America*,* 131(4), EL295-301. doi:10.1121/1.3690963

Simpkins, M. A., B. P. Kelly, and D. Wartzok. (2001). Three-dimensional diving behaviors of ringed seals (*Phoca hispida*). *Marine Mammal Science, 17*(4), 909-925.

Širović, A., H. R. Bassett, S. C. Johnson, S. M. Wiggins, and J. A. Hildebrand. (2014). Bryde's whale calls recorded in the Gulf of Mexico. Marine Mammal Science*,* 30(1), 399-409. doi:10.1111/mms.12036

Širović, A., S. C. Johnson, L. K. Roche, L. M. Varga, S. M. Wiggins, and J. A. Hildebrand. (2015). North Pacific right whales (Eubalaena japonica) recorded in the northeastern Pacific Ocean in 2013. Marine Mammal Science*,* 31(2), 800-807. doi:10.1111/mms.12189

Širović, A., L. N. Williams, S. M. Kerosky, S. M. Wiggins, and J. A. Hildebrand. (2012). Temporal separation of two fin whale call types across the eastern North Pacific. Marine Biology*,* 160(1), 47-57. doi:10.1007/s00227-012-2061-z

Sisneros, J. A. (2009). Adaptive hearing in the vocal plainfin midshipman fish: getting in tune for the breeding season and implications for acoustic communication. Integr Zool*,* 4(1), 33-42.

Sisneros, J. A., & P. H. Rogers. (2016). Directional Hearing and Sound Source Localization in Fishes. In J. A. Sisneros (Ed.), *Fish Hearing and Bioacoustics* (Vol. 877, pp. 121-155).

Sjare, B. L., & T. G. Smith. (1986). The vocal repertoire of white whales, *Delphinapterus leucas*, summering in Cunningham Inlet, Northwest Territories. Coanadian Journal of Zoology, 64(2), 407-415.

Skaug, H. J., Øien, N., Schweder, T., & Bøthun, G. (2004). Abundance of minke whales (*Balaenoptera acutorostrata*) in the Northeast Atlantic: Variability in time and space. *Canadian Journal of Fisheries and Aquatic Sciences, 61*, 870-886.

Slooten, E., S. Dawson, & W. Rayment. (2002). Quantifying abundance of Hector's dolphins between Farewell Spit and Milford Sound. DOC Science Internal Series, 35, 5-18.

Smith, S. O., & Hunter, J. (2003). *Monterey Bay National Marine Sanctuary submerged cultural resources study: 2001.* San Luis Obispo, CA: Underwater Archaeological Consortium. Retrieved from <http://montereybay.noaa.gov/research/techreports/SMITH_HUNTER_2003_2MB.pdf>.

Smith, T. D., & Pike, D. G. (2009). The enigmatic whale: the North Atlantic humpback. *NAMMCO Scientific Publications, 7*, 161-178.

Society for Marine Mammalogy (SMM). (2016). *List of marine mammal species and subspecies. Committee on Taxonomy, Society for Marine Mammalogy*. Accessed May 2016. <https://www.marinemammalscience.org/species-information/list-marine-mammal-species-subspecies/>.

Soldevilla, M. S., E. E. Henderson, G. S. Campbell, S. M. Wiggins, J. A. Hildebrand, & M. A. Roch. (2008). Classification of Risso's and Pacific white-sided dolphins using spectral properties of echolocation clicks. The Journal of the Acoustical Society of America, 124(1), 609-624.

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene, Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, & P. L. Tyack. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations Aquatic Mammals, 33(4), 411-521.

Special Committee on Seals (CSOS). (2015). *Scientific advice on matters related to the management of seal populations: 2015*. Report of Sea Mammal Research Unit and Natural Environment Research Council. St. Andrew's, Scotland: Sea Mammal Research Unit, St. Andrew's University.

Sperling, J. B. (2007). *The behaviour and physiology of the gravid flatback turtle (Natator depressus).* (Ph.D. dissertation). The University of Queensland, Australia.

Sperling, J. B. (2008). Two New Dive Types with a Gradual Ascent Phase in Flatback Turtles (*Natator depressus*). Marine Turtle Newsletter, 120, 9-11.

Spotila, J. R. (2004). *Sea turtles: A complete guide to their biology, behavior, and conservation*. Baltimore, Maryland: John Hopkins University Press.

Spotila, J. R., M. P. O'Conner, and F. V. Paladino. (1997). Thermal biology. In P. L. Lutz and J. A. Musick (Eds.), *The biology of sea turtles* (pp. 297-314). Boca Raton, Florida: CRC Press, Inc.

Spotila, J. R., R. D. Reina, A. C. Steyermark, P. T. Plotkin, and F. V. Paladino. (2000). Pacific leatherback turtles face extinction. *Nature, 405*, 529-530.

Springer, A. M., Estes, J. A., van Vliet, G. B., Williams, T. M., Doak, D. F., Danner, E. M., Forney, K. A., & Pfister, B. (2003). Sequential megafaunal collapse in the North Pacific Ocean: An ongoing legacy of industrial whaling? *Proceedings of the National Academy of Sciences of the United States of America, 100*(21), 12223-12228.

St. Pierre, R. (2006). *Acipenser oxyrinchus* spp. *oxyrinchus*. The IUCN red list of threatened species 2006 e.T243A13046213. Retrieved from <http://dx.doi.org/10.2305/IUCN.UK.2006.RLTS.T243A 13046213.en>.

St. Pierre, R. & Parauka, F.M. (2006). *Acipenser oxyrinchus. The IUCN Red List of Threatened Species 2006*: e.T245A13046974. Retrieved May 2016 from <http://dx.doi.org/10.2305/IUCN.UK2006. RLTS.T245A13046974.en>.

Stacey, P. J., Leatherwood, S., & Baird, R. W. (1994). *Pseudorca crassidens*. *Mammalian Species, 0*(456), 1-6.

Staudigel, H., Hart, S. H., Pile, A., Bailey, B. E., Baker, E. T., Brooke, S., Connelly, D. P., Haucke, L., German, C. R., Hudson, I., Jones, D., Koppers, A. A. P., Konter, J., Leeh, R., Pietsch, T. W., Tebo, B. M., Templeton, A. S., Zierenberg, R., & Young, C. M. (2002). Vailulu'u Seamount, Samoa: Life and death on an active submarine volcano. *Proceedings of the National Academy of Science, 103*(17), 6448–6453.

Stafford, K. M., C. G. Fox, and D. S. Clark. (1998). Long-range acoustic detection and localization of blue whale calls in the northeast Pacific Ocean. *Journal of the Acoustical Society of America, 104*(6), 3616-3625.

Stafford, K. M., S. E. Moore, C. L. Berchok, Ø. Wiig, C. Lydersen, E. Hansen, D. Kalmbach, and K. M. Kovacs. (2012). Spitsbergen's endangered bowhead whales sing through the polar night. *Endangered Species Research, 18*(2), 95-103. doi:10.3354/esr00444

Stafford, K. M., S. L. Nieukirk, and C. G. Fox. (1999a). An acoustic link between blue whales in the eastern tropical Pacific and the Northeast Pacific. *Marine Mammal Science, 15*(4), 1258-1268.

Stafford, K. M., S. L. Nieukirk, and C. G. Fox. (1999b). Low-frequency whale sounds recorded on hydrophones moored in the eastern tropical Pacific. Journal of the Acoustical Society of America, 106(6), 3687-3698.

Stafford, K. M., Nieukirk, S. L., & Fox, C. G. (2001). Geographic and seasonal variation of blue whale calls in the North Pacific. *Journal of Cetacean Research and Management, 3*(1), 65-76.

Stanistreet, J. E., D. Risch, and S. M. Van Parijs. (2013). Passive acoustic tracking of singing humpback whales (*Megaptera novaeangliae*) on a northwest Atlantic feeding ground. *PLoS ONE, 8*(4), e61263. doi:10.1371/journal.pone.0061263

Starbird, C. H., Z. Hillis-Starr, J. T. Harvey, and S. A. Eckert. (1999). Internesting movements and behavior of hawksbill turtles (*Eretmochelys imbricata*) around Buck Island Reef National Monument, U.S. Virgin Islands. *Chelonian Conservation and Biology, 3*, 237– 243.

Steiner, W. W. (1981). Species-specific differences in pure tonal whistle vocalizations of five western North Atlantic dolphin species. Behavioral Ecology and Sociobiology, 9, 241-246.

Sterling, J. T., and R. R. Ream. (2004). At-sea behavior of juvenile male northern fur seals (*Callorhinus ursinus*). Canadian Journal of Zoology, 82(10), 1621-1637.

Stern, S. J. (1992). Surfacing rates and surfacing patterns of minke whales (*Balaenoptera acutorostrata*) off central California, and the probability of a whale surfacing within visual range. Report of the International Whaling Commission, 42, 379-385.

Stewardson, C. L. (2001). Biology and conservation of the Cape (South African) fur seal *Arctocephalus pusillus pusillus* (Pinnipedia: Otariidae) from the Eastern Cape Coast of South Africa. PhD thesis, Australian National University, Canberra.

Stewart, B. S. (2009). Diving Behavior. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 321-327): Academic Press.

Stewart, B. S., and R. L. DeLong. (1994). Postbreeding foraging migrations of northern elephant seals. In B. J. L. Boeuf and R. M. Laws (Eds.), *Elephant seals: population, ecology, behavior and physiology* (pp. 290-309). Berkeley, California: University of California Press.

Stimpert, A. K., W. W. Au, S. E. Parks, T. Hurst, and D. N. Wiley. (2011). Common humpback whale (*Megaptera novaeangliae*) sound types for passive acoustic monitoring. The Journal of the Acoustical Society of America, 129(1), 476-482. doi:10.1121/1.3504708

Stimpert, A. K., D. N. Wiley, W. W. L. Au, M. P. Johnson, and R. Arsenault. (2007). Megapclicks': acoustic click trains and buzzes produced during night-time foraging of humpback whales (*Megaptera novaeangliae*). Biology letters. doi:10.1098/rsbl.2007.0281

Stirling, I. (1971). Studies on the behaviour on the South Ausralian fur seal, *Arctocephalus forsteri* (Lesson) I. Annual cycle, postures and calls, and adult males during breeding season Australian Journal of Zoology, 19(3), 243-246.

Stirling, I. (1973). Vocalization in the ringed seal (*Phoca hispida*). *Journal of the Fishery Research Board of Canada, 30*, 1592-1594.

Stirling, I., Calvert, W., and Cleator, H. (1983). Underwater vocalizations as a tool for studying the distribution and relative abundance of wintering pinipeds in the high Arctic. *Arctic, 36*(3), 262-274.

Straley, J. M. (1999). *Overwintering North Pacific humpback whales in Alaskan waters.* Paper presented at the 13th biennial meeting of the Society for Marine Mammalogy, Kihei, Maui.

Strong, C. (1990). *Ventilation patterns and behavior of Balaenopterid whales in the Gulf of California, Mexico.* California State University, Moss Landing.

Sudara, S., and S. Mahakunayanakul. (1998, 22-24 January 1998). *Distribution and river intrusion of dolphins in the inner Gulf of Thailand.* Paper presented at the World Marine Mammal Science Conference, Monaco.

Sutherland, R. W., and E. G. Sutherland. (2003). Status of the flatback sea turtle (*Natator depressus*) rookery on Crab Island, Australia, with notes on predation by crocodiles. Chelonian Conservation and Biology, 4(3), 612-619.

Szymanski, M. D., D. E. Bain, K. Kiehl, S. Pennington, S. Wong, and K. R. Henry. (1999). Killer whale (*Orcinus orca*) hearing: Auditory brainstem response and behavioral audiograms. Journal of the Acoustical Society of America, 106(2), 1134-1141.

Taruski, A. G. (1979). The whistle repertoire of the North Atlantic pilot whale (*Globicephala melaena*) and its relationship to behavior and environment *Behavior of marine animals - Current perspectives in research, Vol. 3: Cetaceans* (pp. 345-368): Plenum Press.

Terhune, J. M. (1989). Underwater click hearing thresholds of a harbour seal, *Phoca vitulina*. Aquat. Mamm., 15(1), 22-26.

Terhune, J. M. (1991). Masked and unmasked pure tone detection thresholds of a harbour seal listening in air. Canadian Journal of Zoology, 69(8), 2059-2066.

Terhune, J. M., and K. Ronald. (1971). The harp seal, *Pagophilus groenlandicus* (Erxleben, 1777). X. The air audiogram. Canadian Journal of Zoology, 49(3), 385-390.

Terhune, J. M., and K. Ronald. (1972). The harp seal. III. The underwater audiogram. Canadian Journal of Zoology, 50, 565-569.

Terhune, J. M., and K. Ronald. (1973). Some hooded seal (*Cystophora cristata*) sounds in March. Canadian Journal of Zoology, 51, 319-321.

Terhune, J. M., and K. Ronald. (1975a). Masked hearing thresholds of ringed seals. Journal of the Acoustical Society of America, 58(2), 515-516.

Terhune, J. M., and K. Ronald. (1975b). Underwater hearing sensitivity of two ringed seals. Canadian Journal of Zoology, 53, 227-231.

Terhune, J.M., and Ronald, K. (1976). The upper frequency limit of ringed seal hearing. *Canadian Journal of Zoology, 54*, 1226-1229.

Terhune, J. M., and S. Turnbull. (1995). Variation in the psychometric functions and hearing thresholds of a harbour seal. In R. A. Kastelein, J. A. Thomas, and P. E. Nachtigall (Eds.), *Sensory systems of aquatic mammals*. Woerden: De Spil.

Tershy, B. R. (1992). Body Size Diet, Habitat use, and social behavior of *Balaenoptera* whales in the Gulf of California. J. Mamm., 73(3), 477-486.

Tervo, O. M., M. F. Christoffersen, S. E. Parks, R. Møbjerg Kristensen, and P. Teglberg Madsen. (2011). Evidence for simultaneous sound production in the bowhead whale (*Balaena mysticetus*). The Journal of the Acoustical Society of America, 130(4), 2257. doi:10.1121/1.3628327

Tervo, O. M., S. E. Parks, and L. A. Miller. (2009). Seasonal changes in the vocal behavior of bowhead whales (*Balaena mysticetus*) in Disko Bay, Western-Greenland. Journal of the Acoustical Society of America, 126(3), 1570-1580.

Thewissen, J. G. M. (2002). Hearing. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 570-574). San Diego: Academic Press.

Thode, A., D. K. Mellinger, S. Stienessen, A. Martinez, and K. Mullin. (2002). Depth-dependent acoustic features of diving sperm whales (*Physeter macrocephalus*) in the Gulf of Mexico. The Journal of the Acoustical Society of America, 112(1), 308-321.

Thomas, J., P. Moore, R. Withrow, and M. Stoermer. (1990). Underwater Audiogram of a Hawaiian Monk Seal (*Monachus schauinslandi*). Journal of the Acoustical Society of America, 87(1), 417-420.

Thomas, J. A., P. W. B. Moore, E. Nachtigall, and W. G. Gilmartin. (1990). A new sound from a stranded pygmy sperm whale. Aquatic Mammals, 16, 28-30.

Thomas, J. A., & C. W. Turl. (1990). Echolocation characteristics and range detection threshold of a false killer whale (*Pseudorca crassidens*). In J. A. Thomas and R. A. Kastelein (Eds.), *Sensory abilities of cetaceans: Laboratory and field evidence* (pp. 321-334). New York: Plenum.

Thomas, T., W. J. Richardson, W. R. Koski, & B. Würsig. (2003). *Surfacing, respiration and dive cycles of bowhead whales (Balaena mysticetus) in the Beaufort Sea: Calves, subadults and adults*. Paper presented at the Fifteenth Biennial Conference on the Biology of Marine Mammals, Greensboro, North Carolina.

Thompson, D., S. E. W. Moss, & P. Lovell. (2003). Foraging behaviour of South American fur seals Arctocephalus australis: extracting fine scale foraging behaviour from satellite tracks. *Marine Ecology Progress Series, 260,* 285-296.

Thompson, P. O., W. C. Cummings, & S. J. Ha. (1986). Sounds, source levels, and associated behavior of humpback whales, Southeast Alaska. *Journal of the Acoustical Society of America, 80*(3), 735-740.

Thompson, P. O., L. T. Findley, & O. Vidal. (1992). 20-Hz pulses and other vocalizations of fin whales, *Balaenoptera physalus*, in the Gulf of California, Mexico. *Journal of the Acoustical Society of America, 92*(6), 3051-3057.

Thompson, P. O., & W. A. Friedl. (1982). A long term study of low frequency sounds from several species of whales off Oahu, Hawaii. *Cetology, 45*, 1-19.

Thompson, T. J., H. E. Winn, & P. J. Perkins. (1979). Mysticete Sounds. In H. E. Winn and B. L. Olla (Eds.), *Behavior of Marine Animals: Current Perspectives in Research* (Vol. Vol. 3: Cetaceans, pp. 403-431 (chp. 412)).

Thomson, D. H., & W. J. Richardson. (1995). Marine Mammal Sounds. In W. J. Richardson, C. R. Greene, C. I. Malme, and D. H. Thomson (Eds.), *Marine Mammals and Noise* (1st ed., pp. 159-204). San Diego: Academic press.

Thorpe, C. W., & S. M. Dawson. (1991). Automatic measurement of descriptive features of Hector's dolphin vocalizations. *Journal of the Acoustical Society of America, 89*(1), 435-443.

Tillman, M. F. (1977). Estimates of population size for the North Pacific sei whale. *Report of the International Whaling Commission Special Issue, 1,* 98-106.

Tougaard, J., & L. A. Kyhn. (2010). Echolocation sounds of hourglass dolphins (*Lagenorhynchus cruciger*) are similar to the narrow band high-frequency echolocation sounds of the dolphin genus *Cephalorhynchus*. *Marine Mammal Science, 26*(1), 239-245.

Tougaard, J., Henriksen, O.D., & Miller, L.A. (2009). Underwater noise from three types of offshore wind turbines: estimation of impact zones for harbor porpoises and harbor seals. *The Journal of the Acoustical Society of America, 125*(6), 3766-3773. doi:10.1121/1.3117444.

Tracy, C. (1990) *Memorandum.* Green sturgeon meeting and comments. Department of Fisheries, State of Washington. 10 pages.

Tremel, D. P., J. A. Thomas, K. T. Ramirez, G. S. Dye, W. A. Bachman, A. N. Orban, & K. K. Grimm. (1998). Underwater hearing sensitivity of a Pacific white-sided dolphin, *Lagenorhynchus obliquidens*. *Aquatic Mammals, 24*(2), 63-69.

Tripovich, J. S., R. Canfield, T. L. Rogers, & J. P. Y. Arnould. (2008). Characterization of Australian fur seal vocalizations during the breeding season. *Marine Mammal Science, 24*(4), 913-928.

Trukhin, A. M., and A. W. Mizuno. (2002). Distribution and abundance of the largha seal (*Phoca largha* Pall.) on the coast of Primorye Region (Russia): A literature review and survey report. Mammal Study, 27, 1-14.

Tubelli, A. A., A. Zosuls, D. R. Ketten, M. Yamato, and D. C. Mountain. (2012). A prediction of the minke whale (*Balaenoptera acutorostrata*) middle-ear transfer function. The Journal of the Acoustical Society of America, 132(5), 3263-3272. doi:10.1121/1.4756950.

Turtle Expert Working Group. (2007). An assessment of the leatherback turtle population in the Atlantic Ocean. NOAA Technical Memorandum NMFS-SEFSC-555.

Tyack, P. (1981). Interactions between singing Hawaiian humpback whales and conspecifics nearby. Behavioral Ecology and Sociobiology, 8, 105-116.

Tyack, P., and H. Whitehead. (1983). Male competition in large groups of wintering humpback whales. Behaviour, 83, 132-154.

Tyack, P. L. (2000). Functional aspects of cetacean communication. In J. Mann, R. C. Connor, P. L. Tyack, and H. Whitehead (Eds.), *Cetacean societies: Field studies of dolphins and whales*. Chicago, Illinois: University of Chicago Press.

Tyack, P. L. (2008). Implications for marine mammals of large-scale changes in the marine acoustic environment. Journal of Mammalogy, 89(32), 549-558.

Tyurneva, O. Y., Y. M. Yakovlev, V. V. Vertyankin, and N. I. Selin. (2010). The peculiarities of foraging migrations of the Korean-Okhotsk gray whale (Eschrichtius robustus) population in russian waters of the Far Eastern seas. Russian Journal of Marine Biology, 36(2), 117-124. doi:10.1134/s1063074010020069.

Udovydchenkov, I. A., T. F. Duda, S. C. Doney, and I. D. Lima. (2010). Modeling deep ocean shipping noise in varying acidity conditions. Journal of the Acoustical Society of America, 128(3), EL130-136. doi:10.1121/1.3402284.

Urick, R. J. (1983). *Principles of underwater sound* (3rd ed.). New York: McGraw-Hill Book Company.

USFWS (U.S. Fish and Wildlife Service). 2009. Cyber salmon—Chinook salmon. U.S. Fish and Wildlife Service Field Office, Alaska Region. Retrieved from <https://www.fws.gov/alaska/cybersalmon/chin.htm>.

U.S. Fish and Wildlife Service (USFWS). (2009a). Cyber salmon—chum salmon. U.S. Fish and Wildlife Service Field Office, Alaska Region. Retrieved from <https://www.fws.gov/alaska/cybersalmon/chum.htm>.

USFWS (U.S. Fish & Wildlife Service) & NMFS (National Marine Fishery Service). (2003). Endangered and threatened wildlife and plants; Designation of critical habitat for the Gulf sturgeon. *Federal Register 68*(53):13370-13495.

USFWS & NMFS. (2009). *Gulf sturgeon (Acipenser oxyrinchus desotoi) 5-year review: Summary and evaluation*. Panama City, FL and St. Petersburg, FL: USFWS & NMFS. Retrieved from <http://www.nmfs.noaa.gov/pr/pdfs/species/gulfsturgeon_5yearreview.pdf>.

Valentine, P. C., Middleton, T. J., and Fuller, S. J. (2001). *Seafloor maps showing topography, sun-illuminated topography, and backscatter intensity of Stellwagen Bank National Marine Sanctuary region off Boston, Massachusetts.* (Open-File Report 00-410). U.S. Geological Survey.

Van Bree, P. J. H. (1997). On extralimital records of Arctic seals (Mammalia, Pinnipedia) on the west European continental coast in the past and at present—A summary. *Beaufortia, 47*(5), 153-156.

Van Dam, R. P., and Diez, C. E. (1996). Diving behavior of immature hawksbills (*Eretmochelys imbricata*) in a Caribbean cliff-wall habitat. *Marine Biology, 127,* 171-178.

Van Den Berg, A. V., and A. Schuijf. (1983). Discrimination of sounds based on the phase difference between particle motion and acoustic pressure in the shark *Chiloscyllium griseum*. *Proceedings of the Royal Society of London,. Series B, 218*(1210), 127-134.

Van Opzeeland, I., S. Van Parijs, L. Kindermann, E. Burkhardt, and O. Boebel. (2013). Calling in the Cold: Pervasive Acoustic Presence of Humpback Whales (*Megaptera novaeangliae*) in Antarctic Coastal Waters. PloS one*,* 8(9), e73007. doi:10.1371/journal.pone.0073007.

Van Parijs, S. M., V. M. Janik, and P. M. Thompson. (2000). Display-area size, tenure length, and site fidelity in the aquatically mating male harbour seal, *Phoca vitulina*. Canadian Journal of Zoology*,* 78(12), 2209-2217.

Van Parijs, S. M., and K. M. Kovacs. (2002). In-air and underwater vocalizations of eastern Canadian harbour seals,Phoca vitulina. Canadian Journal of Zoology*,* 80(7), 1173-1179. doi:10.1139/z02-088.

Van Waerebeek, K., and B. Würsig. (2009). Dusky Dolphin *Lagenorhynchus obscurus*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 335-338): Academic Press.

Vanderlaan, A. S. M., A. E. Hay, and C. T. Taggart. (2003). Characterization of North Atlantic right-whale (*Eubalaena glacialis*) sounds in the Bay of Fundy. IEEE Journal of Oceanic Engineering*,* 28(2), 164-173.

Verboom, W. C., and R. A. Kastelein. (1995). Acoustic signals by Harbour porpoises (*Phocoena phocoena*). In P. E. Nachtigall, J. Lein, W. W. L. Au, and A. J. Read (Eds.), *Harbour porpoises, laboratory studies to reduce bycatch*: DeSpil Publishers, Woerden, The Netherlands.

Ver Hoef, J. M., Cameron, M. F., Boveng, P. L., London, J. M., & Moreland, E. E. (2014). A spatial hierarchical model for abundance of three ice-associated seal species in the eastern Bering Sea. *Statistical Methodology, 17*, 46-66.

Veron, J. E. N. (2014). *Results of an update of the Corals of the World Information Base for the listing determination of 66 coral species under the Endangered Species Act.* Report to the Western Pacific Regional Fishery Management Council. Honolulu, HI: Western Pacific Regional Fishery Management Council. Retrieved from <http://www.nmfs.noaa.gov/pr/pdfs/species/corals_veron_report2014.pdf>.

Vermeij, M. J. A., Marhaver, K. L., Huijbers, C. M., Nagelkerken, I., and Simpson, S.D. 2010. Coral larvae move toward reef sounds. *PLoS ONE 5*(5):e10660.

Víkingsson, G. A., and M. P. Heide-Jørgensen. (2015). First indications of autumn migration routes and destination of common minke whales tracked by satellite in the North Atlantic during 2001-2011. Marine Mammal Science, 31(1), 376-385. doi:10.1111/mms.12144.

Villadsgaard, A., M. Wahlberg, and J. Tougaard. (2007). Echolocation signals of wild harbour porpoises, *Phocoena phocoena*. *The Journal of Experimental Biology,* 210(1), 56-64.

Villegas-Amtmann, S., D. P. Costa, Y. Tremblay, S. Salazar, and D. Aurioles-Gamboa. (2008). Multiple foraging strategies in a marine apex predator, the Galapagos sea lion *Zalophus wollebaeki*. Marine Ecology Progress Series, 363, 299-309. doi:10.3354/meps07457.

Vladykov, V.D., & Greely, J.R. (1963). Order Acipenseroidei. In: *Fishes of the western North Atlantic*. Sears Foundation. New Haven, CT: Marine Research, Yale University 1(3). 630 pages.

Vu, E. T., D. Risch, C. W. Clark, S. Gaylord, L. T. Hatch, M. A. Thompson, D. N. Wiley, and S. M. Van Parijs. (2012). Humpback whale song occurs extensively on feeding grounds in the western North Atlantic Ocean. Aquatic Biology, 14(2), 175-183. doi:10.3354/ab00390.

Wada, S., M. Oishi, and T. K. Yamada. (2003). A newly discovered species of living baleen whale. Nature, 426(6964), 278-281.

Wade, P. R., & Gerrodette, T. (1993). Estimates of cetacean abundance and distribution in the eastern tropical Pacific. *Report of the International Whaling Commission, 43,* 477-493.

Wahlberg, M. (2002). The acoustic behaviour of diving sperm whales observed with a hydrophone array. Journal of Experimental Marine Biology and Ecology, 281(1-2), 53-62.

Wahlberg, M., K. Beedholm, A. Heerfordt, and B. Mohl. (2011). Characteristics of biosonar signals from the northern bottlenose whale, *Hyperoodon ampullatus*. The Journal of the Acoustical Society of America, 130(5), 3077-3084. doi:10.1121/1.3641434.

Wahlberg, M., F. H. Jensen, N. Aguilar Soto, K. Beedholm, L. Bejder, C. u. Oliveira, M. Rasmussen, M. Simon, A. Villadsgaard, and P. T. Madsen. (2011). Source parameters of echolocation clicks from wild bottlenose dolphins (*Tursiops aduncus* and *Tursiops truncatus*). The Journal of the Acoustical Society of America, 130(4), 2263. doi:10.1121/1.3624822.

Walcott, J., S. Eckert, and J. A. Horrocks. (2013). Diving behaviour of hawksbill turtles during the inter-nesting interval: Strategies to conserve energy. Journal of Experimental Marine Biology and Ecology, 448, 171-178. doi:10.1016/j.jembe.2013.07.007.

Walker, T. A., and C. J. Parmenter. (1990). Absence of a pelagic phase in the life cycle of the flatback turtle, *Natator depressa* (Garman). Journal of Biogeography, 17, 275-278.

Wallace, B. P., C. L. Williams, F. V. Paladino, S. J. Morreale, R. T. Lindstrom, and J. R. Spotila. (2005). Bioenergetics and diving activity of internesting leatherback turtles *Dermochelys coriacea* at Parque Nacional Marino las Baulas, Costa Rica. Journal Of Experimental Biology, 208(20), 3873-3884.

Wang, J. Y., and S. C. Yang. (2009). Indo-Pacific Dolphin *Tursiops aduncus*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 602-607). New York: Academic Press.

Waring, G. T., E. Josephson, Fairfield-Walsh, C.P., & Maze-Foley, K. (2008). *U.S. Atlantic and Gulf of Mexico marine mammal stock sssessments-2008*. (NOAA Technical Memorandum NMFS-NE-205). Woods Hole, Massachusetts: Northeast Fisheries Science Center, National Marine Fisheries Service. 426 pages.

Waring, G. T., Josephson, E., Fairfield-Walsh, C. P., & Maze-Foley, K. (2009). *U.S. Atlantic and Gulf of Mexico marine mammal stock assessments-2008*. (NOAA Technical Memorandum NMFS-NE-210). Woods Hole, Massachusetts: Northeast Fisheries Science Center, National Marine Fisheries Service. 440 pages.

Waring, G., Josephson, E., Maze-Foley, K., & Rosel, P. E. (2011). *U.S. Atlantic and Gulf of Mexico marine mammal stock assessments—2011*. Woods Hole, Massachusetts: Northeast Fisheries Science Center, National Marine Fisheries Service. 325 Pages.

Waring, G., Josephson, E., Maze-Foley, K., & Rosel, P. E. (2013). *U.S. Atlantic and Gulf of Mexico marine mammal stock assessments—2012.* Woods Hole, Massachusetts: Northeast Fisheries Science Center, National Marine Fisheries Service. 425 Pages.

Waring, G. T., Josephson, E., Maze-Foley, K., & Rosel, P. E. (2014). *U.S. Atlantic and Gulf of Mexico marine mammal stock assessments-2013*. (NOAA Technical Memorandum NMFS-NE-228). Woods Hole, Massachusetts: Northeast Fisheries Science Center, National Marine Fisheries Service.

Waring, G., Josephson, E., Maze-Foley, K., & Rosel, P. E. (Eds.). (2015). U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments-2014. Woods Hole, Massachusetts: Northeast Fisheries Science Center, National Marine Fisheries Service.

Watkins, W. A. (1967). The Harmonic Interval Fact or Artifact in Spectral Analysis of Pulse Trains. In W. N. Tavolga (Ed.), *Marine bio-acoustics* (Vol. 2, pp. 15-43): Pergamon Press.

Watkins, W. A. (1981). Activities and Underwater Sounds of Fin Whales. The Scientific Reports of the Whales Research Institute(33), 83-117.

Watkins, W. A., M. A. Daher, N. A. DiMarzio, A. Samuels, D. Wartzok, K. M. Fristrup, P. W. Howey, and R. R. Maiefski. (2002). Sperm whale dives tracked by radio tag telemetry. Marine Mammal Science, 18(1), 55-68.

Watkins, W. A., M. A. Daher, K. Fristrup, and G. N. d. Sciara. (1994). Fishing and Acoustic Behavior of Fraser's Dolphin (*Lagenodelphis hosei*) near Dominica, Southeast Caribbean. Caribbean Journal of Science, 30(1-2), 76-82.

Watkins, W. A., M. A. Daher, A. Samuels, and D. P. Gannon. (1997). Observations of *Peponocephala electra*, the melon-headed whale, in the southeastern Caribbean. Caribbean Journal of Science, 33(1-2), 34-40.

Watkins, W. A., and G. C. Ray. (1977). Underwater sounds from ribbon seal, *Phoca fasciata*. Fishery Bulletin, 75, 450-453.

Watkins, W. A., and W. E. Schevill. (1977). Sperm whale codas. Journal of the Acoustical Society of America, 62, 1485-1490.

Watkins, W. A., W. E. Schevill, and P. B. Best. (1977). Underwater sounds of *Cephalorhynchus heavisidii* (Mammalia: Cetacea). Journal of Mammalogy, 58(3), 316-320.

Watkins, W. A., P. Tyack, and K. E. Moore. (1987). The 20-Hz signals of finback whales (*Balaenoptera physalus*). Journal of the Acoustical Society of America*,* 82(6), 1901-1912.

Watkins, W. A., P. Tyack, K. E. Moore, and G. N. di Sciara. (1987). *Steno bredaneisis* in the Mediterranean Sea. Marine Mammal Science*,* 3(1), 78-82.

Watkins, W. A., and D. Wartzok. (1985). Sensory biophysics of marine mammals. Marine Mammal Science*,* 1, 219-260.

Webb, J. F., J. C. Montgomery, and J. Mogdans. (2008). Bioacoustics and the lateral line system of fishes. In J. F. Webb, R. R. Fay, and A. N. Popper (Eds.), *Fish Bioacoustics* (pp. 145-182): Springer.

Weilgart, L., and H. Whitehead. (1993). Coda Communication by Sperm Whales (*Physeter macrocephalus*) Off the Galapagos Islands. Canadian Journal of Zoology*,* 71(4), 744-752.

Weilgart, L., and H. Whitehead. (1997). Group-specific dialects and geographical variation in coda repertoire in South Pacific sperm whales. Behavioral Ecology and Sociobiology*,* 40(5), 277-285.

Weilgart, L. S., and H. Whitehead. (1990). Vocalizations of the north atlantic pilot whale *Globicephala melas* as related to behavioral contexts. Behavioral Ecology and Sociobiology*,* 26(6), 399-402.

Weirathmueller, M. J., W. S. Wilcock, and D. C. Soule. (2013). Source levels of fin whale 20 Hz pulses measured in the Northeast Pacific Ocean. The Journal of the Acoustical Society of America*,* 133(2), 741-749. doi:10.1121/1.4773277

Weller, D. W., A. Klimek, A. L. Bradford, J. Calambokidis, A. R. Lang, B. Gisborne, A. M. Burdin, W. Szaniszlo, J. Urbán, A. Gomez-Gallardo Unzueta, S. Swartz, and R. L. Brownell. (2012). Movements of gray whales between the western and eastern North Pacific. Endangered Species Research*,* 18(3), 193-199. doi:10.3354/esr00447

Wells, R. (2013). Movements and Dive Patterns of Short-Finned Pilot Whales (*Globicephala macrorhynchus*) Released from a Mass Stranding in the Florida Keys. Aquatic Mammals*,* 39(1), 61-72. doi:10.1578/am.39.1.2013.61

Wells, R. S., and M. D. Scott. (2009). Common Bottlenose Dolphin *Tursiops truncatus*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals* (pp. 249-255): Academic Press.

Wells, R. S., Manire, C. A., Byrd, L., Smith, D. R., Gannon, J. G., Fauquier, D., & Mullin, K., (2009). Movements and dive patterns of a rehabilitated Risso's dolphin, Grampus griseus , in the Gulf of Mexico and Atlantic Ocean. *Marine Mammal Science, 25*(2), 420–429.

Werner, R., and C. Campagna. (1995). Diving behaviour of lactating southern sea lions (*Otaria flavescens*) in Patagonia. Canadian Journal of Zoology*,* 73(11), 1975-1982. doi:10.1139/z95-232

West, K. L., S. Sanchez, D. Rotstein, K. M. Robertson, S. Dennison, G. Levine, N. Davis, D. Schofield, C. W. Potter, and B. Jensen. (2012). A Longman's beaked whale (*Indopacetus pacificus*) strands in Maui, Hawaii, with first case of morbillivirus in the central Pacific. Marine Mammal Science, n/a-n/a. doi:10.1111/j.1748-7692.2012.00616.x

Westgate, A. J., A. J. Read, P. Berggren, H. N. Koopman, and D. E. Gaskin. (1995). Diving behaviour of harbour porpoises, *Phocoena phocoena*. Canadian Journal of Fisheries and Aquatic Sciences*,* 52(5), 1064-1073.

Westoff, G., Fry, B.G., and Bleckmann, H. (2005). Sea snakes are sensitive to low-amplitude water motions. *Zoology, 108*(3), 195-200.

Whitehead, H. (2002). Estimates of the current global population size and historical trajectory for sperm whales. *Marine Ecology Progress Series, 242*, 295-304.

Whitehead, H. (2009). Sperm Whale *Physeter macrocephalus*. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.), Encyclopedia of marine mammals (pp. 1091-1097): Academic Press.

Whitehead, H., & Hooker, S. K. (2012). Uncertain status of the northern bottlenose whale *Hyperoodon ampullatus*: Population fragmentation, legacy of whaling and current trends. *Endangered Species Research, 19*, 47-61.

Whitehead, H., and L. Weilgart. (1991). Patterns of visually observable behaviour and vocalizations in groups of female sperm whales. Behaviour, 118(3-4), 275-296.

Whitehead, H., S. Gowans, A. Faucher, and S. W. McCarrey. (1997). Population analysis of northern bottlenose whales in the Gully, Nova Scotia. *Marine Mammal Science, 13*(2), 173-185.

Whiting, A. U., A. T. M. Chaloupka, and C. J. Limpus. (2009). Seasonality, abundance and breeding biology of one of the largest populations of nesting flatback turtles, *Natator depressus*: Cape Domett, Western Australia. *Australian Journal of Zoology, 56*, 297-303.

Whitt, A. D., K. Dudzinski, and J. R. Laliberté. (2013). North Atlantic right whale distribution and seasonal occurrence in nearshore waters off New Jersey, USA, and implications for management. *Endangered Species Research, 20*(1), 59-69. doi:10.3354/esr00486

Wild, L. A., and C. M. Gabriele. (2014). Putative contact calls made by humpback whales (*Megaptera novaeangliae*) in Southeastern Alaska. *Can. Acoust., 42*(4), 23-31.

Williams, T. M. (2009). Swimming. In W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.). *Encyclopedia of marine mammals* (pp. 1140-1147). New York: Academic Press.

Willis, P. M., and R. W. Baird. (1998). Sightings and strandings of beaked whales on the west coast of Canada. Aquatic Mammals, 24(1), 21-25.

Wilson, M., R. T. Hanlon, P. L. Tyack, and P. T. Madsen. (2007). Intense ultrasonic clicks from echolocating toothed whales do not elicit anti-predator responses or debilitate the squid Loligo pealeii. *Biology Letters, 3*(3), 225-. doi:10.1098/rsbl.2007.00105

Winn, H. E., and P. J. Perkins. (1976). Distribution and sounds of the minke whale, with a review of Mysticete sounds. *Cetology, 19*, 1-12.

Wolski, L. F., R. C. Anderson, A. E. Bowles, and P. K. Yochem. (2003). Measuring hearing in the harbor seal (*Phoca vitulina*): Comparison of behavioral and auditory brainstem response techniques. *Journal of the Acoustical Society of America, 113*(1), 629-637.

Wong, S. N. P., and H. Whitehead. (2014). Seasonal occurrence of sperm whales (*Physeter macrocephalus*) around Kelvin Seamount in the Sargasso Sea in relation to oceanographic processes. Deep Sea Research Part I: *Oceanographic Research Papers, 91,* 10-16. doi:10.1016/j.dsr.2014.05.001.

Würsig, B., and C. Clark. (1993). Behavior. In J. J. Burns, J. J. Montague, and C. J. Cowles (Eds.). *The bowhead whale* (pp. 157-199). Lawrence, KS: The Society for Marine Mammalogy.

Würsig, B., and W. J. Richardson. (2009). Effects of Noise. In W. F. Perrin, B. G. Wursig, and J. G. M. Thewissen (Eds.), *Encyclopedia of marine mammals*, 2nd edition (2 ed., pp. 765-773). San Diego, California: Academic Press.

Würsig, B., and M. Würsig. (1980). Behavior and Ecology of the Dusky Dolphin, (*Lagenorhynchus obscurus*) in the South Atlantic. *Fishery Bulletin, 77*(4), 871-890.

Wyneken, J. (1997). Sea turtle locomotion: Mechanisms, behavior, and energetics. In P. L. Lutz and J. A. Musick (Eds.), *The biology of sea turtles* (pp. 165-198). Boca Raton, FL: CRC Press.

Wynne, K., and M. Schwartz. (1999). *Guide to marine mammals and turtles of the U.S. Atlantic and Gulf of Mexico*. Narragansett, Rhode Island: Rhode Island Sea Grant.

Yack, T. M., J. Barlow, J. Calambokidis, B. Southall, and S. Coates. (2013). Passive acoustic monitoring using a towed hydrophone array results in identification of a previously unknown beaked whale habitat. *The Journal of the Acoustical Society of America, 134*(3), 2589-2595. doi:10.1121/1.4816585.

Yamada, T. K. (2009). Omura's whale. Pages 799-801 W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Eds.).Encylopedia of marine mammals, 2nd ed. New York: Academic Press.

Yan, H. Y., and A. N. Popper. (1992). Auditory sensitivity of the cichlid fish Astronotus *Ocellatus cuvier*. J *Comp Physiol A Sens Neural Behav Physiol, 171*(1), 105-109.

Yatabe, A., N. Kubo, M. Otsuka, S. Shima, T. Kubodera, and T. K. Yamada. (2010). Stomach contents and structure of a Longman's beaked whale (*Indopacetus pacificus*) Stranded in Kyushu, Japan. *Aquatic Mammals, 36*(2), 172-177.

Yin, S. E. (1999). Movement patterns, behaviors, and whistle sounds of dolphin groups off Kaikoura, New Zealand. (M.S. thesis), Texas A & M University, College Station, TX.

Yoshida, Y. M., T. Morisaka, M. Sakai, M. Iwasaki, I. Wakabayashi, A. Seko, M. Kasamatsu, T. Akamatsu, and S. Kohshima. (2014). Sound variation and function in captive Commerson's dolphins (*Cephalorhynchus commersonii*). *Behavioral Processes, 108C*, 11-19. doi:10.1016/j.beproc.2014.08.017.

Young, B. A. (2003). Snake bioacoustics: Toward a richer understanding of the behavioral ecology of snakes. *The Quarterly Review of Biology, 78*(3), 303-325.

Yuen, M. M. L., P. E. Nachtigall, M. Breese, and A. Y. Supin. (2005). Behavioral and auditory evoked potential audiograms of a false killer whale (*Pseudorca crassidens*). *The Journal of the Acoustical Society of America, 118*(4), 2688-2695.

Zeddies, D. G., R. R. Fay, M. D. Gray, P. W. Alderks, A. Acob, and J. A. Sisneros. (2012). Local acoustic particle motion guides sound-source localization behavior in the plainfin midshipman fish, *Porichthys notatus*. *The Journal of Experimental Biology*, 215(Pt 1), 152-160. doi:10.1242/jeb.064998

Zelick, R., D. Mann, and A. N. Popper. (1999). Acoustic communication in fishes and frogs. Pages 363-411 in R. R. Fay and A. N. Popper (Eds.). *Comparative hearing: fish and amphibians*. New York: Springer-Verlag.

Zimmer, W. M. X., M. P. Johnson, P. T. Madsen, and P. L. Tyack. (2005). Echolocation clicks of free-ranging Cuvier's beaked whales *(Ziphius cavirostris*). *The Journal of the Acoustical Society of America, 117*(6), 3919-3927.

Zimmer, W. M. X., P. L. Tyack, M. P. Johnson, and P. T. Madsen. (2005). Three-dimensional beam pattern of regular sperm whale clicks confirms bent-horn hypothesis. *Journal of the Acoustical Society of America, 117*(3), 1473-1485.

Zoidis, A. M., M. A. Smultea, A. S. Frankel, J. Hopkins, A. Day, S. Ertl, A. Whitt, and D. Fertl. (2008). Sounds attributed to humpback whale (*Megaptera novaeangliae*) calves recorded in Hawai‘i. *The Journal of the Acoustical Society of America, 123(*3), 1737-1746.

4 Environmental Consequences

This chapter presents an analysis of the potential direct and indirect impacts of each alternative on the affected environment. The following discussion elaborates on the nature of the characteristics that might relate to resources. "Significantly," as used in NEPA, requires considerations of both context and intensity. Context means that the significance of an action must be analyzed in several contexts such as society as a whole (e.g., human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of a proposed action. For instance, in the case of a site-specific action, significance would usually depend on the impacts in the locale rather than in the world as a whole. Both short- and long-term impacts are relevant (40 CFR part 1508.27). Intensity refers to the severity or extent of the potential environmental impact, which can be thought of in terms of the potential amount of the likely change. In general, the more sensitive the context, the less intense a potential impact needs to be in order to be considered significant. Likewise, the less sensitive the context, the more intense a potential impact would be expected to be significant.

In determining impacts to the environment, both the indirect and direct impacts of an action are identified and assessed. The aspects of an action that may affect the environment are the "stressors" for which risk of exposure is estimated and protective measures proposed to reduce the likelihood of possible exposure. The principal stressors related to the employment of LFA sonar are the:

- Presence and movements of the T-AGOS vessels;
- Passive sonar (SURTASS);
- Transmission of the HF/M3 active component of the monitoring/mitigation system; and
- Transmission of the LFA sonar.

Although these potential stressors related to the use of LFA sonar have been described in detail in the 2001 FOEIS/EIS (DoN, 2001), the 2007 FSEIS (DoN, 2007), and the 2012 SEIS/SOEIS (DoN, 2012), and are incorporated herein by reference, a brief summary is provided, including how potential impacts are reduced or eliminated by the operational characteristics of the SURTASS LFA sonar system and vessels in addition to the suite of mitigation and monitoring measures implemented aboard SURTASS LFA sonar vessels.

➢ **PRESENCE AND MOVEMENT OF T-AGOS VESSELS**

Potential adverse impacts associated with the presence and movements in the marine environment of up to four SURTASS LFA vessels for routine training, testing, and military operations are ship strikes, harmful ship discharges, and noise generated by the vessel engines or propellers. The potential for SURTASS LFA sonar vessels to strike a marine mammal, sea turtle, or marine fish is so low that it is discountable. In the 15 years of SURTASS LFA sonar operation, there has never been a ship strike associated with the operation of the vessels. The miniscule potential for ship strikes is due in part to the low speed at which the SURTASS LFA vessels travel, which is 3 kt (5.6 kph) during sonar operations and up to 10 kt (18.5 kph) during transit. Additionally, since the lookouts that keep watch during routine vessel transit and maneuvering are also trained visual observers for marine mammals and sea turtles, they are likely to detect any marine mammals or sea turtles in the vessel's path. SURTASS LFA vessel movements are not unusual or extraordinary and are representative of routine operations of seagoing vessels. In addition to the low speed of travel, the design of the T-AGOS vessels, with the catamaran-type split hull shape and enclosed propeller system, make the potential for striking and harming a marine mammal or sea turtle very unlikely. The lower ship speed also results in so little engine or propeller cavitation noise being generated into the surrounding marine environment that its extent and impact would be negligible.

Although some incidental discharges from the SURTASS LFA sonar vessels are normal for ship operations, the vessels are operated in compliance with all requirements of the Clean Water Act (CWA) and the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), which is implemented by the Act to Prevent Pollution from Ships (APPS) (33 United States Code [U.S.C.] 1901 to 1915). Therefore, no discharges of pollutants regulated under the APPS or CWA will result from the operation of the SURTASS LFA sonar vessels nor will unregulated environmental impacts from the operation of the SURTASS LFA sonar vessels occur.

- **PASSIVE SONAR (SURTASS)**

The SURTASS component is a passive system that only receives and does not transmit any sound energy into the marine environment. Additionally, when the SURTASS HLA is being towed by a T-AGOS vessel, the vessel speed is so low (~3 kt [5.6 kph]) that the potential for any animal being struck by the array is not at all likely, as the low tow speed would provide sufficient time for a marine animal to move and avoid the array if it were in such close proximity. It is unlikely that a marine mammal or sea turtle would become entangled in the towed SURTASS HLA because of the low (slow) tow speed. For these reasons, operation of the SURTASS HLA is not reasonably likely to result in impacts to the environment.

- **TRANSMISSION OF THE HIGH-FREQUENCY ACTIVE SONAR (HF/M3) COMPONENT OF THE MONITORING/MITIGATION SYSTEM**

The HF/M3 sonar is a Navy-developed, enhanced HF commercial sonar used as a mitigation and monitoring asset to detect, locate, and track marine mammals and, to an extent, sea turtles, that may pass close enough to the SURTASS LFA sonar's transmit array to enter the LFA mitigation zone. The HF/M3 sonar operates with a similar power level, signal type, and frequency as HF "fish finder" type sonars. The HF/M3 sonar and its operating protocols were designed to minimize possible impacts on marine animals.

The SL of 220 dB re 1 µPa @ 1 m [rms] is required for the HF/M3 sonar to effectively detect marine mammals (and possibly sea turtles) to the extent of the 180-dB LFA sonar mitigation under the most adverse oceanographic conditions (low echo return and high ambient noise). The maximum HF/M3 sonar pulse is 40 msec, with source frequencies from 30 to 40 kHz, and a variable duty cycle that is nominally about 3 to 4 percent. The HF/M3 sonar system is located at the top of the LFA sonar VLA, about 328 ft (100 m) below the sea surface. Due to the water depth at which the deployed LFA VLA is positioned, the HF/M3 sonar system was not designed to detect marine mammals or sea turtles at or near the surface in proximity to the SURTASS LFA vessel.

The parameters at which the HF/M3 sonar operates and the high transmission loss of the signals due to the high operating frequency together reduce the possibility for the sonar to affect marine mammals, sea turtles, or fishes. Additionally, the HF/M3 sonar's source frequency is not in the range of best hearing frequencies for mysticetes, pinnipeds, sea turtles, or fishes but is within the best hearing range for odontocetes. However, the required ramp-up period from a SL of 180 dB re 1 µPa rms @ 1 m in 10-dB increments to full power is designed to provide sufficient time for a marine mammal, such as an odontocete that can hear the HF/M3 signal, to move away from the vessel and the transmitting HF/M3 sonar. In total, these factors result in a predicted negligible impact on marine mammals, sea turtles, or fishes from exposure to HF/M3 sonar.

➢ **TRANSMISSION OF LFA SONAR**

The only remaining component of the action alternatives that may affect the marine environment is the transmission of low-frequency signals by the LFA sonar. The characteristics of the signals transmitted by LFA sonar and its operational parameters are described in Chapter 2 and must be considered in determining the potential for impacts on the environment. The following sections outline specific analysis that estimate potential impacts on relevant environmental resources from the transmission of active low-frequency LFA sonar signals.

4.1 Marine Water Resources

As described in Chapter 3, the marine water resource that may experience direct or indirect impacts from implementation of the alternatives is water quality, in that there may be intermittent increaes in the noise level (ambient noise) in the frequency band (100-500 Hz) in which LFA sonar operates. The stressor that is analyzed is the same for all alternatives, which is the transmission of low-frequency sound energy from up to four SURTASS LFA sonar systems.

Water Resource Potential Impacts:

- Intermittent increase in ambient noise level during SURTASS LFA sonar transmissions

4.1.1 No Action Alternative

Under the No Action Alternative, the Proposed Action would not occur and there would be no change to baseline marine water resources. Therefore, no significant impacts to marine water resources would occur with implementation of the No Action Alternative.

4.1.2 Alternative 1/Alternative 2

Under Alternative 1, the maximum number of LFA sonar transmission hours will not exceed 432 hours per vessel per year. Under Alternative 2/Preferred Alternative, the maximum number of LFA sonar transmission hours will not exceed 255 hours per vessel per year. Under both action alternatives, transmissions will be consistent with the operating profile described in Chapter 2.

4.1.2.1 Potential Impacts

When deployed and transmitting, transmissions from SURTASS LFA sonar will temporarily add to the ambient noise level in the frequency band (100 to 500 Hz) in which LFA operates, but the impact on the overall noise levels in the ocean will be minimal. In most of the ocean, the 10 to 500 Hz portion of the ambient noise spectrum is dominated by anthropogenic noise sources, particularly shipping and seismic airguns. Commercial vessels are the most common source of low-frequency noise and their impact on ambient noise is basin-wide (Hildebrand, 2009).

SURTASS LFA sonar produces a coherent low-frequency signal with a duty cycle of less than 20 percent and an average pulse length of 60 sec. The operational time for this system under Alternative 1 is a maximum of 432 hours per year for up to four vessels. This compares to approximately 22 million ship-days per year for the world's commercial shipping industry, presuming an 80 percent activity rate. The total acoustic energy output of individual sources was considered in calculating an annual noise energy budget in energy units of Joules (Hildebrand, 2005). Commercial supertankers were estimated to contribute 3.7×10^{12} Joules of acoustic energy into the marine environment each year (Joules/yr); seismic airguns were estimated to contribute 3.9×10^{13} Joules/yr; mid-frequency military sonar was estimated to contribute 2.6×10^{13} Joules/yr; and each LFA sonar vessel operating at 432 hr/yr was estimated to contribute 1.7×10^{11} Joules/yr (Hildebrand, 2005). The percentage of the total anthropogenic acoustic energy budget added by each LFA source is estimated to be 0.25 percent when these anthropogenic sources are considered (Hildebrand, 2005). Therefore, within the existing ocean environment, the potential for accumulation of noise due to the intermittent operation of SURTASS LFA sonar is considered negligible (DoN, 2012).

4.1.2.2 Comparison of Potential Impacts between Alternatives

Implementation of the Alternative 1 would not result in significant impacts to water resources. Alternative 2/Preferred Alternative would have an even smaller and less significant impact on ocean ambient noise levels than Alternative 1 due to the fact that the transmission time is less.

4.2 Biological Resources

This analysis focuses on wildlife that are important to the function of the ecosystem or are protected under federal or state law or statute and may be affected by the Proposed Action, as identified during the species screening in Chapter 3. The information below builds on the analyses previously conducted in the Navy's 2001 EIS/OEIS and 2007 and 2012 SEIS/SOEISs for SURTASS LFA Sonar (DoN, 2001, 2007, 2012), which are incorporated by reference. Potential impacts on biological resources from transmission of LFA sonar include:

- **Non-auditory impacts:** Non-auditory impacts 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. These types of impacts have the potential to cause (1) resonance of the lungs/organs, (2) tissue damage, and (3) mortality.
- **Auditory impacts:** Auditory impacts include permanent threshold shift (PTS), which is a condition that occurs when sound intensity is very high and/or of such long duration that the result is a permanent loss of hearing sensitivity over the frequency band of the exposure; i.e., a physical injury. PTS constitutes Level A incidental "harassment" for marine mammals under the MMPA as it is considered auditory tissue injury that causes irreparable damage (Southall et al., 2007). Temporary threshold shift (TTS) is a lesser impact to hearing caused by underwater sounds of sufficient loudness to cause a transient condition in which an animal's hearing sensitivity over the frequency band of exposure is impaired for a period of time (minutes to days). With TTS, hearing is not permanently or irrevocably damaged and no physical tissue

Biological Resource Potential Impacts:

- Invertebrates: high hearing threshold and low probability of being exposed to LFA transmissions make it unlikely that biologically meaningful responses will occur
- Fishes: low to moderate probability of non-auditory, auditory, behavioral, masking, or physiological stress effects when fish are in close proximity (<0.54 nmi (<1 km)) of the LFA sonar
- Sea turtles: low to moderate probability of non-auditory, auditory, behavioral, masking, or physiological stress effects when sea turtles are in close proximity (<0.54 nmi [<1 km]) of the LFA sonar
- Marine mammals: potential for auditory or behavioral effects evaluated quantitatively with the best available science; low to moderate probability of non-auditory, masking, or physiological stress assessed with best available information

damage occurs, so TTS is not considered an injury (Richardson et al., 1995; Southall et al., 2007) and constitutes Level B incidental harassment under the MMPA[1].

- **Behavioral change:** Behavioral responses to sounds in a marine animal's environment 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., 2003/04). For military readiness activities such as the employment of SURTASS LFA sonar, Level B incidental "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.
- **Masking:** The presence of intense sounds in the environment can potentially interfere with an animal's ability to hear relevant sounds. This impact, known as "auditory masking", could interfere with the animal's ability to detect biologically-relevant sounds, such as those produced by predators, prey, or reproductively active mates. During auditory masking, an animal may, thus, not be able to escape predacious attack, locate food, or find a reproductive partner.
- **Physiological stress:** Exposure to underwater sound may evoke a response in a physiological mediator (e.g., glucocorticoids, cytokines, or thyroid hormones) (Atkinson et al., 2015). The type, duration, and magnitude of the stress response may have a metabolic cost, which is termed the allostatic load. How stress responses might be linked to individual- and population-level consequences is an area much in need of research (National Research Council, 2005).

The potential for impacts is assessed from the perspective of an individual animal as well as the populations that comprise those individuals. Under the ESA, the potential for an impact to the fitness level of an individual, defined as changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success, is considered (NMFS, 2012). Similarly under the MMPA, "any act that injures or has the significant potential to injure" or "disturbs or is likely to disturb…causing disruption of natural behavioral patterns…to a point where they are abandoned or significantly altered" is considered.

4.2.1 No Action Alternative

Under the No Action Alternative, the Proposed Action would not occur and there would be no change to biological resources. Therefore, no significant impacts to biological resources would occur with implementation of the No Action Alternative.

4.2.2 Alternative 1/Alternative 2

The study area for the analysis of impacts to biological resources associated with Alternative 1 and Alternative 2/Preferred Alternative includes the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea. SURTASS LFA sonar will not operate in polar regions as depicted in Figure 1-1. Additional geographical restrictions include maintaining received levels for SURTASS LFA sonar below established levels within 12 nmi (22 km) of any land, within designated OBIA boundaries during their effective periods of biological activity, and within known recreational and commercial dive sites, as described in Chapter 2. Under Alternative 1, the maximum number of LFA sonar transmission hours will not exceed 432 hours per vessel per year. Under Alternative 2/Preferred Alternative, the maximum

1 NOAA's Office of National Marine Sanctuaries considers TTS to be an injury to sanctuary resources under the NMSA.

number of LFA sonar transmission hours will not exceed 255 hours per vessel per year. Under both action alternatives, transmissions will be consistent with the operating profile described in Chapter 2.

4.2.2.1 Potential Impacts to Marine Wildlife

4.2.2.1.1 Invertebrates

Little information is available on the potential impacts to marine invertebrates from exposure to low-frequency sound (Hawkins et al., 2015). Most studies have focused on squid or crustaceans and the impacts from exposure to impulsive airgun signals rather than sonar. Based on studies to date, hearing in invertebrates appears to be limited to detection of particle motion (Mooney et al., 2012; Mooney et al., 2010), which would require invertebrates to be within close proximity to a sound source to sense its transmissions.

Non-auditory Impacts

Limited new information on the potential for non-auditory impacts has been published since the 2012 SEIS/SOEIS (DoN, 2012), which is incorporated here by reference. In summary, André et al. (2011) found damage to statocyst hair cells in four cephalopod species (*Loligo vulgaris, Sepia officinalis, Octopus vulgaris,* and *Ilex coindetii*) after exposure to two hours of 50- to 400-Hz sweeps at 157 ± 5 dB re 1 µPa; however, it is impossible to determine if damage was due to the sound exposure or errors that occurred in the experimental design and lack of controls. A follow-on study was conducted with Mediterranean and European squid (*Illex coindetii* and *Loligo vulgaris*) that included controls (Solé et al., 2013). They found a similar result to André et al. (2011) with permanent and substantial alteration of the sensory hair cells of the statocysts. Aguilar de Soto et al. (2013) exposed New Zealand scallop larvae (*Pecten novaezeandiae*) to recorded signals from a seismic airgun survey every 3 sec for up to 70 hr. They found a delay in development and malformations of the larvae in the noise-exposed samples. However, there are no anthropogenic sources to which animals might be exposed with characteristics similar to those used in these studies. The sound exposures are far longer in duration and higher in energy than any exposure a wild animal would likely ever receive and acoustically very different than a free field sound to which animals would be exposed in the real world.

While data are still very limited, they do suggest that invertebrates sense particle motion, requiring them to be in close proximity to a sound source to sense it. The best estimation is that invertebrates would need to be within tens of yards (meters) of the source to be exposed to particle motion that may cause non-auditory impacts. Invertebrates are very unlikely to be in sufficient proximity to sense LFA sonar given its operational parameters. Therefore, the fraction of the cephalopod and decapod stocks that could possibly be found in the water column near a ship using SURTASS LFA sonar would be negligible.

Auditory Impacts

The potential for auditory impacts such as PTS and TTS has not been well studied in marine invertebrates. Without sufficient information, it is impossible to determine the potential impacts from exposure to LFA sonar. However, as stated earlier, given that invertebrates sense particle motion, they must be in close proximity to a sound source in order to sense it. Invertebrates are very unlikely to be in sufficient proximity to sense LFA sonar given its operational parameters. Therefore, the fraction of the cephalopod and decapod stocks that could possibly be found in the water column near a ship using SURTASS LFA sonar would be negligible.

Behavioral Change

There have only been a few studies of the potential for behavioral responses due to sound exposure. Information presented in the 2007 and 2012 SEIS/SOEISs is incoporated by reference, with more recent studies summarized below (DoN, 2007, 2012).

In one study, behavioral responses of invertebrates to sound were shown to scale in magnitude with the received sound level. Samson et al. (2014) played sounds of different amplitudes (100 to 165 dB re 1 μPa) and frequency (80 to 500 Hz) to common cuttlefish. The strongest reactions occurred at frequencies of 100, 150 and 200 Hz and increased with amplitude. The cuttlefish also displayed habituation to stimuli repeated closely in time (i.e., 30 minutes); the strength of the response decreased logarithmically as the number of stimuli presentations increased.

Solan et al. (2016) played back continuous (i.e., for a 7-day period) and impulsive broadband noise to manila clams, brittlestars, and decapods in small tanks on anti-vibration stands. The received sound level at the water-sediment interface was between 135 and 140 dB re 1 μPa. They found that noise exposure reduced the amount of fluid and particle handling by the clams, which affects nutrient cycling in the seafloor sediment, but had no impact on brittlestars or decapods.

Nedelec et al. (2014) exposed sea hare eggs to playback of vessel noise. They were able to demonstrate that the noise presentation reduced both the numbers of eggs that hatched as well as the number of veligers (i.e., young sea hares) that survived. Maximum spectral sound pressure levels were approximately 110 dB re 1 $\mu Pa^2/Hz$ while the maximum particle acceleration level was approximately 82 dB re $(\mu m/sec^2)^2/Hz$. The authors correctly noted that these results should be interpreted with caution, as they used closely placed underwater speakers for the noise presentation instead of real vessels that would be operating at greater distances from the eggs and veligers.

One study examined the impact of seismic airgun surveys on the fishing yield of shrimp, suggesting no behavioral response (Andriguetto-Filho et al., 2005). Squid exposed to airgun stimuli fired their ink sacs when the airgun began discharging at full power. However, when the amplitude of the airgun was started at reduced power and ramped up to full power, the squid did not fire their ink sacs (McCauley and Fewtrell, 2008). Thus the manner of presentation, or context, appears to be an important factor affecting behavioral response, even in these relatively simple organisms.

None of the transmissions from these sound sources are similar to what a marine invertebrate might experience from LFA sonar. However, given that invertebrates sense particle motion, they must be in close proximity to a sound source in order to sense it. Invertebrates are very unlikely to be in sufficient proximity to sense LFA sonar given its operational parameters and thus there is very limited potential for behavioral responses.

Masking

There are no data that indicate whether masking occurs in marine invertebrates (Hawkins et al., 2015). Without sufficient information, it is impossible to determine the potential impacts from exposure to LFA sonar. However, as stated earlier, given that invertebrates sense particle motion, they must be in close proximity to a sound source in order to sense it. Invertebrates are very unlikely to be in sufficient proximity to sense LFA sonar given its operational parameters, resulting in a very limited potential for masking to occur.

Physiological stress

There is a profound lack of understanding of the potential for stress responses to occur in marine invertebrates, much less how those responses might result in a metabolic cost (Hawkins et al., 2015). One study exposed shore crabs to ambient noise at RL of 108-111 dB rms and ship noise at RL of 148-155 dB rms for durations of approximately 7 min (Wale et al., 2013). They found that oxygen consumption was 67 percent greater in the single-exposure ship-noise playback than during the single-exposure ambient-noise playback. However, during repeated exposures, the oxygen consumption during ambient noise exposures increased, whereas there was no change in the physiological response with repeated exposures to ship noise. Oxygen consumption is correlated with metabolism, which increases with greater stress, suggesting the shore crabs were exhibiting a physiological response. It should be noted, however, that the ship-noise exposure is fairly extreme and far higher in energy than what would be experienced by a shore crab in the wild.

- **SUMMARY**

The paucity of data on responses to sound sources and the lack of any investigation using sonar signals make a definitive analysis impossible. However, the relatively high hearing threshold of larger invertebrates for which data are available (e.g., approximately 110 dB re 1µPa; Mooney et al. 2010), combined with the low probability of larger invertebrates being near the SURTASS LFA sound source, makes it unlikely that biologically meaningful responses by invertebrates will occur and there is no potential for fitness level consequences. Therefore, considering the fraction of the cephalopod and decapod stocks that could possibly be found in the water column near a ship using SURTASS LFA sonar, the potential for impacts at the population level would be negligible.

- **COMPARISON OF POTENTIAL IMPACTS BETWEEN ALTERNATIVES**

Under Alternative 2/Preferred Alternative, SURTASS LFA sonar transmissions hours would be reduced by 41 percent compared to the transmission hours under Alternative 1 (i.e., maximum of 255 hr per vessel per yr vs. maximum of 432 hr per vessel per year, respectively). Therefore, it is even more unlikely that biologically meaningful responses by invertebrates will occur under Alternative 2/Preferred Alternative than under Alternative 1.

4.2.2.1.2 Marine Fishes

The 2007 and 2012 SEIS/SOEISs included extensive discussions of research studies on fishes and their potential responses to LFA sonar; those documents are incorporated herein by reference (DoN, 2007, 2012). For the convenience of the reader, a summary of the research that examined the response of fishes to LFA sonar signals is included below; the remainder of this section will focus on research that has been published since the 2012 SEIS/SOEIS.

Popper et al. (2014) developed sound exposure guidelines for fishes in which they identified three types of fishes depending on how they might be affected by underwater sound. The categories include fishes with no swim bladder or other gas chamber (e.g., dab and other flatfish); fishes with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g., salmonids); and fishes with a swim bladder that is involved in hearing. Fishes with a swim bladder involved in hearing are most sensitive to sound since they are able to detect particle motion and pressure.

Non-auditory Impacts

With the caveat that only a few species were examined in the studies focusing on the potential impacts of SURTASS LFA sonar signals and seismic airguns, neither source, despite being very intense, had any impact on non-auditory tissues (Kane et al., 2010; Popper et al., 2007; Popper et al., 2005; Song et al., 2008). In all fishes, the swim bladder was intact after exposure and there was no damage to tissues either at the gross or cellular levels as determined by an expert fish pathologist (Kane et al., 2010; Popper et al., 2007). No new studies of non-auditory impacts to fishes have been published since the 2012 SEIS/SOEIS that are relevant to LFA sonar. Since previous studies had exposed fish up to 193 dB rms without injury, Popper et al. (2014) based their threshold of greater than 193 dB re 1 µPa rms for mortality and potential mortal injury and recoverable injury for fishes with a swim bladder both involved and not involved in hearing on these studies. For fishes with no swim bladder, Popper et al. (2014) estimated the potential for mortality and potential mortal injury and recoverable injury as being low at all distances from LF sources.

The Popper et al. (2014) thresholds were updated by NMFS as part of their Biological Opinion on the Navy's Northwest Training and Testing (NWTT) activities (NMFS, 2015). Since the above studies of LFA sonar expsoure (Kane et al., 2010; Popper et al., 2007) used signal durations of 324 sec, NMFS defined a SEL_{cum}[2] threshold of much greater than 218 dB SEL_{cum} for mortality and >218 dB SEL_{cum} for recoverable injury to adjust for signal duration.

To receive an exposure that would exceed the NMFS threshold of 218 dB SEL_{cum}, an individual fish would need to be within 1 m of an LFA projector element (SL of 215 dB re 1 µPa at 1 m) for more than 2 sec or within a general proximity to the sonar array (<0.54 nmi [<1 km]) of the LFA sonar, since the RL is 180 dB rms at 0.54 nmi (1 km), for a longer period of time while it was transmitting. The probability of this occurring is extremely unlikely; thus, the potential for non-auditory injury to an individual fish is a discountable impact.

Since the potential for non-auditory injury to an individual fish is discountable in that it is extremely unlikely to occur, the potential for more than a minimal portion of any fish stock to experience such exposures is negligible; thus, the potential for non-auditory injury to fish stocks is a discountable impact.

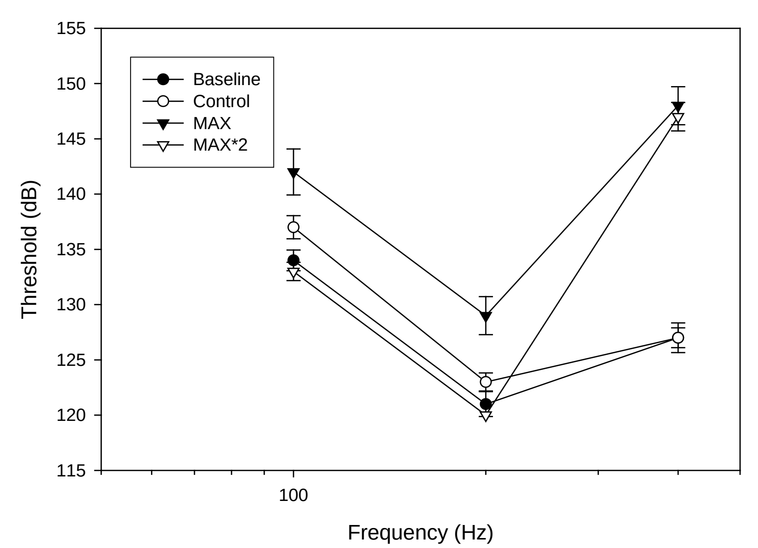
Auditory Impacts

A number of studies have examined the impacts of high intensity sound on the sensory hair cells of the ear, but the most relevant to this discussion are those conducted with LFA sonar signals. A study on the impacts of SURTASS LFA sonar sounds on three species of fishes (rainbow trout, a fish with a swim bladder not involved in hearing and a reference species for ESA-listed salmonids; channel catfish, a fish with a swim bladder involved in hearing; and hybrid sunfish, a fish without a swim bladder) examined long-term impacts on sensory hair cells of the ear. In all species, even up to 96 hours post-exposure, there were no indications of any damage to sensory cells (Halvorsen et al., 2013; Popper et al., 2007).

The overall findings of the Popper et al. (2007) study show the following with respect to impacts on fish hearing:

1. Catfish and some (but not all) specimens of rainbow trout showed 10 to 20 dB SPL of hearing loss immediately after exposure to the LFA sound when compared to baseline and control animals (Figure 4-1), but hearing appeared to return to, or close to, normal within about 24

2 SEL_{cum} = cumulative sound energy level



These data are for rainbow trout and compare hearing for baseline and control animals, and animals that received MAX and MAX*2 signals. Data represent means and standard errors of the means. Note that maximum hearing loss occurred at 400 Hz where there was over a 20 dB SPL TTS. It is not clear why there was more hearing loss after MAX stimulation than MAX*2 but this could be related to signals being closer together in the former. (Note: the "thresholds" shown are not calibrated and so do not reflect the lowest sounds that fishes necessarily hear at these frequencies.)

Figure 4-1. Examples of Hearing Data Obtained in the SURTASS LFA Sonar Studies.

hours for catfish. Recovery data on rainbow trout that had a hearing loss was insufficient to reach firm conclusions on the time for recovery, but preliminary data suggest that recovery is likely to occur in less than 96 hours. Moreover, there is evidence that hearing loss in the trout, when it occurs at all, is primarily at 400 Hz, whereas it is over the complete range of frequencies (200 to 1,000 Hz) tested for catfish.

2. There is an interesting and potentially very important variation in the impacts of exposure on trout. Some groups of trout showed hearing loss, whereas others did not. All animals received identical treatment, and the only variable between experimental times was likely to be how the fish were raised prior to being obtained for the study. The significance here is not only were there differences in the impacts of sound on different species, but there may also be differences within a species, depending on environmental and other variables. However, and most importantly, under no circumstances did exposure to LFA sound result in unrecoverable hearing loss in rainbow trout, and there was no impact on any other organ systems. While there is no direct evidence to support the differences in impact on different groups of rainbow trout, another study has shown that fish from the identical genetic stock (i.e., probably same parents) will have different hearing thresholds, possibly depending on how the eggs were stored prior to being allowed to develop (Wysocki et al., 2007). This provides an additional variable in trying to understand the impacts of sound on fishes, but also indicates that the hearing of salmonids is not consistently affected by exposure to intense sounds.

No new studies of auditory impacts to fishes have been published since the 2012 SEIS/SOEIS that are relevant to LFA sonar. Given the results of the above studies, Popper et al. (2014) defined a threshold of greater than 193 dB rms for TTS for fishes with no swim bladder and fishes with a swim bladder not involved in hearing, and a threshold of 193 dB rms for TTS for fishes with a swim bladder involved in hearing.

The Popper et al. (2014) thresholds were updated by NMFS as part of their Biological Opinion on the Navy's Northwest Training and Testing (NWTT) activities (NMFS, 2015). Because these studies used signal durations of 324 sec, NMFS defined a SEL_{cum} threshold of >218 dB SEL_{cum} for fishes with no swim bladder and 210 dB SEL_{cum} for fishes with a swim bladder both involved and not involved in hearing.

To receive an exposure that would exceed the NMFS thresholds of 218 dB SEL_{cum} or 210 dB SEL_{cum}, an individual fish would need to be within 1 m of an LFA projector (SL of 215 dB re 1 µPa at 1 m) for more than 2 sec or within a general proximity of the array(<0.54 nmi [<1 km]) of the LFA sonar, since the RL is 180 dB rms at 0.54 nmi (1 km), for a longer period of time while it was transmitting. The probability of this occurring is extremely unlikely. Therefore, the potential for auditory injury to an individual fish is a discountable impact.

In fish, permanent hearing loss or PTS has not been documented (NMFS, 2015). Permanent hearing loss may be caused by the death of sensory hair cells in the ear, damage to auditory nerves, or damage to other tissues, such as the swim bladder, that may be part of the auditory pathway (Popper et al., 2014). Unless sensory hair cells die, fishes sensory hair cells can regenerate, unlike in marine mammals where hair cell loss is permanent (Smith et al., 2006).

Since the potential for TTS or auditory injury to an individual fish is discountable in that it is extremely unlikely to occur, the potential for more than a minimal portion of any fish stock to experience such exposures is negligible. Therefore, the potential for auditory injury to fish stocks is a discountable impact.

Behavioral Change

A number of studies have examined the impacts of high intensity sound on behavioral change, but the most relevant to this discussion are those conducted with LFA sonar signals, which were outlined above. The overall findings of the Popper et al. (2007) study show the following with respect to behavioral responses of fishes:

- Fish behavior[3] after sound exposure was no different from behavior prior to or after tests. At the onset of the sound presentation, the trout would tend to move to the bottom of the experimental tank, but this did not last for the duration of the sound. Immediately after the sound was turned off the fish would mill around the tank in the same pattern as they did prior to sound presentation. Catfish showed an immediate quick “startle”[4] response and slight motion of the body, but then the fish tended to line up facing the signal source and generally stayed in that position for the duration of the sound. Once the sound was turned off, the catfish would return to normal “milling” around the tank in a pattern that was statistically no different from pre-sound patterns.

In studies conducted since the 2012 SEIS/SOEIS, the behavioral response of herring, a species with a swim bladder involved in hearing, to sonar signals from 1.0 to 1.6 kHz, as well as an outboard motor, was studied in a floating pen in open water in a fjord (Doksaeter et al., 2012). Similar to the LFA studies, this study found no behavioral response to the sonar signal, even at received sound levels of up to 168 dB re 1 µPa. Interestingly, the fish did show a pronounced diving response to much lower received

3 Note that behavior in the tank has no relevance to how fish would behave if they were not confined to the tank. Behavior monitoring was done only to provide insight into the health of the fish during the experiments and to compare in-cage responses before, during, and after sound exposure.

4 The word “startle” is used with caution. The behavior of the fish was, indeed, one that indicated detection of something unknown—a rapid movement over a short distance. However, the word “startle” has taken on a very specific meaning for some fish biologists and includes a twist of the body (c-start) at the onset of a stimulus and then rapid movement away from the stimulus. In these experiments, the video recording was not fast enough to determine if an actual c-start occurred.

sound levels from an outboard motor. One confounding factor was that the outboard motor was much closer than the naval frigate that transmitted the sonar signal.

Neo et al. (2016) played back low-frequency broadband signals to European seabass held in a floating pen. The temporal characteristics of the sound exposures ranged from continuous to regularly spaced impulses, irregularly spaced impulses, and regularly spaced impulses with increasing amplitude (i.e., 'ramp-up'). The received levels for the continuous signal was 163 to 169 dB re 1 µPa. The SEL levels for the impulsive signals were 156 to 157 dB re 1µPa^2-sec. Fish swam away from the speaker and dove following presentation of sound. The regularly spaced impulsive signal appeared to cause the strongest responses. Fish dove in response to the 'ramp-up', but did not swim away from the source, leading the authors to question the effectiveness of the ramp-up procedure.

Noise has been shown to affect the foraging success of fishes, though these studies were conducted in a constrained environment. Three-spined sticklebacks and European minnows were held in 2.6-gallon (gal) (10-liter [L]) aquaria and presented with recordings of large vessel noise with peak spectral noise levels of 130 dB re 1 μPa^2/Hz (Voellmy et al., 2014). The minnows showed a decrease in foraging behavior. Sticklebacks maintained normal foraging behavior, but their success rate decreased.

One caveat to developing an understanding of impacts of sounds on behavior is that such studies are only useful when fish are unconstrained. That is, if fish are in any kind of cage or tank, no matter what the size, it is possible that the physical barriers will result in behaviors that would not normally be encountered in the wild in response to exposure to the same type of signal. Studies that examined impacts on behavior involving confined animals must be considered with the caveat that the observed response may not be indicative of how fish would respond in the wild.

All of the impacts described here are measurable responses. However none of these responses rise to the level considered by Popper et al. (2014) for defining response thresholds, which was defined as "substantial change in behavior…may include long-term changes in behavior and distribution, such as moving from preferred sites for feeding and reproduction, or alteration of migration patterns. This behavioral criterion does not include impacts on single animals, or where animals become habituated to the stimulus, or small changes in behavior such as a startle response or small movements."

Therefore, the thresholds defined by Popper et al. (2014) are the best available for considering the potential for behavioral response. For fishes with no swim bladder and fishes with a swim bladder not involved in hearing, there is a low probability of behavioral response occurring at any distance from low frequency sources. For fishes with a swim bladder involved in hearing, a threshold of >197 dB SPLrms was defined.

To be exposed to a RL of >197 dB SPL_{rms}, an individual fish would need to be within close proximity (<0.54 nmi (<1 km)) of the LFA sonar while it was transmitting. There is the potential for minor, temporary changes in behavior, including increased swimming rate, avoidance of the sound source, or changes in orientation to the sound source, none of which are significant. Therefore, the potential for biologically significant behavioral responses of an individual fish to LFA sonar is insignificant.

Since the potential for behavioral responses by an individual fish is discountable, and fishes must be in close proximity to the LFA sonar while it was transmitting for such a response to occur, it is unlikely that more than a minimal to negligible portion of any fish stock would experience behavioral responses. Therefore, the potential for behavioral responses by fish stocks is an insignificant impact.

Masking

There are no data on masking of fishes by sonar. If masking were to occur, it would only be during LFA sonar transmissions (nominal 60-sec duration wavetrain every 10 min) and within the narrow bandwidth of the signal (duration of each continuous-frequency sound transmission within the wavetrain is no longer than 10 sec in the frequency range of 100 to 500 Hz). Given the hearing abilities of fishes and the operational profile of LFA sonar, there is a very limited potential for LFA sonar to mask fish signals.. This conclusion is supported by Popper et al. (2014) in which they subjectively assess the relative risk of masking occurring as a low probability at any distance for fishes with no swim bladder and fishes with a swim bladder not involved in hearing. For fishes with swim bladder involved in hearing, Popper et al. (2014) subjectively assess the relative risk of masking occurring as a low probability at intermediate and far distances (hundreds to thousands of meters) and a moderate probability at near distances (tens of meters).

There is the potential for temporary masking to occur within the frequency range of 100 to 500 Hz during LFA transmissions (nominal duration of 60 sec), but with a maximum duty cycle of 20 percent, any masking would be minimal. Therefore, the potential for masking to an individual fish by LFA sonar is insignificant.

Since the potential for masking to an individual fish is insignificant, and fishes would only be masked in the frequency range of transmissions while the LFA sonar was transmitting, it is unlikely that more than a minimal to negligible portion of any fish stock would experience masking. Therefore, the potential for masking to fish stocks is an insignificant impact.

Physiological stress

Very few studies have examined the potential for physiological stress in fishes. Smith et al. (2004) found that increased ambient noise (160 to 170 dB rms) caused a transient stress response in goldfish that was not sustained over long-term exposures. Wysocki et al. (2006) also found that three species of fishes (the common carp and the gudgeon, hearing specialists, and the European perch, a hearing generalist) increased cortisol secretion when exposed to ship noise. Nichols et al. (2015) examined the impact of outboard motor noise on stress levels in juvenile giant kelpfish, a coastal marine species. Continuous or intermittent outboard motor noise, separated by recordings of natural ambient noise, was played back in small (18 gal [67 L]) tanks. Intermittent noise created statistically significantly higher levels of cortisol than continuous noise or ambient noise only recordings. Random intermittent noise signals produce more stress than regular intermittent signals. Furthermore, the cortisol level scaled linearly with increases in sound levels in the tanks, the first time a magnitude response has been studied.

Similar to other potential impacts on fishes, the probability of a stress response is low and would require fishes to be within general proximity (<0.54 nmi [<1 km]) of the LFA sonar, which is unlikely since the sonar array and vessel are moving through the ocean. Therefore, the potential for a stress response by an individual fish by LFA sonar is insignificant.

Since the potential for a stress response by an individual fish is discountable, and fishes could only exhibit a stress response while the LFA sonar was transmitting, it is unlikely that more than a minimal to negligible portion of any fish stock would exhibit a stress response. Therefore, the potential for stress responses by fish stocks is an insignificant impact.

➢ **SUMMARY**

Given the studies of sound exposure to fishes, the potential for impacts is restricted to within close proximity of LFA sonar while it is transmitting. A summary of the thresholds defined by Popper et al. (2014), and modified by NMFS (2015) to account for the signal duration of exposure, shows that the probability of an impact is low to moderate and would require fishes to be within close proximity (<0.54 nmi [<1 km]) of the LFA sonar (Table 4-1). There is a minimal to negligible potential for an individual fish to experience non-auditory impacts, auditory impacts, or a stress response. There is a low potential for minor, temporary behavioral responses by or masking to an individual fish to occur when LFA sonar is transmitting and there is no potential for fitness level consequences. Since a minimal to negligible portion of any fish stock would be in sufficient proximity during LFA sonar transmissions to experience such impacts, there is minimal potential for LFA sonar to affect fish stocks.

Table 4-1. Summary of Fish Exposure Thresholds for Low Frequency Sonar (NMFS, 2015; Popper et al., 2014).

Type of Animal	*Mortality and Potential Injury*	*Recoverable Injury*	*TTS*	*Masking*	*Behavior*
Fish: No swim bladder	>218 dB SEL_{cum}	>218 dB SEL_{cum}	>218 dB SEL_{cum}	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
Fish: Swim bladder not involved in hearing	>218 dB SEL_{cum}	>218 dB SEL_{cum}	210 dB SEL_{cum}	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
Fish: Swim bladder involved in hearing	>218 dB SEL_{cum}	>218 dB SEL_{cum}	210 dB SEL_{cum}	(N) Moderate (I) Low (F) Low	>197 dB SPL_{rms}

(N) = near (i.e. 10s of meters from the source); (I) = intermediate (i.e. 100s of meters from the source); (F) = far (1000s of meters from the source)

➢ **COMPARISON OF POTENTIAL IMPACTS BETWEEN ALTERNATIVES**

Under Alternative 2/Preferred Alternative, SURTASS LFA sonar transmissions hours would be reduced by 41 percent compared to the transmission hours under Alternative 1 (i.e., maximum of 255 hr per vessel per yr vs. maximum of 432 hr per vessel per year, respectively). Therefore, it is even more unlikely that impacts to marine fishes will occur under Alternative 2/Preferred Alternative than under Alternative 1.

4.2.2.1.3 Sea Turtles

The information below builds on the analyses previously conducted in the Navy's 2007 and 2012 SEIS/SOEISs for SURTASS LFA Sonar (DoN, 2007, 2012), which are incorporated by reference. Although it is known that sea turtles can hear LF sound (Lavender et al., 2014; Martin et al., 2012), there is limited information on their behavioral and physiological responses to LF sound underwater. Very few studies exist on the potential impacts of underwater sound on sea turtles and most of the available research examined the impacts of sounds of much longer duration or of different types (e.g., seismic airgun) than LFA sonar signals. Additionally, very little is known about sea turtle hearing and what, if anything, may cause a sea turtle to incur permanent or even temporary loss of hearing (Popper et al., 2014).

This lack of information on hearing sensitivity is confounded by a lack of information on sea turtle use of the open ocean. The best available sea turtle population estimates (abundances) are underestimates in that they only consist of counts of nesting femalesThe distribution of sea turtles in nearshore and coastal waters, with nearshore foraging hotspots having been identified for the loggerhead turtles (Seminoff, 2014) and nearshore breeding aggregations numbering in the thousands for some species (i.e., olive ridley), is very different than their open ocean distribution. Nearly all species of sea turtles occur in low numbers over most of their ranges, resulting in distributions in the open ocean that are greatly and widely dispersed. Coupled with low numbers dispersed over enormous areas is the additional complexity of some sea turtle species, such as the leatherback and olive ridley turtles, spending their entire lives dispersed widely in pelagic waters, while the early lifestages of other sea turtle species spend the “lost years” drifting around the central ocean gyres. In addition, most sea turtle species spend a high percentage of their lives in the upper 328 ft (100 m) of the water column, particularly if they are transiting between foraging and nesting grounds in the open ocean. The potential for sea turtles to be exposed to LFA sonar must be considered within this context.

Non-auditory Impacts

No data are available on the potential for LF sound to cause non-auditory injury in sea turtles. Direct injury to sea turtles is unlikely because of relatively lower peak pressures and slower rise times than impulsive sound sources such as seismic airguns. Popper et al. (2014) estimated the probability for mortality and potential mortal injury to be low at all distances from LF sonar.

Auditory Impacts

No studies have been conducted on hearing loss in any turtles (Popper et al., 2014). Furthermore, there have been no studies to determine if the hair cells of the basilar papilla are lost, damaged, or fatigued during exposure to intense sounds. However, given that sea turtles hear best underwater at 100-400 Hz (Lavender et al., 2014; Martin et al., 2012), there is the potential for diving sea turtles to experience auditory impacts from exposure to LFA sonar. Popper et al. (2014) estimated the probability for TTS to be moderate at near and intermediate distances (tens to hundreds of meters) and low at far distances (thousands of meters).

Behavioral Change

Behavioral responses to anthropogenic activity have not been extensively investigated. The majority of available research is on the response of sea turtles to underwater seismic noise. Studies of captive turtles exposed to sound from individual seismic airguns suggest that they may show startle or avoidance responses to airguns (Bartol and Musick, 2003; McCauley et al., 2000; O'Hara and Wilcox, 1990). The work by O’Hara and Wilcox (1990), McCauley et al. (2000), and DeRuiter and Doukara (2012) reported behavioral changes of sea turtles in response to exposure to seismic airgun transmissions. O’Hara and Wilcox (1990) reported avoidance behaviors by loggerheads in response to airguns with sound levels (RL) of 175 to 176 dB re 1 µPa (peak-to-peak). McCauley et al. (2000) reported noticeable increases in swimming behavior for both green and loggerhead turtles at RLs of 166 dB re 1 µPa (peak-to-peak). At 175 dB re 1 µPa (peak-to-peak) RL, both green and loggerhead sea turtles displayed increasingly erratic behavior (McCauley et al., 2000). DeRuiter and Doukara (2012) reported that basking loggerhead turtles interrupted basking behavior and dove in response to the sound from seismic airguns; 49 (or 57 percent) of 86 observed turtles dove at or before their closest range to the airguns and at least six loggerheads dove immediately following an airgun shot, often showing a startle response. However, seismic airguns transmit impulsive signals characterized by a large frequency bandwidth, high energy, and short duration signals. Therefore, airgun signals cannot be directly compared with SURTASS LFA sonar, since the signal characteristics are very different, and the likelihood of impacts on living tissue are dissimilar as well. Popper et al. (2014) estimated the probability for behavioral impacts to be low at all distances from LF sonar.

Masking

Little is known about how sea turtles use sound underwater. It is likely they can sense underwater objects through auditory and visual cues, but they are not known to produce sounds underwater for communication. Masking impacts may occur for sea turtle species since their frequencies of greatest hearing sensitivity overlap the frequencies at which LFA sonar transmits, but masking would only occur during sonar transmissions, which is unlikely to result in ecological consequences for sea turtles. Popper et al. (2014) estimated the probability for masking to be low at all distances from LF sonar.

Physiological Stress

Physiological stress responses have been observed in sea turtles during capture and handling (Gregory et al., 1996; Gregory and Schmid, 2001), but no acoustic exposure studies have been conducted to determine the potential for a stress response from underwater sound. Without sufficient information, it is impossible to determine the potential for physiological stress from exposure to LFA sonar. However, as stated earlier, given the hearing sensitivities of sea turtles and the operational profile of LFA sonar, sea turtles are very unlikely to be in proximity to LFA sonar while it is transmitting, resulting in a very limited potential for a stress response to occur.

- **SUMMARY**

The paucity of data on underwater hearing sensitivities of sea turtles, whether sea turtles use underwater sound, or the responses of sea turtles to sound exposures make a quantitative analysis of the potential impacts from LFA sonar transmissions impossible (NMFS, 2012), but available information suggests that there is a low to moderate potential for impacts to occur (Table 4-2). In addition, given the lack of data on the distribution and abundance of sea turtles in the open ocean, it is not feasible to estimate the percentage of a stock that could be located in a LFA sonar mission area. Given that the majority of sea turtles encountered in the oceanic areas in which LFA sonar is proposed to operate would in high likelihood be transiting and not lingering, the possibility of significant behavior changes, especially from displacement, are unlikely and there is no potential for fitness level consequences. The geographical restrictions imposed on LFA sonar operations would greatly limit the potential for exposure to occur in areas such as nesting sites where sea turtles would be aggregated, especially in large numbers. While it is possible that a turtle could hear the transmissions if it were in close proximity to LFA sonar, when this is combined with the low probability of sea turtles being near the LFA sound source while it is transmitting, the potential for impacts from exposure to LFA sonar is considered negligible.

- **COMPARISON OF POTENTIAL IMPACTS BETWEEN ALTERNATIVES**

Under Alternative 2/Preferred Alternative, SURTASS LFA sonar transmissions hours would be reduced by 41 percent compared to the transmission hours under Alternative 1 (i.e., maximum of 255 hr per vessel

Table 4-2. Sea Turtle Exposure Thresholds for Low Frequency Sonar (NMFS, 2015; Popper et al., 2014).

Type of Animal	*Mortality and Potential Injury*	*Recoverable Injury*	*TTS*	*Masking*	*Behavior*
Sea turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low

(N) = near (i.e. tens of meters from the source); (I) = intermediate (i.e. 100s of meters from the source); (F) = far (thousands of meters form the source)

per yr versus maximum of 432 hr per vessel per year, respectively). Therefore, it is even more unlikely that impacts to sea turtles will occur under Alternative 2/Preferred Alternative than under Alternative 1.

4.2.2.1.4 Marine Mammals

Marine mammals exposed to natural or man-made sound may experience non-auditory and auditory impacts, ranging the spectrum of severity (Southall et al., 2007). When exposed to LFA sonar, marine mammals may experience auditory impacts (i.e., PTS and TTS), behavioral change, acoustic masking, or physiological stress (Atkinson et al., 2015; Clark et al., 2009; Nowacek et al., 2007; Southall et al., 2007). Underwater sound has also been implicated in strandings of marine mammals, considered a non-auditory impact. Details and information on these types of impacts and the associated conclusions provided in previous documentation for SURTASS LFA sonar (DoN, 2007, 2012) are incorporated by reference herein except as addressed below in summaries of recent research and information that may pertain to impacts associated with LF sources or may be pertinent to the assessment of impacts associated with SURTASS LFA sonar. A quantitative analysis of the potential impacts on marine mammals from LFA sonar can be found in Chapter 4.2.3.

Non-auditory Impacts

Nowacek et al. (2007) and Southall et al. (2007) reviewed potential types of non-auditory injury to marine mammals from active sonar transmissions. These types of injuries 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. The detailed descriptions and information on these types of non-auditory impacts provided in previous documentation for SURTASS LFA sonar (DoN, 2007, 2012) and related conclusions are incorporated by reference herein.

The consequences of direct acoustic impacts, such as ear bulla fractures, were elucidated in a recent study of museum specimens (Yamato et al., 2016). A review of 2,127 skulls found eleven examples of well-healed fractures, suggesting that marine mammals are capable of surviving traumatic injury to the ear. The study was not able to determine the cause of the ear bulla fractures, although disease and external pressure waves were considered.

Additional research on gas bubble occurrence and composition attempted to shed light on the potential for gas bubble formation due to sound exposure. Dennison et al. (2012) examined 22 live stranded dolphins for the presence of gas bubbles using ultrasound. Bubbles were identified in the kidneys of 21 of the 22 dolphins and in hepatic portal blood vessels of two of the 22 animals. Nine of the dolphins died, and the presence of the bubbles in their tissues was confirmed with necroscopy and computer tomography. Thirteen of the 22 dolphins were released; of those thirteen, only two restranded, suggesting that minor bubble formation is tolerable and does not necessarily lead to decompression sickness.

Bernaldo de Quirós et al. (2012) examined the amount of bubbles and the time since death to compare measurements made on deep divers and non-deep divers during 88 necropsies. Not surprisingly, the number of bubbles increased with time since death. When considering only recently dead animals, the amount of bubbles was greater in deep divers than in non-deep diving species. Bernaldo de Quirós et al. (2013) suggest that the composition of gases found in the bubbles can be used to discriminate whether the bubbles formed from decomposition or decompression. Examining by-caught animals that were held at depth in nets and then quickly raised to the surface, they found that the by-caught animals had a greater number of bubbles, consistent with decompression of supersaturated tissues. They were also able to examine the increase of putrefaction gases in different tissues, finding that bubbles in the coronary veins were the slowest to show impacts of decomposition.

The above scientific studies do not provide new data to contradict any of the assumptions or conclusions in previous LFA documentation (DoN, 2007, 2012), especially the conclusion that SURTASS LFA sonar transmissions are not expected to cause gas bubble formation or strandings, particularly those of beaked whales.

Auditory Impacts

The most well-understood potential impact from exposure to high-intensity sound is auditory impacts, specifically TTS; no studies have provided direct data on PTS. Several studies by a number of investigators have been conducted, focusing on the relationships among the amount of TTS and the level, duration, and frequency of the stimulus (Finneran, 2015; NOAA, 2016a). None of these studies have resulted in direct data on the potential for PTS, empirical measurements of hearing, or the impacts of noise on hearing for mysticetes, which are believed to be most sensitive to LFA sonar. The best available data are used for the analysis of potential auditory impacts and, when necessary, conservative assumptions are implemented that aim to provide the greatest protection to marine animals. The detailed descriptions and information on auditory impacts provided in previous documentation for SURTASS LFA sonar (DoN, 2007, 2012) are incorporated by reference herein. Summaries of additional recent research and analysis methods on auditory impacts are described below.

The potential for PTS and TTS was evaluated as MMPA Level A harassment for all marine mammals at RLs greater than or equal to 180 dB rms in preceding SURTASS LFA sonar EISs (DoN, 2007, 2012), even though NMFS stated that TTS is not a physical injury in MMPA rulemaking for SURTASS LFA sonar (NOAA, 2002, 2007, 2012). However, the Navy considered TTS as part of MMPA Level A harassment since such limited data existed on how LF hearing specialists are affected by LFA sonar. Since the 2012 SEIS/SOEIS was released, NOAA published acoustic guidance that incorporates new data and summarizes the best available information. The guidance is described below, but it defines functional hearing groups, develops auditory weighting functions, and identifies acoustic threshold levels at which PTS and TTS occur (NOAA, 2016a). The Navy used this methodology for estimating the potential for PTS and TTS for SURTASS LFA sonar. The revised methodology is described as follows.

NOAA (2016a) has finalized their guidance for assessing the impacts of anthropogenic sound on marine mammals under their regulatory jurisdiction, which includes whales, dolphins, seals, and sea lions. NOAA's guidance specifically identifies the received levels, or acoustic threshold levels, above which individual marine mammals are predicted to experience changes in their hearing sensitivity (PTS or TTS) for acute, incidental exposure to underwater sound.

Recognizing that marine mammal species do not have equal hearing capabilities, five functional hearing groups of marine mammals were defined:

- Low-frequency (LF) Cetaceans—this group consists of the mysticetes with a collective generalized hearing range of 7 Hz to 35 kHz.
- Mid-frequency (MF) Cetaceans—includes most of the dolphins, all toothed whales except for *Kogia* spp., and all the beaked and bottlenose whales with a generalized hearing range of approximately 150 Hz to 160 kHz.
- High-frequency (HF) Cetaceans—incorporates all the true porpoises, the river dolphins, plus *Kogia* spp., *Cephalorhynchid* spp. (genus in the dolphin family Delphinidae), and two species of *Lagenorhynchus* (Peale's and hourglass dolphins) with a generalized hearing range estimated from 275 Hz to 160 kHz.
- Phocids Underwater (PW)—consists of true seals with a generalized underwater hearing range from 50 Hz to 86 kHz.
- Otariids Underwater (OW)—includes sea lions and fur seals with a generalized underwater hearing range from 60 Hz to 39 kHz.

Within their generalized hearing ranges, the ability to hear sounds varies with frequency, as demonstrated by examining audiograms of hearing sensitivity (Finneran, 2015; NOAA, 2016a). To reflect higher noise sensitivities at particular frequencies, auditory weighting functions were developed for each functional hearing group that reflected the best available data on hearing ability (composite audiograms), susceptibility to noise-induced hearing loss, impacts of noise on hearing, and data on equal latency (Figure 4-2). These weighting functions are applied to individual sound received levels to reflect the hearing ability of each species to process received acoustic energy.

NOAA (2016a) defined acoustic threshold levels at which PTS is predicted to occur for each functional hearing group for impulsive and non-impulsive signals. LFA sonar is a non-impulsive source in that its signals do not have the high peak pressure with rapid rise time and decay that impulsive sounds do; instead the pressure (i.e., intensity) of the LFA sonar transmission is consistent throughout the signal. The acoustic threshold levels for non-impulsive sounds are defined as the cumulative sound exposure level (SEL) over a 24-hr period with the appropriate frequency weighting for each functional hearing group (Figure 4-2; Table 4-3), which is reflected in the subscript of each threshold (e.g., the LF cetacean threshold is identified as $L_{E,LF,24h}$). The cumulative SEL metric takes into account both received level and duration of exposure over the duration of the activity within a 24-hr period. The TTS threshold is defined as 20 dB less than the PTS threshold. A summary of the cumulative sound exposure acoustic thresholds for PTS and TTS are provided (Table 4-3).

Behavioral Change

The primary potential impact on marine mammals from exposure to LFA sonar is change in a biologically significant behavior. The National Research Council (2005) 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, wherein an impact on individuals can lead to population-level consequences and affect

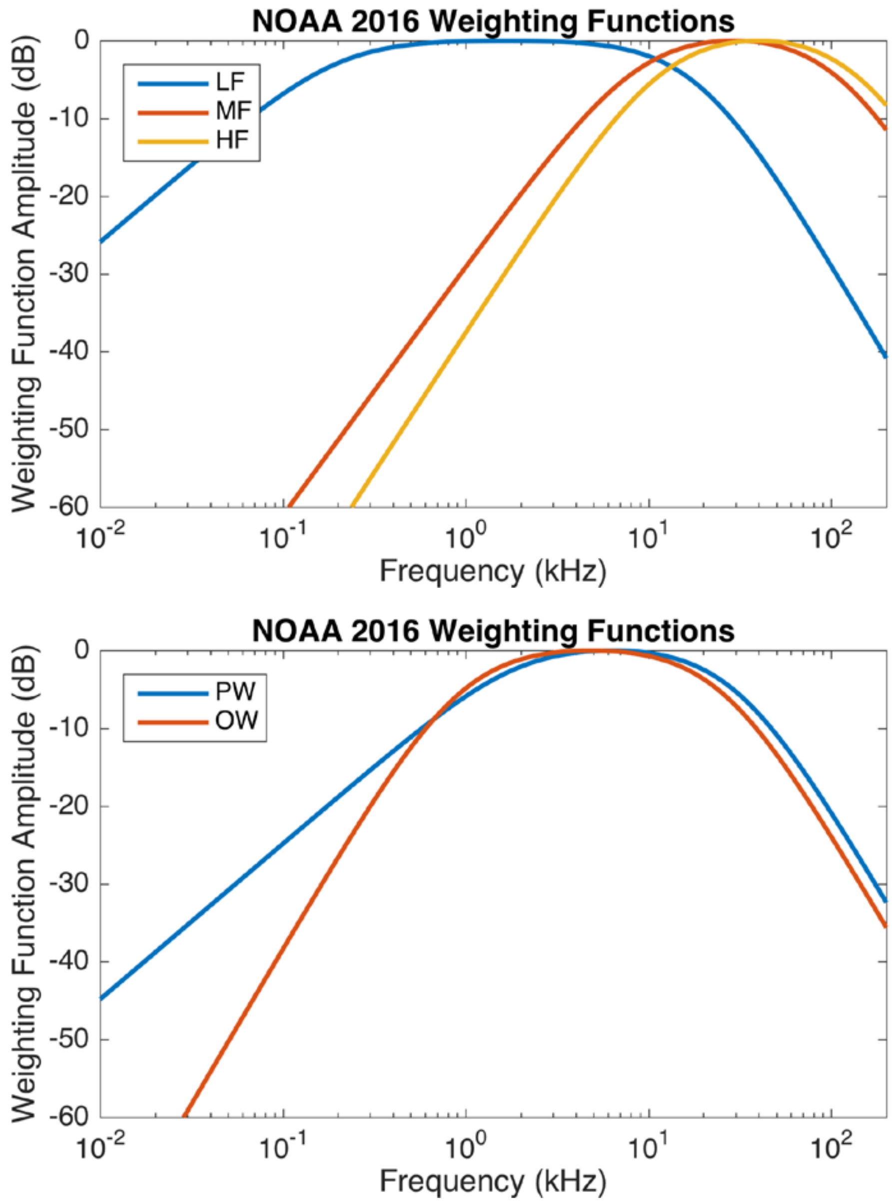


Figure 4-2. Auditory Weighting Functions for Cetaceans (Top Panel: LF, MF, and HF Species) and Pinnipeds (Bottom Panel: PW, OW) (NOAA, 2015, 2016a).

the viability of the species. The complexities associated with such an evaluation are becoming clear as researchers compile and evaluate data on extensively studied species as exemplar models of how short-term changes in behavior may accumulate to indirectly impact fitness through individual survival and reproduction (Maresh et al., 2014; New et al., 2014; Robinson et al., 2012). It is unlikely that such an analysis will be possible for the majority of marine species because of the difficulties associated with collecting the necessary information (Tougaard et al., 2015).

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

Table 4-3. PTS and TTS Acoustic Threshold Levels for Marine Mammals Exposed to Non-impulsive Sounds (NOAA, 2016a).

Hearing Group	***PTS Onset***	***TTS Onset***
Low-frequency (LF) cetaceans ($L_{E,LF,24h}$)	199 dB SEL	179 dB SEL
Mid-frequency (MF) cetaceans ($L_{E,MF,24h}$)	198 dB SEL	178 dB SEL
High-frequency (HF) cetaceans ($L_{E,HF,24h}$)	173 dB SEL	153 dB SEL
Phocid pinnipeds underwater ($L_{E,PW,24h}$)	201 dB SEL	181 dB SEL
Otariid pinnipeds underwater ($L_{E,OW,24h}$)	219 dB SEL	199 dB SEL

responses scaled relative to RL and context. These experiments still represent the most relevant predictions of the potential for behavioral changes from exposure to LFA sonar. 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 and animals returned to their normal activities within tens of minutes after initial exposure (Clark et al., 2001). Perhaps the most important result came from the LFS SRP Phase II study, where the LFA stimulus was presented to migrating gray whales. When the source was in the migratory path, the whales diverted around the source at received levels of 170-178 dB re 1µPa. However, when the source was moved offshore to the edge of the migratory corridor, with an increased SL to maintain the same received levels at the whales, the migrating gray whales exhibited no response to the LFA stimulus (Clark et al., 1999). The context of an exposure scenario is clearly important for determining the probability, magnitude, and duration of a response (Ellison et al., 2012).

The results of the LFS SRP were used to derive the LFA risk continuum function, from which the potential for biologically significant behavioral response is calculated as described in the impact analysis section below. This function has been described in detail in the Navy's 2001, 2007, and 2012 SEISs for SURTASS LFA sonar (DoN, 2001, 2007, 2012), which as previously noted are incorporated by reference. The risk continuum is based on the premise that a smooth, continuous function that maps RL to risk is most appropriate for defining the potential or risk for a biologically significant behavioral response (Figure 4-3). A summary of the risk continuum function follows; the reader is referred to Appendix B for additional details.

The parameters of the risk continuum function are based on the LFS SRP results. These experiments, which exposed baleen whales to RLs ranging from 120 to about 155 dB re 1 µPa (rms) (SPL), detected only minor, short-term behavioral responses. Short-term behavioral responses do not necessarily constitute significant changes in biologically important behaviors. The fact that none of the LFS SRP observations revealed a significant change in a biologically important behavior helped determine an upper bound for risk. However, the LFS SRP results cannot be used to prove that there is zero risk at these levels. Accordingly, the risk continuum assumes that risk is small, but not zero, at the RLs achieved during the LFS SRP. The basement value below which risk is negligible is 120 dB SPE. Fifty percent risk of a behavioral response is defined at 165 dB SPE. The steepness of the curve, termed the risk transition sharpness parameter, is defined as 10 for LFA sonar.

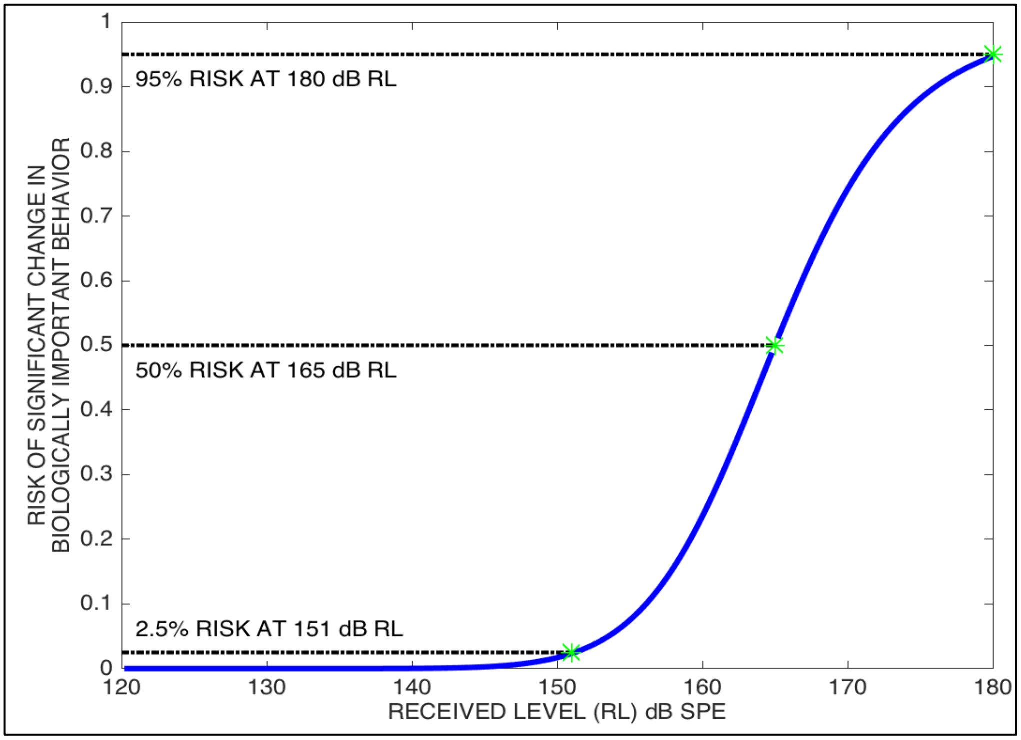


Figure 4-3. Risk Continuum Function for SURTASS LFA Sonar Analysis that Relates the Risk of Significant Change in Biologically Important Behavior to Received Levels in Decibels Single Ping Equivalent (SPE).

The risk continuum modeled a smooth increase in risk that culminates in a 95 percent level of risk of significant change in a biologically important behavior at 180 dB SPE. In this region, the risk continuum is unsupported by observations. Since the risk continuum function was derived from the behavioral response data of baleen whales collected with an actual SURTASS LFA sonar source, these data are realistic contextually and remain the best available for the response of LF-sensitive marine mammals to the SURTASS LFA sonar source.

Additional studies of behavioral responses of marine mammals to naval sonar have occurred since 2012. None have used a low-frequency (<1 kHz) source or been deployed from a slow moving vessel. Therefore their applicability to determining potential responses to LFA sonar is not clear. Nevertheless, these data represent additional information gathered since the 2012 SEIS/SOEIS for SURTASS LFA sonar and are presented herein for awareness. Southall et al. (2012) provided an overview of the Southern California Behavioral Response Study (SOCAL-BRS). This program uses advanced tagging efforts and visual and acoustic observations to investigate behavioral responses to mid-frequency sonar signals. Blue whales exposed to simulated mid-frequency sonar showed complex, though brief, avoidance responses (Goldbogen et al., 2013). Surface feeding animals typically showed no response to the sonar signal, while non-feeding and deep-feeding animals both aborted deep feeding dives and made prolonged mid-water dives. Body orientation and horizontal displacement away from the source were additional responses.

Beaked whales appear to be remarkably sensitive to noise exposure. Moretti et al. (2014) examined historical records of mid-frequency sonar operations and the vocal behavior of Blainville’s beaked whales. They were able to describe the probability of the beginning of a Group Vocal Period as a function of the received level of operational mid-frequency sonars. These data were used to create a behavioral dose-response function for Blainville's beaked whales that has a structure similar to the LFA risk continuum, but with a 50 percent probability of response at 150 dB re 1µPa and a shallower slope (steepness parameter). Cuvier's beaked whale responses to mid-frequency sonar have also been described (Deruiter et al., 2013). One whale exposed to low-level simulated sonar at close ranges (RL 89 to 127 dB) responded strongly, ceasing echolocation and fluking, extended its dive duration and swam away rapidly. However, another whale incidentally exposed to distant operational mid-frequency sonars at low levels (78-106 dB) did not show a response. This variation in responses again illustrates the importance of context in interpreting these results.

Miller et al. (2015) presented a single northern bottlenose whale with a 1 to 2 kHz sonar signal. The initial received level at the animal was 98 dB re 1 µPa, and at this level the whale approached the sound source. When the level reached 130 dB re 1µPa, the whale turned 180° away and began the longest and deepest dive ever recorded for this species (94 min and 7,674 ft (2,339 m)). This one data point suggests that this species may also show marked responses to anthropogenic noise, as do many of the beaked whales.

This same bottlenose whale response, as well as those of minke and humpback whales, were examined by an expert panel to assess the severity of these responses (Sivle et al., 2015). The minke whale began avoiding the sonar signal at a received level of 146 dB re 1µPa. Eleven humpbacks were tested, and their response levels ranged from 94 to 179 dB re 1µPa. Responses were judged using a severity score table based on that of Southall et al. (2007) and modified by (Miller et al., 2012) that included four subgroups: a) No response (score=0), b) Responses unlikely to affect vital rates (score=1 to 3), c) Responses with the potential to affect vital rates (score=4 to 6), and d) Responses likely to affect vital rates if repeated or of long duration (score=7 to 9). The avoidance by the minke whale and the long duration avoidance by the bottlenose whale both earned a severity score of 8. The scores of the humpback whale responses ranged from 1 to 7.

Antunes et al. (2014) presented 1 to 2 and 6 to 7 kHz simulated sonar signals to pilot whales as part of the 3S Experiment. One or more individuals within groups of long-finned pilot whales were instrumented with suction-cup-attached archival tags (DTAGs; (Johnson and Tyack, 2003)) along the coast of northern Norway (Miller et al., 2012). After a baseline, pre-exposure period, the whales were exposed to sonar signals. Source levels were increased as the vessel approached the tagged whales. The two-dimensional tracks of the animals were examined to determine the changepoint in their behavior. A dose-response curve was created, which had a 50 percent probability of behavioral change at 170 dB re 1 µPa or 173 dB SEL. While the value of the 50 percent probability of response is similar to that of the LFA risk function, the slope of their function is much shallower than the LFA function.

Killer whales were also presented with these 1 to 2 and 6 to 7 kHz FM sweeps (Miller et al., 2014). They appeared to respond with changes in swim speed and direction. The response thresholds range from 94 to 164 dB re 1µPa. The authors created a dose-response function with a 50 percent probability of avoidance value at 142 dB re 1µPa. They attributed the remarkable variation in response thresholds to intra-individual variability and other unidentified contextual values, such as proximity of the source.

Sperm whales were exposed to 1 to 2 kHz simulated naval sonar as well as playback of killer whales calls (Isojunno et al., 2016). The whales stopped foraging in response to the 1-2 kHz sonar signal at received levels of 131 to 165 dB re 1µPa as well as to the playback of the killer whales signals. No change in foraging was observed in response to the 6-7 kHz signals.

Harbor porpoise were exposed to 1 to 2 and 6 to 7 kHz simulated sonar signals that were composed of upsweeps and downsweeps, with and without harmonics (Kastelein et al., 2012). The 1 to 2 kHz signal with harmonics had sound energy at frequencies of 7 to 11 kHz (the harmonics) in addition to sound energy at the fundamental frequencies of 1 to 2 kHz. For 1 to 2 and 6 to 7 kHz simulated sonar signals, there was no difference in the sound level needed to cause a startle response between the upsweeps and downsweeps. However, the animals were much more sensitive to the 1 to 2 kHz signals with harmonics (50 percent response level = 99 dB re 1µPa) than without (50 percent response level = 133 dB re 1 µPa). The response level for 6 to 7 kHz signals without harmonics was 101 dB re 1 µPa. These findings highlight the importance of signal structure on behavioral response.

Henderson et al. (2014) reported on the results of visual observation of wild delphinid groups incidentally exposed to mid-frequency sonar. Twenty-six of the 46 groups (56.5 percent) encountered during MFA sonar transmissions showed some behavioral response, including changes in behavioral state or travel direction and acoustic behavior. The mean received level during responses was 122 dB re 1 µPa. However, the authors also reported that behavioral change was observed in 46 percent of the groups that were not exposed to sonar.

Houser et al. (2013b) exposed trained dolphins to mid-frequency sonar at levels from 115-185 dB re 1 µPa. They found a strong dose-response function in behavioral response to the sound. They also reported rapid habituation at RLs less than or equal to 160 dB. No habituation was observed at 175 dB and the animals refused to perform during the 185 dB condition. California sea lions exposed to the same stimuli also showed a dose-response function, although no habituation was observed (Houser et al., 2013a).

Harbor porpoise exposed to 1.33 to 1.43 kHz sonar signals with a 1.25-sec duration responded with a brief change in swimming direction or speed (Kastelein, 2013). The 50 percent response threshold ranged from RLs of 124 to 140 dB. The signal type that produced the least response (i.e., highest response threshold) was a FM downsweep without harmonics.

Masking

Erbe et al. (2016) reviewed the current state of understanding of masking in marine mammals, including anti-masking strategies for both receivers and senders. When a signal and noise are received from different directions, a receiver with directional hearing can reduce the masking impact. This is known as spatial release from masking, and this ability has been found in dolphins, killer whales and harbor seals. Given the hearing abilities of marine mammals, it is likely that most, if not all, species have this ability to some extent.

The detectability of a signal amidst noise may also affected by the temporal and spectral properties of the signal. Cunningham et al. (2014) conducted masking experiments where the signals were complex, including frequency and amplitude modulation as well as the presence of harmonics, parameters that are typical for natural animal signals. The ability of the receivers to detect complex signals was far better than predicted using simple energetic masking predictions, likely because of the complex structure of the signal.

Animals may attempt to counteract masking by increasing the source level of their vocalizations in the presence of noise, known as the Lombard impact. Killer whales and belugas have been shown to increase their source level as the level of ship noise in the environment increased (Holt et al., 2011; Scheifele et al., 2005). Migrating humpback whales off Australia increased the amplitude of their social calls by 0.9 dB for every 1.0 dB increase in wind-created ambient noise (Dunlop et al., 2014). While increasing their amplitude may be effective at improving communication, it may come with an increased metabolic cost, as was shown with bottlenose dolphins (Holt et al., 2015).

The potential for masking from LFA sonar signals is limited for a number of reasons. First, the typical LFA sonar signal is not a constant tone but consists of a sequence of sound transmissions (waveforms) that vary in frequency and duration. Continuous-frequency waveforms have durations of no longer than 10 seconds. Waveforms with varying frequencies (frequency-modulated or FM waveforms) have limited bandwidths (30 Hz). Therefore, within the frequency range in which masking is possible, the impact will be limited because animals that use this frequency range typically use signals with greater durations and bandwidths. Thus, only a portion of the frequency band for the animal's signal is likely to be masked by the LFA sonar transmissions. Furthermore, when LFA sonar is in operation, the source is active only 7.5 to 10 percent of the time, with a maximum of 20 percent duty cycle, which means that for 90 to 92.5 percent of the time, there is no potential for masking. Therefore, within the area in which energetic masking is possible, any impact 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.

Physiological Stress

Atkinson et al. (2015) reviewed the physiology of the stress response in marine mammals. As a result of the interest of the National Research Council in the population consequences of underwater noise (National Research Council, 2005), there has been broadened research into marine mammal responses to environmental stressors and linking these reponses to costs at the individual level that may have reprecussions at the population level (Maresh et al., 2014; New et al., 2014; Robinson et al., 2012). The data do not exist for such an assessment with noise exposure, but the processes being developed highlight the research gaps that need to be prioritized for those advances to be made.

Limited amount of research has been conducted on stress responses resulting from sound exposure. Belugas demonstrated no catecholamine (hormones released in situations of stress) response to the playback of oil drilling sounds (Thomas et al., 1990), but showed an increase in catecholamines following exposure to impulsive sounds produced from a seismic water gun (Romano et al., 2004). A bottlenose dolphin exposed to the same seismic water gun signals did not demonstrate a catecholamine response, but did demonstrate an elevation in aldosterone, a hormone that has been suggested as being a significant indicator of stress in odontocetes (St. Aubin and Geraci, 1989). Increases in heart rate were observed in bottlenose dolphins to which calls from other bottlenose dolphins were played, although no increase in heart rate was observed when ambient noise from aquarium tanks was played back (Miksis et al., 2001). A beluga's heart rate was observed to increase during exposure to noise, with increase dependent on frequency band of noise and duration of exposure, with a sharp decrease to normal or below-normal levels upon cessation of the exposure (Lyamin et al., 2011). It is unknown how chronic exposure to acoustic stressors may affect marine mammals. Opportunistic comparison of levels of stress-related hormone metabolites in North Atlantic right whale feces collected before and after the events of 11 September 2001 showed a decrease in metabolite levels corresponding to lower levels of ambient noise due to reduced ship traffic (Rolland et al., 2012). Collectively, these results suggest a variable response that depends on the characteristics of the received signal and prior experience with the received signal.

Atkinson et al. (2015) highlighted the need for long-term monitoring of individuals to better understand natural life-history influences on variations in stress responses and develop baselines that can be used for comparison. Since marine mammals are air-breathers that live in an underwater, oceanic environment, they have separated their need for oxygen from many biological functions for which it is directly linked in terrestrial mammals. Thus, there appear to be significant modifcations to expected physiological mediators, resulting in unexpected observations. For example, where a terrestrial animal may start breathing heavily as part of a stress response, a marine mammal may have decoupled that response to conserve oxygen for underwater survival. Much more research is needed to begin to understand the potential for physiological stress in marine mammals during noise exposure scenarios.

- **SUMMARY**

Non-auditory impacts to marine mammals from active sonar transmissions includes 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. No existing research studies or observations in the past fifteen years of LFA sonar operation provide evidence that LFA sonar has the potential to cause non-auditory impacts.

The potential for masking and physiological stress was assessed with the best available data. The potential for masking from LFA sonar signals is limited because continuous-frequency waveforms have durations of no longer than 10 seconds and frequency-modulated waveforms have limited bandwidths (30 Hz). Furthermore, when LFA sonar is in operation, the source is active only 7.5 to 10 percent of the time, with a maximum 20 percent duty cycle, which means that for 90 to 92.5 percent of the time, there is no potential for masking. Much more research is needed to begin to understand the potential for physiological stress in marine mammals during noise exposure scenarios. The existing data suggest a variable response that depends on the characteristics of the received signal and prior experience with the received signal.

The potential for auditory impacts (PTS and TTS) and behavioral change can be quantitatively assessed. NOAA (2016a) has published acoustic guidance that specifically identifies the received levels, or acoustic threshold levels, above which individual marine mammals are predicted to experience changes in their hearing sensitivity for acute, incidental exposure to underwater sound. The results of the LFS SRP were used to derive the LFA risk continuum function, from which the potential for biologically significant behavioral response is calculated. The quantitative impact analysis for marine mammals is found in Chapter 4.2.3.

4.2.2.2 Potential Impacts to Protected Habitats and OBIAs

Marine 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. As was discussed in Chapter 3, there are three types of marine and aquatic habitats protected under U.S. legislation or Presidential EO, critical habitat, EFH, MPAs, and NMSs. The potential impacts to these protected habitats are described in this section.

OBIAs are designated as part of a comprehensive suite of mitigation measures unique to SURTASS LFA sonar, possible because of its specific operating characteristics, including frequency range, bandwidth, source depth, pulse length, pulse repetition rate, and duty cycle. OBIAs are not intended to apply to other Navy activities and sonar operations, but rather as a mitigation measure to reduce incidental takings by SURTASS LFA sonar (NOAA, 2007). Furthermore, as NMFS noted in the 2012 Final Rule for SURTASS LFA sonar (NOAA, 2012), “We designate OBIAs to protect marine mammals. OBIAs are not intended to protect areas per se.” The criteria for designating OBIAs as well as the current list of potential OBIAs is included in Chapter 3. This section provides background on the process and analyses that were conducted as part of the potential impacts consideration in this SEIS/SOEIS.

4.2.2.2.1 Critical Habitat

The ESA, and its amendments, require the the Federal government to consider whether there are areas of habitat believed to be essential to the species’ conservation. Those areas may be proposed for designation as critical habitat under the ESA. Although NMFS has jurisdiction over many marine and anadromous species listed under ESA and their designated critical habitat, the U.S. Fish and Wildlife Service also has jurisdiction over some marine/anadromous speciesand shares jurisdiction with NMFS for some species, such as the Atlantic salmon, gulf sturgeon, and all sea turtles. Within the proposed operational area of SURTASS LFA sonar, critical habitat has been designated for six of the ESA-listed marine mammals, three sea turtles, nine marine or anadromous fishes, and three marine invertebrates or plant species (Table 3-7).

As the above analyses have outlined, the transmission of LF sound by SURTASS LFA sonar is the one stressor considered as part of the action alternatives that may affect critical habitat. The potential for indirect impacts to the habitat on which these biological resources depend is the focus of this analysis. In many cases, critical habitat is designated to protect foraging or reproductive areas in which animals congregrate for these biologically significant behaviors. SURTASS LFA sonar is unlikely to affect the prey on which animals may be foraging, as discussed above, under either action alternative. Water quality nor the physical processes that may affect the retention of prey in a specific critical habitat area will not be affected by the operation of SURTASS LFA sonar.

The operation of SURTASS LFA sonar will add to ambient noise levels when only when the sonar is transmitting. SURTASS LFA sonar produces a coherent LF signal with a duty cycle of less than 20 percent and an average pulse length of 60 sec. Under Alternative 1, the operational time for this system is a maximum of 432 hr per year for up to four vessels; under Alternative 2, the operational time is a maximum of 255 hr per year for up to four vessels. The percentage of the total anthropogenic acoustic energy budget added by each LFA sonar source operating for 432 hr/yr is estimated to be 0.25 percent per system (or less), when other man-made sources are considered (Hildebrand, 2005). Under Alternative 2, in which each vessel would operate a maximum of 255 hr/yr, this potential impact would be even less. Therefore, the impact on the overall noise levels in the ocean and the potential for masking will be minimal. No impact to critical habitats is anticipated.

4.2.2.2.2 Essential Fish Habitat

In recognition of the critical importance that habitat plays in all lifestages of fish and invertebrate species, the MSFCMA, as amended, protects habitat essential to the production of federally managed marine and anadromous species within the U.S. EEZ. Congress defined EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” (16 U.S.C. §1802[10]). Information on EFH occurring within the SURTASS LFA sonar operational area is provided in Chapter 3.

Adverse impacts to EFH are defined as “any impact that reduces quality and/or quantity of EFH”; adverse impacts include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH (50 CFR §600).

As discussed above, the one stressor of the Proposed Action is the transmission of LF sound. There is no potential for physical or chemical alterations of the water or substrate from sound transmissions (Chapter 4.1). In addition, there is no potential for loss of, or injury to, benthic organisms or prey species since they have little or no sensitivity to LF sound (Chapter 4.2.).

There is a potential for SURTASS LFA sonar to temporarily add to the ambient noise levels when it is transmitting, which might result in masking for fishes. As discussed in Chapter 4.2, there are no data on masking of fishes by sonar. If masking were to occur, it would only be during SURTASS LFA sonar transmissions (nominal 60-sec duration wavetrain every 10 min) and within the narrow bandwidth of the signal (duration of each continuous-frequency sound transmission within the wavetrain is no longer than 10 sec within the operating frequency range of 100-500 Hz). Given the hearing abilities of fishes and the operational profile of SURTASS LFA sonar, fishes have a very limited potential for masking to occur. This conclusion is supported by Popper et al. (2014) in which they qualitatively assess the relative risk of masking occurring as a low probability at any distance for fishes with no swim bladder and fishes with a swim bladder not involved in hearing. For fishes with swim bladder involved in hearing, Popper et al. (2014) subjectively assess the relative risk of masking occurring as a low probability at intermediate and far distances (hundreds to thousands of meters) and a moderate probability at near distances (tens of meters).

Since the potential for masking to an individual fish is insignificant, and fishes would only be masked in the frequency range of transmissions while the SURTASS LFA sonar was transmitting, it is unlikely that more than a minimal to negligible portion of any fish stock would experience masking. Therefore, the potential for masking to fish stocks is an insignificant impact under either action alternative.Therefore, there is little to no potential for impacts to EFH from either action alternative.

4.2.2.2.3 Marine Protected Areas

The term "marine protected area" 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. The variety of names and uses of MPAs has led to confusion over what the term really means and where MPAs are used. The IUCN defines a protected area as "a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values" (International Union for the Conservation of Nature [IUCN], 2012). 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." Although the objectives for establishing protection of marine areas vary widely, MPAs are typically used to achieve two broad objectives: 1) habitat protection, and 2) fisheries management and protection (McCay and Jones, 2011). The reader is referred to Chapter 3 for a review of MPAs within the region of the Proposed Action.

As discussed above, the one stressor of the Proposed Action is the transmission of LF sound. There is no potential for physical or chemical alterations of the water or substrate from sound transmissions. There is a potential for SURTASS LFA sonar to temporarily add to the ambient noise levels when it is transmitting (Chapter 4.1). Increases in ambient noise levels would only occur during SURTASS LFA sonar transmissions (nominal 60-sec duration wavetrain every 10 min) and within the narrow bandwidth of the signal (duration of each continuous-frequency sound transmission within the wavetrain is no longer than 10 sec). Therefore, there is little to no potential for impacts to MPAs under Alternative 1 and an even less potential under Alternative 2/Preferred Alternative since SURTASS LFA sonar transmission time would be reduced by 41 percent. An evaluation of MPAs occurred as part of the process for identifying candidate OBIAs, as is described in the OBIA section.

4.2.2.2.4 National Marine Sanctuaries

Sanctuary resources are divided into four categories: water, habitat, living (biota), and maritime archaeological resources. The only potential impact on water or habitat resources is the addition of LF sound in the frequency band of SURTASS LFA sonar transmissions (100 to 500 Hz) during at-sea missions when LFA sonar is actively operating. As was discussed previously in the Marine Water Resources section, the potential for accumulation of noise due to the intermittent operation of SURTASS LFA sonar is considered negligible. Therefore, implementation of either action alternative would not result in significant impacts to water or habitat resources in any sanctuary and no harm would occur to these sanctuary resources under the NMSA. Neither would the potential stressor of increased LF sound in the oceanic ambient environment result in any potential for impacts to maritime archaeological resources, and no harm would occur to these resources under the NMSA. The only potential for impacts to a sanctuary resource from exposure to SURTASS LFA sonar operations is to the living resources of each sanctuary.

Since all sanctuaries except the *Monitor* NMS have identified marine mammal, sea turtle, fish, and invertebrate species that occur, at least seasonally, in sanctuary waters, to avoid redundancy in repetition of the same conclusions for each NMS, the potential for injury under ONMS's interpretation of the NMSA to these groups of living resources will be described by taxa, which are relevant to all sanctuaries' living resources except as outlined by sanctuary.

All sanctuaries have invertebrate resources within their borders, with some sanctuaries having extremely large and diverse assemblages of invertebrates. Although a definitive analysis is not possible due to lack of data, review of the available scientific literature indicates that the studied invertebrates likely are capable of detecting particle motion, which would necessitate an invertebrate being within close proximity to an LFA sonar element to sense its transmissions. The relatively high hearing threshold of larger invertebrates for which data are available (e.g., approximately 110 dB re 1µPa; Mooney et al. 2010), combined with the low probability of larger pelagic invertebrates remaining near the SURTASS LFA sonar array makes it unlikely that biologically meaningful responses by invertebrates will occur and there is no potential for fitness level consequences. Since benthic invertebrates have no potential (except during their motile developmental stage) to be in close proximity to an LFA sonar array, the likelihood for any responses are vanishingly small with no population or fitness level consequences reasonably possible as a result of SURTASS LFA sonar operations. There is no potential for injury under the NMSA to invertebrates from exposure to SURTASS LFA sonar under either action alternative.

The potential for impacts to marine fishes exists but is predicated on a fish being in close proximity to LFA sonar while it is transmitting. A low potential for minor, temporary behavioral responses or masking to an individual fish may occur from exposure to LFA sonar transmissions but there is no resulting potential for fitness level consequences. The likelihood is minimal to negligible for an individual fish to experience non-auditory impacts, auditory impacts (TTS or PTS), or a stress response following exposure to SURTASS LFA sonar signals. The possibility of more than a minimal part of any fish stock being in sufficient proximity during LFA sonar transmissions to experience such impacts results in the minimal potential for LFA sonar to affect fish stocks. Since there is a slight potential for marine fishes to experience temporary behavioral responses following exposure to LFA sonar, there is the potential for injury to marine fishes under ONMS's interpretation of the NMSA. The potential would be less under Alternative 2/Preferred Alternative since SURTASS LFA sonar transmission time would be reduced by 41 percent compared to Alternative 1.

The geographical limitations imposed on LFA sonar operations would greatly limit the potential for exposure of sea turtles in areas such as nesting sites where sea turtles would be aggregated, especially in large numbers. The possibility of significant behavior changes, especially from displacement, are unlikely and there is no potential for fitness level consequences. A sea turtle could hear LFA sonar transmissions if in close proximity to an LFA sonar element, albeit very unlikely. These factors result in the low to moderate potential for sea turtle impacts from exposure to SURTASS LFA sonar. Since behavioral impacts may be possible to sea turtle, there is the potential for injury to sea turtles under ONMS's interpretation of the NMSA. The potential would be less under Alternative 2/Preferred Alternative since SURTASS LFA sonar transmission time would be reduced by 41 percent compared to Alternative 1.

Marine mammals exposed to SURTASS LFA sonar may experience auditory impacts (i.e., PTS and TTS), behavioral change, acoustic masking, or physiological stress, but there is no evidence to suggest that LFA sonar has the potential to cause non-auditory impacts. Due to the operational characteristics of LFA sonar transmissions, a limited potential exists for masking. Existing data on physiological stress in marine mammals suggest a variable response that depends on the characteristics of the received signal and prior experience with the received signal. The potential for auditory impacts (PTS and TTS) and behavioral change associated with exposure of marine mammals to SURTASS LFA sonar has been quantitatively assessed. With the application of the full suite of mitigation measures that are employed whenever SURTASS LFA sonar is transmitting, there is no expectation of PTS (MMPA Level A harassment) to any marine mammals or stocks. The analysis results (Table 4-7) show that the potential for TTS occurring is very low while the most likely response, if any, following exposure to SURTASS LFA sonar transmissions is behavioral responses, which vary in magnitude by species. The potential for injury to marine mammals is possible under ONMS's interpretation of the NMSA as marine mammals may experience transient TTS and behavioral impacts, but these would not be adverse effects. The potential would be less under Alternative 2/Preferred Alternative since SURTASS LFA sonar transmission time would be reduced by 41 percent compared to Alternative 1.

Olympic Coast National Marine Sanctuary

Part of the Olympic Coast NMS is located less than 12 nmi from shore in the coastal standoff range for SURTASS LFA sonar and the portion of the sanctuary outside of 12 nmi has been designated as an OBIA (OBIA 21) for SURTASS LFA sonar. The effective period for sanctuary component of OBIA 21 is December through January, March, and May. SURTASS LFA sonar cannot be transmitted at RLs above 180 dB re 1 µPa (rms) during these months nor at any time in the nearer shore portion of the sanctuary that lies within the coastal standoff range. Numerous benthic invertebrates, fishes (including the ESA-listed eulachon, green sturgeon, and Pacific salmon), and three species of sea turtles occur at least seasonally within the sanctuary. The sanctuary also encompasses critical habitat for the leatherback turtle and is home to several species of marine mammals with others only migrating through sanctuary waters.

Greater Farallones, Monterey Bay, and Cordell Bank National Marine Sanctuaries

Part of each of these sanctuaries lies within the Central California OBIA (OBIA 10, Table 4-5) for SURTASS LFA sonar and part of each of these sanctuaries lies within the coastal standoff range (<12 nmi from shore) for SURTASS LFA sonar. The effective period for OBIA 10 is from June through November. In the portions of these sanctuaries less than 12 nmi from any land or from June through November in the portions of these sanctuaries within OBIA 10, SURTASS LFA sonar cannot be transmitted such that the RLs are above 180 dB re 1 µPa (rms). These sanctuaries' waters are important foraging grounds for several ESA-listed baleen whales.

Channel Islands National Marine Sanctuary

Channel Island NMS lies wholey within the coastal standoff range for SURTASS LFA sonar. As such, LFA sonar transmissions can never exceed RLs above 180 dB re 1 µPa (rms) in sanctuary waters.

Hawaiian Islands Humpback Whale National Marine Sanctuary

Only Penguin Bank in Hawaiian Islands Humpback Whale NMS is located outside the coastal standoff range of SURTASS LFA sonar. Penguin Bank is an OBIA for SURTASS LFA sonar (OBIA 16), with an effective period from November through April. As a result, LFA sonar transmissions cannot exceed 180 dB re 1 µPa (rms) in any part of the sanctuary from November through April and only in the waters surrrounding Penguin Bank after that time. In addition to the seasonally occurring humpback whale, the sanctuary is home, at least seasonally, to 29 other marine mammal species, five species of sea turtles, and many fishes.

National Marine Sanctuary of American Samoa

The largest of all the NMSs, NMS of American Samoa is principally oceanic but most of its five units are located within the coastal standoff range for SURTASS LFA sonar. Principally noted for its coral reefs with as many as 2,700 documented species, which include seven species of ESA-listed coral, about 100 fishes, and two sea turtle species. Marine mammals have not been well studied in the sanctuary but at least 12 species, including the endangered humpback and sperm whales, have been observed.

Gerry E. Studds Stellwagen Bank National Marine Sanctuary

Stellwagen Bank NMS is part of OBIA 3 (Table 4-5) (Appendix C). As such, SURTASS LFA sonar cannot be transmitted at RLs of 180 dB re 1 µPa (rms) or greater at the OBIA boundary during the effective time period of January 1 through November 14. During this time period, the low RLs would result in negligible potential for impact to living resources, including marine mammals, fishes, or sea turtles, and there would be no potential for harm under the NMSA. The remainder of the year encompasses part of winter, when sea turtles and mysticetes migrate southward out of sanctuary waters as water temperatures cool. Some odontocetes may occur in sanctuary waters during the early winter months, but these animals would not likely be aggregating to forage.

Monitor National Marine Sanctuary

The *Monitor* NMS, established to protect the wreck of the U.S.S. *Monitor*, has no key species identified in the sanctuary waters, though the artificial reef habitat created by the *Monitor* wreck provides overwinter habitat for the endangered loggerhead turtle. Marine mammals and sea turtles migrate through the small area of this sanctuary, although many fish species are resident.

Gray's Reef National Marine Sanctuary

Gray's Reef NMS includes a diverse benthic community of invertebrates, but among the occurring invertebrates, only cephalopods (squid) and decapods (shrimp and crabs) are known to sense LF sound. Marine mammals, including the endangered North Atlantic right whale, and sea turtles occur at least seasonally in sanctuary waters.

Florida Keys National Marine Sanctuary

Part of the Florida Keys NMS is located < 12 nmi from shore in the coastal standoff range for SURTASS LFA sonar. The dominant living resources of the Florida Keys NMS are benthic invertebrates, which include seven species of threatened coral. Reef fishes are abundant with highly migratory larger fish species occurring seasonally. Large nesting beaches of loggerhead and green turtles are located within the sanctuary and more than 20 species of odontocetes and the ESA-listed West Indian manatee have been documented.

Flower Garden Banks National Marine Sanctuary

Flower Garden Banks NMS is best known for its unique coral reefs growing atop salt domes. Coral species include four species listed as threatened. Nearly 300 species of fish and two species of sea turtles have been documented within the waters of the sanctuary. Marine mammals are only rarely observed in the sanctuary.

4.2.2.2.5 Offshore Biologically Important Areas (OBIAs)

Twenty-two marine mammal OBIAs (Table 3-10) are currently designated for LFA sonar. Since the 2012 SEIS/SOEIS and MMPA Final Rule for SURTASS LFA sonar, consideration and assessment of global marine areas as potential OBIAs has continued as part of the Adaptive Management process implemented by NMFS in the 2012 MMPA rulemaking (NOAA, 2012). The Adaptive Management framework allows the Navy and NMFS to consider, on a case-by-case basis, newly available peer-reviewed scientific data, information, or survey data on marine areas that may be eligible for consideration as OBIAs.

From 2012 to the present, the Navy and NMFS have continued to assess areas of the world's oceans for potential OBIAs for LFA sonar. The Navy and NMFS monitor scientific literature, data, and information that may support the potential marine areas or provide additional candidates for consideration as OBIAs for LFA sonar. The Navy and NMFS have maintained a list of potential marine areas for which information or data have not been sufficient to designate as OBIAs, as well as reviewing new literature to determine if additional areas should be added to the list of potential areas. Potential areas are periodically evaluated or re-assessed to determine if information and data are available to provide adequate support under one of the OBIA biological criteria. Under Adaptive Management, the Navy and NMFS conduct a full assessment of potential marine areas and consider those that meet the geographic, biologic, and hearing sensitivity criteria for OBIA selection.

As a continuation of the Navy and NMFS' ongoing effort to assess areas of the world's oceans for potential OBIAs for SURTASS LFA sonar, the Navy and NMFS conducted a comprehensive assessment of potential marine areas as part of the analysis and development of this SEIS/SOEIS. Two major efforts, one within U.S. waters and another on a global scale, the products of which have been extensively reviewed, are described below. In addition, other sources that have been reviewed include the World Database on Protected Areas, which is a joint program of the International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme (UNEP) (IUCN and UNEP, 2016); the

2014 United Nations List of Protected Areas (Deguignet et al., 2014); the Convention on Biological Diversity; MPA Global (Wood, 2007); the Marine Conservation Institute MPAtlas (2015), and cetaceanhabitat.org. Summaries of these analyses are described below.

In 2015, the U.S. NOAA-sponsored Cetacean and Sound Mapping Working Group (CetMap) identified, mapped, and published a catalog of known areas of importance for cetaceans they called Biologically Important Areas (BIAs) (Van Parijs et al., 2015). CetMap BIAs were developed for U.S. waters. Unlike OBIAs, BIAs have no direct regulatory significance, but were designed to meet the purpose of identifying areas in support of resource management, planning, and analysis through the augmentation of existing spatial imaging tools (NOAA, 2015, 2016b). To assess the potential of the CetMap BIAs as potential OBIAs for SURTASS LFA sonar, the Navy conducted a geospatial analysis of the CetMap BIAs to determine which of the areas met the geographic criteria for OBIAs, i.e., was located in a non-polar region and beyond 12 nmi (22 km) from any land. The remaining BIAs or portions of the BIAs that met the geographic criteria were then assessed for the hearing sensitivity and biological criteria for LFA sonar OBIAs. The biological data and information associated with several of the CetMap BIAs formed the basis for the expansion of several existing OBIAs for SURTASS LFA sonar as well as the creation of additional potential OBIAs.

On 24 October 2013, the Marine Mammal Protected Area Task Force (MMPATF) was created as a joint effort of the IUCN World Commission of Protected Areas (WCPA) and Species Survival Commission (SSC) and the International Committee on Marine Mammal Protected Areas (ICMMPA). A focal point of the MMPATF is to define criteria and best practices for identifying and establishing Important Marine Mammal Areas (IMMAs). IMMAs are defined as discrete portions of habitat that are important to one or more marine mammal species. Similar to the CetMap BIAs, IMMAs are designed to represent priority sites for marine mammal conservation worldwide without management implications (IUCN WCPA-SSC Joint Task Force on Biodiversity and Protected Areas and IUCN WCPA-SSC Joint Task Force on Marine Mammal Protected Areas, 2015). Ongoing efforts are coordinating review of criteria for protected areas under the Convention for Biological Diversity Ecologically or Biologically Significant Areas, International Maritime Organization Particularly Sensitive Sea Areas, and IUCN Key Biodiversity Areas.

Several online databases are routinely updated with new protected area designations. The World Database on Protected Areas was downloaded and reviewed in January 2016, as was MPA Global (Wood, 2007) and the Marine Conservation Institute MPAtlas (2015). Cetaceanhabitat.org is an online directory of protected areas with cetacean habitat derived from Hoyt (2005, 2011) that is updated on a regular basis. Marine mammal MPAs from Hoyt (2005, 2011) have been reviewed and evaluated against the geograhic, biological, and hearing criteria of the OBIAs. In addition, the website was accessed on 27 January 2016 and a review of 96 areas that had been added since the publiction of Hoyt (2011) were evaluated.

Based on this extensive review, eight new candidate OBIAs and the expansion of four existing OBIAs were evaluted by NMFS and Navy subject matter experts (SMEs) as part of the analysis and development of this SEIS/SOEIS. During the review, it was suggested that Existing OBIA 5 (North Pacific Right Whale Critical Habitat) be expanded to include recent sightings of North Pacific right whales outside of defined critical habitat. After additional evaluation, Navy and NMFS agreed that sufficient data exist to meet the criteria for designation as a candidate OBIA. Existing OBIA 5 was renamed Gulf of Alaska to appropriately reflect the expansion beyond North Pacific Right Whale Critical Habitat and this expanded OBIA was added to the list of candidates (Table 4-4).

Table 4-4. Potential offshore biologically important areas (OBIAs) for SURTASS LFA sonar recommended for this SEIS/SOEIS.

Potential OBIA Number	*Potential OBIA Name*	*Water Body/Location*	*Relevant Low-Frequency Marine Mammal Species*	*Effective Seasonal Period*	*Notes*
1	Grand Manan North Atlantic Right Whale Critical Habitat	Bay of Fundy, Canada	North Atlantic right whale	June through December, annually	
2	Great South Channel, Gulf of Maine, and Stellwagen Bank National Marine Sanctuary (OBIA 3) Expansion	Northeast U.S. Atlantic waters	North Atlantic right whale	January 1 to November 14, annually	Expansion of northeastern U.S. critical habitat for the North Atlantic right whale
3	Southeastern U.S. Critical Habitat for the North Atlantic Right Whale (OBIA 4) Expansion	Southeast U.S. Atlantic waters	North Atlantic right whale	January 15 to April 15, annually	Expansion of OBIA 4—Southeastern U.S. critical habitat for the North Atlantic right whale
4	Eastern Gulf of Mexico	Eastern Gulf of Mexico	Bryde's whale	Year-round	
5	Central California	Southwest U.S. Pacific waters	Blue whale, Humpback whale	June through November, annually	Expansion of OBIA 10—Central California National Marine Sanctuaries
6	Southern Chile Coastal Waters	Gulf of Corcovado, Southeast Pacific Ocean; southwestern Chile	Blue whale	February to April, annually	
7	Offshore Sri Lanka	North-Central Indian Ocean	Blue whale	December through April, annually	
8	Great Barrier Reef	Coral Sea, Southwestern Pacific Ocean; northeastern Australia	Humpback whale	May through September, annually	Expansion of OBIA 18—Great Barrier Reef Between 16° and 21° S
9	Camden Sound/Kimberly Region	Southeast Indian Ocean; northwestern Australia	Humpback whale	June through September, annually	

Table 4-4. Potential offshore biologically important areas (OBIAs) for SURTASS LFA sonar recommended for this SEIS/SOEIS.

Potential OBIA Number	*Potential OBIA Name*	*Water Body/Location*	*Relevant Low-Frequency Marine Mammal Species*	*Effective Seasonal Period*	*Notes*
10	Perth Canyon	Southeast Indian Ocean; southwestern Australia	Pygmy blue whale/Blue whale	January through May, annually	
11	Gulf of Alaska	Gulf of Alaska	North Pacific right whale	March through August, annually	Expansion of OBIA 5—North Pacific Right Whale Critical Habitat

After additional evaluation, two preliminary candidate OBIAs were agreed to by NMFS and the Navy to not meet the criteria for designation. The preliminary candidate OBIA called the Southern Australia Southern Right Whale Calving Area was determined to consist of biological behavior solely within the coastal exclusion zone defined for LFA sonar; therefore, that candidate OBIA was elminated from further consideration because it did not meet the geographic criterion. The Tanner and Cortes Banks preliminary candidate OBIA was considered as possibly meeting the foraging biological criterion. Calambokidis et al. (2015) identified Tanner and Cortes banks as a CetMap BIA, stating that it represented a common and persistent feeding area based on 52 sightings of blue whales in the region. However, most of these sightings occurred over ten years ago, and the analysis did not consider data from satellite-tagged individuals. Irvine et al. (2014) used data from 171 blue whales tagged between 1993 and 2008 to define core areas where blue whales are most likely to occur. Tanner and Cortes banks were within the distributional range of blue whales, but residence time within the banks as defined by home range and core area was not significant. For this reason, NMFS and the Navy agreed that this area did not meet the biological criterion for designation as an OBIA. Ongoing studies of blue whale habitat use are augmenting the work of Irvine et al. (2014) with satellite tags on blue whales from 2014 to 2017 (Mate et al., 2015; Mate et al., 2016) and may provide further insight into areas off the U.S. west coast that may meet the criteria for designation as an OBIA. NMFS and the Navy agreed to continue to evaluate Tanner and Cortes banks as new data become available.

Therefore, after the SME review of preliminary candidate OBIAs, six new potential OBIAs and the expansion of five existing OBIAs were determined to meet the geographic, biological, and hearing criteria and were evaluated by the Navy for practicability. These eleven potential OBIAs were approved during the practicability review and will be implemented as part of the Proposed Action (Table 4-4). When coupled with the existing OBIAs, a comprehensive list of 28 OBIAs result that is part of the Proposed Action (Table 4-5).

4.2.3 Quantitative Impact Analysis for Marine Mammals

The Navy conducted a risk assessment to analyze and assess potential impacts associated with employing up to four SURTASS LFA sonar systems for routine training, testing, and military operations in the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea. 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 or endangered marine species or result in the destruction or adverse modification of critical habitat.

The acoustic impact analysis presented herein represents an evolution that builds upon the analysis, methodology, and impact criteria documented in previous SURTASS LFA sonar NEPA efforts (DoN, 2001, 2007, 2012), but incorporates the most current acoustic impact criteria and methodology to assess the potential for auditory impacts (PTS and TTS) and behavioral responses of marine mammal species. A summary of the analysis, as well as the exposure estimates, follow; a more thorough description of the impact analysis is provided in Appendix B.

Table 4-5. Comprehensive List of Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar.

OBIA Number	*OBIA Name*	*Water Body/Location*	*Relevant Low-Frequency Marine Mammal Species*	*Effective Seasonal Period*	*OBIA Boundary Change*[5]	*Notes*
1	Georges Bank	Northwest Atlantic Ocean	North Atlantic right whale	Year-round	R	
2	Roseway Basin Right Whale Conservation Area	Northwest Atlantic Ocean	North Atlantic right whale	June through December, annually		
3	Great South Channel, U.S. Gulf of Maine, and Stellwagen Bank NMS	Northwest Atlantic Ocean/ Gulf of Maine	North Atlantic right whale	January 1 to November 14, annually	E-CH	OBIA 3 boundary revised to encompass expansion of northeastern U.S. critical habitat for the North Atlantic right whale (Potential OBIA 2)
4	Southeastern U.S. Right Whale Critical Habitat	Northwest Atlantic Ocean	North Atlantic right whale	November 15 to April 15, annually	E-CH	OBIA 4 boundary revised to encompass expansion of southeastern U.S. critical habitat for the North Atlantic right whale (Potential OBIA 3)
5	Gulf of Alaska[6]	Gulf of Alaska	North Pacific right whale	March through August, annually	E, R	OBIA 5 boundary revised to encompass additional foraging area for the North Pacific right whale (Potential OBIA 11)
6	Navidad Bank[7]	Caribbean Sea/Northwest Atlantic Ocean	Humpback whale	December through April, annually	R	Silver Bank no longer encompassed within OBIA boundary

5 E=OBIA boundary expanded per data justification; E-CH=OBIA boundary expanded to encompass designated critical habitat; R=OBIA landward boundary revised per higher resolution 12-nmi data

6 OBIA name changed to indicate expansion of OBIA beyond extent of North Pacific right whale critical habitat

7 OBIA name changed to indicate that Silver Bank is no longer encompassed within OBIA boundary but is instead encompassed in and afforded the protections of the coastal standoff range for SURTASS LFA sonar

Table 4-5. Comprehensive List of Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar.

OBIA Number	*OBIA Name*	*Water Body/Location*	*Relevant Low-Frequency Marine Mammal Species*	*Effective Seasonal Period*	*OBIA Boundary Change*[5]	*Notes*
7	Coastal Waters of Gabon, Congo and Equatorial Guinea	Southeastern Atlantic Ocean	Humpback whale and Blue whale	June through October, annually	R	
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, annually	R	
10	Central California[8]	Northeastern Pacific Ocean	Blue whale and Humpback whale	June through November, annually	E, R	OBIA 10 boundary revised to encompass additional foraging area for the blue and humpback whales (Potential OBIA 5)
11	Antarctic Convergence Zone	Southern Ocean	Blue whale, Fin whale, Sei whale, Minke whale, Humpback whale, and Southern right whale	October through March, annually	R	
12	Piltun and Chayvo Offshore Feeding Grounds	Sea of Okhotsk	Western Pacific gray whale	June through November, annually	R	
13	Coastal Waters off Madagascar	Western Indian Ocean	Humpback whale and Blue whale	July through September, annually for humpback whale breeding; November through December for migrating blue whales	R	
14	Madagascar Plateau, Madagascar Ridge, and Walters Shoal	Western Indian Ocean	Pygmy blue whale, Humpback whale, and	November through December, annually		

8 OBIA name changed to indicate that expanded OBIA boundary is not coterminous with sanctuaries' boundaries

Table 4-5. Comprehensive List of Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar.

OBIA Number	*OBIA Name*	*Water Body/Location*	*Relevant Low-Frequency Marine Mammal Species*	*Effective Seasonal Period*	*OBIA Boundary Change[5]*	*Notes*
			Bryde's whale			
15	Ligurian-Corsican-Provençal Basin and Western Pelagos Sanctuary	Northern Mediterranean Sea	Fin whale	July to August, annually	R	
16	Penguin Bank, Hawaiian Islands Humpback Whale National Marine Sanctuary	North-Central Pacific Ocean	Humpback whale	November through April, annually	R	
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/South-western Pacific Ocean	Humpback whale and Dwarf minke whale	May through September, annually	E, R	OBIA 18 boundary revised to encompass additional breeding/calving area for the humpback whale (Potential OBIA 8)
19	Bonney Upwelling	Southern Ocean	Blue whale, Pygmy blue whale, and Southern right whale	December through May, annually	R	
20	Northern Bay of Bengal and Head of Swatch-of-No-Ground (SoNG)	Bay of Bengal/Northern Indian Ocean	Bryde's whale	Year-round	R	
21	Olympic Coast National Marine Sanctuary and The Prairie, Barkley Canyon, and Nitnat Canyon	Northeastern Pacific Ocean	Humpback whale	Olympic National Marine Sanctuary: December, January, March, and May, annually; The Prairie, Barkley Canyon, and Nitnat Canyon: June through September, annually		

Table 4-5. Comprehensive List of Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar.

OBIA Number	*OBIA Name*	*Water Body/Location*	*Relevant Low-Frequency Marine Mammal Species*	*Effective Seasonal Period*	*OBIA Boundary Change*[5]	*Notes*
22	Abrolhos Bank	Southwest Atlantic Ocean	Humpback whale	August through November, annually		
23	Grand Manan North Atlantic Right Whale Critical Habitat	Bay of Fundy, Canada	North Atlantic right whale	June through December, annually		Potential OBIA 1; Canadian critical habitat for the North Atlantic right whale
24	Eastern Gulf of Mexico	Eastern Gulf of Mexico	Bryde's whale	Year-round		Potential OBIA 4
25	Southern Chile Coastal Waters	Gulf of Corcovado, Southeast Pacific Ocean; southwestern Chile	Blue whale	February to April, annually		Potential OBIA 6
26	Offshore Sri Lanka	North-Central Indian Ocean	Blue whale	December through April, annually		Potential OBIA 7
27	Camden Sound/Kimberly Region	Southeast Indian Ocean; northwestern Australia	Humpback whale	June through September, annually		Potential OBIA 9
28	Perth Canyon	Southeast Indian Ocean; southwestern Australia	Pygmy blue whale/Blue whale	January through May, annually		Potential OBIA 10

Twenty-six representative mission areas in the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea were analyzed to represent the acoustic regimes and marine mammal species that may be encountered during LFA sonar operations (Table 4-6). Due to the large number of potential mission areas and seasons to be considered in the impact analysis, a seasonal sensitivity study was conducted to determine the optimal modeling season for each mission area. The modeling season was chosen based on an analysis of the sound velocity profiles and resulting sound propagation and transmission loss fields, with the season with the longest range acoustic propagation typically being selected. Seasons as applied herein are defined according to the following monthly breakdown:

- Winter: December, January, and February
- Spring: March, April, and May
- Summer: June, July, and August
- Fall: September, October, and November.

For consistency, the seasonality for marine mammals in all mission areas is presented according to this monthly arrangement, even for mission areas located in the southern hemisphere. Winter in the southern hemisphere is austral summer, when for instance, most baleen whales would be expected to be foraging in Antarctic waters.

To estimate the potential impacts to marine mammals in each of the 26 mission areas, a list of marine mammal stocks likely to be encountered in each region was developed and abundance and density estimates derived for the selected modeling season (Chapter 3). These population data were derived from the most current published literature and documentation available.

To predict acoustic exposure, the LFA sonar ship was simulated traveling in a triangular pattern at a speed of 4 kt (7.4 kph), with the time on each bearing (each “leg” of the triangle) being 8 hr (480 min). The duration of LFA sonar transmissions was modeled as 24 hr at each mission area, with a signal duration of 60 sec and a duty cycle of 10 percent (i.e., the source transmitted for 60 sec every 10 min for 24 hr). The acoustic field around the LFA sonar vessel was predicted with the operating parameters of LFA sonar in the Navy standard parabolic equation propagation model. Each marine mammal species potentially occurring in a modeling area was simulated by creating animats programmed with behavioral values describing their dive behavior, including dive depth, surfacing time, dive duration, swimming speed, and direction change.

The Acoustic Integration Model© (AIM) integrated the acoustic field created from the underwater transmissions of LFA sonar with the four-dimensional (4D) movement of marine mammals to estimate their potential sonar exposure at each 30-sec timestep within the 24-hr modeling period. Thus, the output of AIM is the time history of exposure for each animat.

Since AIM records the exposure history for each individual animat, the potential impact is determined on an individual animal basis. The sound energy received by each individual animat over the 24-hr modeled period was calculated as SEL and the potential for PTS and then TTS was considered using the NOAA (2016a) acoustic guidance. The sound energy received by each individual animat over the 24-hr modeled period was also calculated as dB SPE and used as input to the risk continuum function to assess the potential risk of biologically significant behavioral reaction. To ensure that each individual is considered for only one potential impact (i.e., there is no double counting), the potential for PTS is

Table 4-6. Locations of the 26 Representative Mission Areas Modeled for SURTASS LFA Sonar Global Operations and the Season Modeled for Each Area.

Mission Area	*Mission Area Name*	*Season*	*Location of Modeling Area Center*	*Notes*
1	East of Japan	Summer	38°N, 148°E	Adjacent to Navy Japan Complex OPAREA
2	North Philippine Sea	Fall	29°N, 136°E	Adjacent to Navy Japan/Okinawa ComplexOPAREA
3	West Philippine Sea	Fall	22°N/124°E	
4	Offshore Guam	Summer	11°N, 145°E	Navy Mariana Islands Testing and Training Area
5	Sea of Japan	Fall	39°N, 132°E	
6	East China Sea	Summer	26°N, 125°E	Navy Japan/Okinawa Complex OPAREA
7	South China Sea	Fall	14°N, 114°E	
8	Offshore Japan 25° to 40°N	Summer	30°N, 165°E	
9	Offshore Japan 10° to 25°N	Winter	15°N, 165°E	
10	Hawaii North	Summer	25°N, 158°W	Navy Hawaii-Southern California Testing and Training Area; Hawaii Operating Area
11	Hawaii South	Fall	19.5°N, 158.5°W	Navy Hawaii-Southern California Testing and Training Area; Hawaii Operating Area
12	Offshore Southern California	Spring	32°N, 120°W	Navy Hawaii-Southern California Testing and Training Area; Southern California Operating Area
13	Western North Atlantic (off Florida)	Winter	29°N, 76°W	Navy Atlantic Fleet Testing and Training Area; Jacksonville Operating Area
14	Eastern North Atlantic	Summer	56.4N, 10W	Northwest Approaches
15	Mediterranean Sea	Summer	39°N, 6°E	
16	Arabian Sea	Summer	14°N, 65°E	
17	Andaman Sea	Summer	7.5°N, 96°E	
18	Panama Canal	Winter	5°N, 81°W	Western Approach
19	Northeast Australia	Spring	23°S, 155°E	
20	Northwest of Australia	Winter	18°S, 110°E	
21	Northeast of Japan	Summer	52°N, 163°E	
22	Southern Gulf of Alaska	Summer	51°N, 150°W	

Table 4-6. Locations of the 26 Representative Mission Areas Modeled for SURTASS LFA Sonar Global Operations and the Season Modeled for Each Area.

Mission Area	*Mission Area Name*	*Season*	*Location of Modeling Area Center*	*Notes*
23	Southern Norwegian Basin (between Iceland and Norway)	Summer	65°N, 0°	
24	Western North Atlantic (off Virginia/Maryland)	Summer	36.9°N, 71.6°W	Navy Atlantic Fleet Testing and Training Area; Virginia Capes Operating Area
25	Labrador Sea	Winter	57°N, 50°W	
26	Sea of Okhotsk	Spring	51°N, 150°E	

considered first, as it represents the highest threshold. If an individual does not exceed the PTS threshold, then the potential for TTS is considered. If an animal does not exceed the TTS threshold, then the potential for a behavioral response is considered. Thus, individuals are not considered for more than one acoustic impact during a 24-hr exposure scenario.

The potential for PTS, TTS, and behavioral change has been estimated based on 24 hr of LFA sonar operations (Table 4-7). The potential for PTS (MMPA Level A) is considered within the context of the mitigation and monitoring efforts that will occur (Chapter 5). The NOAA (2016a) acoustic guidance for estimating the potential for PTS defines weighted thresholds as sound exposure levels (Table 4-3). The length of a nominal LFA transmission is 60 sec, which lowers the thresholds by approximately 18 dB SEL ($10x\log_{10}$ [60 sec] =17.8) if the assumption is made that all RLs are at the same RL. However, if transmissions at 300 Hz are considered for this example, as it is in the middle of the frequency range of LFA transmissions (100 to 500 Hz), the thresholds must be appropriately weighted to account for each functional hearing group's sensitivity. This results in an increase in the thresholds of approximately 1.5, 56, 56, 15, and 20 dB, respectively, for LF, MF, HF, PW, and OW groups when considering a signal at 300 Hz. Based on simple spherical spreading (i.e., a transmission loss [TL] based on $20\times\log_{10}$ [range in meters]), all functional hearing groups except LF cetaceans would need to be within 22 ft (7 m) for an entire LFA transmission (60 sec) to potentially experience PTS. An LF cetacean would need to be within 135 ft (41 m) for an entire LFA transmission to potentially experience PTS. Based on the mitigation procedures used during LFA sonar operations, the chances of this occurring are negligible. Therefore, no PTS (MMPA Level A harassment) is expected with mitigation.

The percentage of marine mammal stocks that may experience TTS or behavioral changes from LFA sonar exposures was calculated for one season in each of the 26 mission areas. The noise exposure scenario was for a 24-hr period, with LFA sonar transmitting 60-sec signals every ten min for the entire period. Based on historical mission data, it is unlikely that such a scenario would occur, but it is a conservative method for estimating potential impacts.

4.3 Economic Resources

Analysis of impacts to economic resources is focused on potential impacts to commercial fisheries, subsistence harvesting of marine mammals, and recreational marine activities.

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Mission Area 1: East of Japan; Summer Season					
Blue whale	WNP	9,250	–[2]	–	–
Bryde's whale	WNP	20,501	0.0115%	0.0011%	0.0126%
Common minke whale	WNP "O"	25,049	0.0393%	0.0056%	0.0449%
Fin whale	WNP	9,250	0.0071%	0.0007%	0.0079%
Humpback whale	WNP stock and DPS[3]	1,328	0.0384%	0.0065%	0.0449%
North Pacific right whale	WNP	922	–	–	–
Sei whale	NP	7,000	0.0336%	0.0033%	0.0368%
Baird's beaked whale	WNP	8,000	0.1702%	0.0000%	0.1702%
Common bottlenose dolphin	WNP	168,791	0.0212%	0.0000%	0.0212%
Cuvier's beaked whale	WNP	90,725	0.0131%	0.0000%	0.0131%
False killer whale	WNP	16,668	0.0550%	0.0000%	0.0550%
Ginkgo-toothed beaked whale	NP	22,799	0.0084%	0.0000%	0.0084%
Harbor porpoise	WNP	31,046	0.0000%	0.0000%	0.0000%
Hubbs' beaked whale	NP	22,799	0.0084%	0.0000%	0.0084%
Killer whale	WNP	12,256	0.0030%	0.0000%	0.0030%
Kogia spp.	WNP	350,553	0.0032%	0.0000%	0.0032%
Pacific white-sided dolphin	NP	931,000	0.0010%	0.0000%	0.0010%
Pantropical spotted dolphin	WNP	438,064	0.0070%	0.0000%	0.0070%
Pygmy killer whale	WNP	30,214	0.0177%	0.0000%	0.0177%
Risso's dolphin	WNP	83,289	0.0405%	0.0000%	0.0405%
Rough-toothed dolphin	WNP	145,729	0.0139%	0.0000%	0.0139%
Short-beaked common dolphin	WNP	3,286,163	0.0078%	0.0000%	0.0078%
Short-finned pilot whale	WNP	53,608	0.0655%	0.0000%	0.0655%
Sperm whale	NP	102,112	0.0035%	0.0000%	0.0035%
Spinner dolphin	WNP	1,015,059	0.0001%	0.0000%	0.0001%
Stejneger's beaked whale	WNP	8,000	0.0240%	0.0000%	0.0240%
Striped dolphin	WNP	570,038	0.0023%	0.0000%	0.0023%
Mission Area 2: North Philippine Sea; Fall Season					
Blue whale	WNP	9,250	0.0004%	0.0001%	0.0005%
Bryde's whale	WNP	20,501	0.0115%	0.0033%	0.0149%

1 NP=North Pacific; EP=Eastern Pacific; WNP=Western North Pacific; CNP=Central North Pacific; ENP=Eastern North Pacific; WSP=Western South Pacific; ETP=Eastern Tropical Pacific; AK=Alaska; ECS=East China Sea; SOJ=Sea of Japan; IA=Inshore Archipelago; NMI=Northern Mariana Islands; C/O/W=California/Oregon/Washington; IND=Indian; NIND=Northern Indian; SIND=Southern Indian; WAU=Western Australia; AS=Arabian Sea; WNA=Western North Atlantic; ENA=Eastern North Atlantic; WM=Western Mediterranean

2 Species not found in this mission area during modeled season but occurring there in other seasons.

3 DPS=distinct population segment, which is a discrete population or group of populations of the same species that is significant to the entire species. Populations are identified as stocks under the MMPA and as DPSs under the ESA. Thus, the humpback whale is listed by stock and DPS (DPS/stock) where relevant.

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Common minke whale	WNP "O"	25,049	0.0632%	0.0165%	0.0798%
Fin whale	WNP	9,250	–	–	–
Humpback whale	WNP stock and DPS	1,328	0.2149%	0.0710%	0.2860%
North Pacific right whale	WNP	922	–	–	–
Omura's whale	WNP	1,800	0.0131%	0.0038%	0.0169%
Blainville's beaked whale	WNP	8,032	0.0220%	0.0000%	0.0220%
Common bottlenose dolphin	WNP	168,791	0.0203%	0.0000%	0.0203%
Cuvier's beaked whale	WNP	90,725	0.0210%	0.0000%	0.0210%
False killer whale	WNP	16,668	0.0434%	0.0000%	0.0434%
Fraser's dolphin	WNP	220,789	0.0084%	0.0000%	0.0084%
Ginkgo-toothed beaked whale	NP	22,799	0.0077%	0.0000%	0.0077%
Killer whale	WNP	12,256	0.0020%	0.0000%	0.0020%
Kogia spp.	WNP	350,553	0.0032%	0.0000%	0.0032%
Long-beaked common dolphin	WNP	279,182	0.1051%	0.0000%	0.1051%
Longman's beaked whale	WNP	4,571	0.0193%	0.0000%	0.0193%
Melon-headed whale	WNP	36,770	0.0290%	0.0000%	0.0290%
Pacific white-sided dolphin	NP	931,000	–	–	–
Pantropical spotted dolphin	WNP	438,064	0.0063%	0.0000%	0.0063%
Pygmy killer whale	WNP	30,214	0.0173%	0.0000%	0.0173%
Risso's dolphin	WNP	83,289	0.0445%	0.0000%	0.0445%
Rough-toothed dolphin	WNP	145,729	0.0138%	0.0000%	0.0138%
Short-beaked common dolphin	WNP	3,286,163	0.0043%	0.0000%	0.0043%
Short-finned pilot whale	WNP	53,608	0.0773%	0.0000%	0.0773%
Sperm whale	NP	102,112	0.0034%	0.0000%	0.0034%
Spinner dolphin	WNP	1,015,059	0.0002%	0.0000%	0.0002%
Striped dolphin	WNP	570,038	0.0115%	0.0000%	0.0115%
Mission Area 3: West Philippine Sea; Fall Season					
Blue whale	WNP	9,250	0.0005%	0.0002%	0.0007%
Bryde's whale	WNP	20,501	0.0121%	0.0051%	0.0172%
Common minke whale	WNP "O"	25,049	0.0501%	0.0250%	0.0752%
Fin whale	WNP	9,250	–	–	–
Humpback whale	WNP stock and DPS	1,328	0.2796%	0.1300%	0.4096%
Omura's whale	WNP	1,800	0.0138%	0.0058%	0.0196%
Blainville's beaked whale	WNP	8,032	0.0160%	0.0000%	0.0160%
Common bottlenose dolphin	WNP	168,791	0.0238%	0.0000%	0.0238%
Cuvier's beaked whale	WNP	90,725	0.0008%	0.0000%	0.0008%
Deraniyagala's beaked whale	NP	22,799	0.0056%	0.0000%	0.0056%
False killer whale	WNP	16,668	0.0487%	0.0000%	0.0487%
Fraser's dolphin	WNP	220,789	0.0084%	0.0000%	0.0084%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Ginkgo-toothed beaked whale	NP	22,799	0.0056%	0.0000%	0.0056%
Killer whale	WNP	12,256	0.0020%	0.0000%	0.0020%
Kogia spp.	WNP	350,553	0.0015%	0.0000%	0.0015%
Long-beaked common dolphin	WNP	279,182	0.1069%	0.0000%	0.1069%
Longman's beaked whale	WNP	4,571	0.0140%	0.0000%	0.0140%
Melon-headed whale	WNP	36,770	0.0326%	0.0000%	0.0326%
Pantropical spotted dolphin	WNP	438,064	0.0070%	0.0000%	0.0070%
Pygmy killer whale	WNP	30,214	0.0194%	0.0000%	0.0194%
Risso's dolphin	WNP	83,289	0.0394%	0.0000%	0.0394%
Rough-toothed dolphin	WNP	145,729	0.0120%	0.0000%	0.0120%
Short-finned pilot whale	WNP	53,608	0.0412%	0.0000%	0.0412%
Sperm whale	NP	102,112	0.0029%	0.0000%	0.0029%
Spinner dolphin	WNP	1,015,059	0.0002%	0.0000%	0.0002%
Striped dolphin	WNP	570,038	0.0065%	0.0000%	0.0065%
Mission Area 4: Offshore Guam; Summer Season					
Blue whale	WNP	9,250	–	–	–
Bryde's whale	WNP	20,501	0.0023%	0.0005%	0.0029%
Common minke whale	WNP "O"	25,049	–	–	–
Fin whale	WNP	9,250	–	–	–
Humpback whale	WNP stock and DPS	1,328	–	–	–
Omura's whale	WNP	1,800	0.0026%	0.0006%	0.0033%
Sei whale	NP	7,000	–	–	–
Blainville's beaked whale	WNP	8,032	0.0307%	0.0000%	0.0307%
Common bottlenose dolphin	WNP	168,791	0.0015%	0.0000%	0.0015%
Cuvier's beaked whale	WNP	90,725	0.0022%	0.0000%	0.0022%
Deraniyagala's beaked whale	NP	22,799	0.0105%	0.0000%	0.0105%
Dwarf sperm whale	WNP	350,553	0.0038%	0.0000%	0.0038%
False killer whale	WNP	16,668	0.0070%	0.0000%	0.0070%
Fraser's dolphin	CNP	16,992	0.0517%	0.0000%	0.0517%
Ginkgo-toothed beaked whale	NP	22,799	0.0077%	0.0000%	0.0077%
Killer whale	WNP	12,256	0.0012%	0.0000%	0.0012%
Longman's beaked whale	WNP	4,571	0.1052%	0.0000%	0.1052%
Melon-headed whale	NMI	2,455	0.1845%	0.0000%	0.1845%
Pantropical spotted dolphin	WNP	438,064	0.0031%	0.0000%	0.0031%
Pygmy killer whale	WNP	30,214	0.0005%	0.0000%	0.0005%
Pygmy sperm whale	WNP	350,553	0.0016%	0.0000%	0.0016%
Risso's dolphin	WNP	83,289	0.0071%	0.0000%	0.0071%
Rough-toothed dolphin	WNP	145,729	0.0031%	0.0000%	0.0031%
Short-finned pilot whale	WNP	53,608	0.0139%	0.0000%	0.0139%
Sperm whale	NP	102,112	0.0024%	0.0000%	0.0024%
Spinner dolphin	WNP	1,015,059	0.0000%	0.0000%	0.0000%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Striped dolphin	WNP	570,038	0.0006%	0.0000%	0.0006%
Mission Area 5: Sea of Japan; Fall Season					
Bryde's whale	WNP	20,501	0.0023%	0.0002%	0.0025%
Common minke whale	WNP "O"	25,049	0.0071%	0.0005%	0.0076%
	WNP "J"	893	0.0800%	0.0054%	0.0854%
Fin whale	WNP	9,250	0.0789%	0.1024%	0.1812%
North Pacific right whale	WNP	922	–	–	–
Omura's whale	WNP	1,800	0.0027%	0.0002%	0.0029%
Western North Pacific gray whale	WNP stock/ Western DPS	140	0.0090%	0.0023%	0.0113%
Baird's beaked whale	WNP	8,000	0.0204%	0.0000%	0.0204%
Common bottlenose dolphin	IA	105,138	0.0020%	0.0000%	0.0020%
Cuvier's beaked whale	WNP	90,725	0.0186%	0.0000%	0.0186%
Dall's porpoise	SOJ	173,638	0.0290%	0.0000%	0.0290%
False killer whale	IA	9,777	0.0806%	0.0000%	0.0806%
Harbor porpoise	WNP	31,046	0.0418%	0.0000%	0.0418%
Killer whale	WNP	12,256	0.0029%	0.0000%	0.0029%
Kogia spp.	WNP	350,553	0.0022%	0.0000%	0.0022%
Long-beaked common dolphin	WNP	279,182	0.1374%	0.0000%	0.1374%
Pacific white-sided dolphin	NP	931,000	–	–	–
Risso's dolphin	IA	83,289	0.0394%	0.0000%	0.0394%
Rough-toothed dolphin	WNP	145,729	0.0079%	0.0000%	0.0079%
Short-beaked common dolphin	WNP	3,286,163	0.0087%	0.0000%	0.0087%
Short-finned pilot whale	WNP	53,608	0.0097%	0.0000%	0.0097%
Sperm whale	NP	102,112	0.0092%	0.0000%	0.0092%
Spinner dolphin	WNP	1,015,059	0.0001%	0.0000%	0.0001%
Stejneger's beaked whale	WNP	8,000	0.0232%	0.0000%	0.0232%
Striped dolphin	IA	570,038	0.0011%	0.0000%	0.0011%
Spotted seal	Southern stock and DPS	3,500	0.0002%	0.0000%	0.0002%
Mission Area 6: East China Sea; Summer Season					
Bryde's whale	ECS	137	0.6723%	0.7883%	1.4606%
Common minke whale	WNP "O"	25,049	0.0459%	0.0646%	0.1105%
	WNP "J"	893	0.5263%	0.7418%	1.2681%
Fin whale	ECS	500	0.1091%	0.1336%	0.2427%
North Pacific right whale	WNP	922	–	–	–
Omura's whale	WNP	1,800	0.0051%	0.0060%	0.0111%
Western North Pacific gray whale	WNP stock/ Western DPS	140	–	–	–
Blainville's beaked whale	WNP	8,032	0.0222%	0.0000%	0.0222%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Common bottlenose dolphin	IA	105,138	0.0038%	0.0000%	0.0038%
Cuvier's beaked whale	WNP	90,725	0.0012%	0.0000%	0.0012%
False killer whale	IA	9,777	0.0345%	0.0000%	0.0345%
Fraser's dolphin	WNP	220,789	0.0116%	0.0000%	0.0116%
Ginkgo-toothed beaked whale	NP	22,799	0.0078%	0.0000%	0.0078%
Killer whale	WNP	12,256	0.0023%	0.0000%	0.0023%
Kogia spp.	WNP	350,553	0.0017%	0.0000%	0.0017%
Long-beaked common dolphin	WNP	279,182	0.1258%	0.0000%	0.1258%
Longman's beaked whale	WNP	4,571	0.0195%	0.0000%	0.0195%
Melon-headed whale	WNP	36,770	0.0354%	0.0000%	0.0354%
Pacific white-sided dolphin	NP	931,000	–	–	–
Pantropical spotted dolphin	WNP	219,032	0.0163%	0.0000%	0.0163%
Pygmy killer whale	WNP	30,214	0.0014%	0.0000%	0.0014%
Risso's dolphin	IA	83,289	0.0517%	0.0000%	0.0517%
Rough-toothed dolphin	WNP	145,729	0.0066%	0.0000%	0.0066%
Short-beaked common dolphin	WNP	3,286,163	0.0043%	0.0000%	0.0043%
Short-finned pilot whale	WNP	53,608	0.0102%	0.0000%	0.0102%
Sperm whale	NP	102,112	0.0035%	0.0000%	0.0035%
Spinner dolphin	WNP	1,015,059	0.0002%	0.0000%	0.0002%
Striped dolphin	IA	570,038	0.0027%	0.0000%	0.0027%
Spotted seal	Southern stock and DPS	1,000	0.0025%	0.0001%	0.0027%
Mission Area 7: South China Sea; Fall Season					
Bryde's whale	WNP	20,501	0.0084%	0.0006%	0.0090%
Common minke whale	WNP "O"	25,049	0.0387%	0.0032%	0.0419%
	WNP "J"	893	0.5924%	0.0484%	0.6407%
Fin whale	WNP	9,250	0.0049%	0.0009%	0.0058%
Humpback whale	WNP stock and DPS	1,328	0.0434%	0.0038%	0.0472%
North Pacific right whale	WNP	922	–	–	–
Omura's whale	WNP	1,800	0.0096%	0.0007%	0.0103%
Western North Pacific gray whale	WNP stock/ Western DPS	140	0.0117%	0.0019%	0.0136%
Blainville's beaked whale	WNP	8,032	0.0134%	0.0000%	0.0134%
Common bottlenose dolphin	IA	105,138	0.0012%	0.0000%	0.0012%
Cuvier's beaked whale	WNP	90,725	0.0007%	0.0000%	0.0007%
Deraniyagala's beaked whale	NP	22,799	0.0047%	0.0000%	0.0047%
False killer whale	IA	9,777	0.0204%	0.0000%	0.0204%
Fraser's dolphin	WNP	220,789	0.0063%	0.0000%	0.0063%
Ginkgo-toothed beaked whale	NP	22,799	0.0047%	0.0000%	0.0047%
Killer whale	WNP	12,256	0.0017%	0.0000%	0.0017%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Kogia spp.	WNP	350,553	0.0012%	0.0000%	0.0012%
Long-beaked common dolphin	WNP	279,182	0.0850%	0.0000%	0.0850%
Longman's beaked whale	WNP	4,571	0.0118%	0.0000%	0.0118%
Melon-headed whale	WNP	36,770	0.0209%	0.0000%	0.0209%
Pantropical spotted dolphin	WNP	219,032	0.0063%	0.0000%	0.0063%
Pygmy killer whale	WNP	30,214	0.0008%	0.0000%	0.0008%
Risso's dolphin	IA	83,289	0.0304%	0.0000%	0.0304%
Rough-toothed dolphin	WNP	145,729	0.0043%	0.0000%	0.0043%
Short-finned pilot whale	WNP	53,608	0.0051%	0.0000%	0.0051%
Sperm whale	NP	102,112	0.0023%	0.0000%	0.0023%
Spinner dolphin	WNP	1,015,059	0.0001%	0.0000%	0.0001%
Striped dolphin	IA	570,038	0.0010%	0.0000%	0.0010%
Mission Area 8: Offshore Japan 25° to 40°N; Summer Season					
Blue whale	WNP	9,250	–	–	–
Bryde's whale	WNP	20,501	0.0123%	0.0032%	0.0155%
Common minke whale	WNP "O"	25,049	0.0102%	0.0018%	0.0121%
Fin whale	WNP	9,250	0.0117%	0.0028%	0.0145%
Humpback whale	WNP stock and DPS	1,328	0.2480%	0.1111%	0.3591%
Sei whale	NP	7,000	0.0255%	0.0066%	0.0322%
Baird's beaked whale	WNP	8,000	0.0044%	0.0000%	0.0044%
Blainville's beaked whale	WNP	8,032	0.0217%	0.0000%	0.0217%
Common bottlenose dolphin	WNP	168,791	0.0016%	0.0000%	0.0016%
Cuvier's beaked whale	WNP	90,725	0.0103%	0.0000%	0.0103%
Dwarf sperm whale	WNP	350,553	0.0053%	0.0000%	0.0053%
False killer whale	WNP	16,668	0.0865%	0.0000%	0.0865%
Hubbs' beaked whale	NP	22,799	0.0055%	0.0000%	0.0055%
Killer whale	WNP	12,256	0.0029%	0.0000%	0.0029%
Longman's beaked whale	WNP	4,571	0.0164%	0.0000%	0.0164%
Melon-headed whale	WNP	36,770	0.0294%	0.0000%	0.0294%
Mesoplodon spp.	WNP	22,799	0.0055%	0.0000%	0.0055%
Northern right whale dolphin	NP	68,000	–	–	–
Pacific white-sided dolphin	NP	931,000	0.0014%	0.0000%	0.0014%
Pantropical spotted dolphin	WNP	438,064	0.0076%	0.0000%	0.0076%
Pygmy killer whale	WNP	30,214	0.0013%	0.0000%	0.0013%
Pygmy sperm whale	WNP	350,553	0.0022%	0.0000%	0.0022%
Risso's dolphin	WNP	83,289	0.0023%	0.0000%	0.0023%
Rough-toothed dolphin	WNP	145,729	0.0040%	0.0000%	0.0040%
Short-beaked common dolphin	WNP	3,286,163	0.0123%	0.0000%	0.0123%
Short-finned pilot whale	WNP	53,608	0.0199%	0.0000%	0.0199%
Sperm whale	NP	102,112	0.0044%	0.0000%	0.0044%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Spinner dolphin	WNP	1,015,059	0.0006%	0.0000%	0.0006%
Stejneger's beaked whale	WNP	8,000	0.0156%	0.0000%	0.0156%
Striped dolphin	WNP	570,038	0.0030%	0.0000%	0.0030%
Hawaiian monk seal	Hawaii	1,112	0.0518%	0.0011%	0.0518%
Northern fur seal	Western Pacific	503,609	–	–	–
Mission Area 9: Offshore Japan 10° to 25°N; Winter Season					
Blue whale	WNP	9,250	0.0004%	0.0003%	0.0007%
Bryde's whale	WNP	20,501	0.0061%	0.0051%	0.0112%
Fin whale	WNP	9,250	0.0004%	0.0003%	0.0007%
Humpback whale	WNP stock and DPS	1,328	0.1006%	0.1063%	0.2069%
Omura's whale	WNP	1,800	0.0070%	0.0058%	0.0128%
Sei whale	NP	7,000	0.1729%	0.1442%	0.3171%
Blainville's beaked whale	WNP	8,032	0.0175%	0.0000%	0.0175%
Common bottlenose dolphin	WNP	168,791	0.0013%	0.0000%	0.0013%
Cuvier's beaked whale	WNP	90,725	0.0083%	0.0000%	0.0083%
Deraniyagala's beaked whale	NP	22,799	0.0082%	0.0000%	0.0082%
Dwarf sperm whale	WNP	350,553	0.0034%	0.0000%	0.0034%
False killer whale	WNP	16,668	0.0100%	0.0000%	0.0100%
Fraser's dolphin	CNP	16,992	0.0433%	0.0000%	0.0433%
Ginkgo-toothed beaked whale	NP	22,799	0.0082%	0.0000%	0.0082%
Killer whale	WNP	12,256	0.0021%	0.0000%	0.0021%
Longman's beaked whale	WNP	4,571	0.0110%	0.0000%	0.0110%
Melon-headed whale	WNP	36,770	0.0208%	0.0000%	0.0208%
Pantropical spotted dolphin	WNP	438,064	0.0072%	0.0000%	0.0072%
Pygmy killer whale	WNP	30,214	0.0006%	0.0000%	0.0006%
Pygmy sperm whale	WNP	350,553	0.0014%	0.0000%	0.0014%
Risso's dolphin	WNP	83,289	0.0016%	0.0000%	0.0016%
Rough-toothed dolphin	WNP	145,729	0.0036%	0.0000%	0.0036%
Short-finned pilot whale	WNP	53,608	0.0107%	0.0000%	0.0107%
Sperm whale	NP	102,112	0.0046%	0.0000%	0.0046%
Spinner dolphin	WNP	1,015,059	0.0005%	0.0000%	0.0005%
Striped dolphin	WNP	570,038	0.0029%	0.0000%	0.0029%
Mission Area 10: Hawaii North; Summer Season					
Blue whale	CNP	81	–	–	–
Bryde's whale	Hawaii	798	0.1557%	0.0286%	0.1843%
Common minke whale	Hawaii	25,049	–	–	–
Fin whale	Hawaii	58	–	–	–
Humpback whale	Central stock/ Hawaii DPS	10,103	–	–	–
Sei whale	Hawaii	178	–	–	–

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Blainville's beaked whale	Hawaii	2,338	0.1094%	0.0000%	0.1094%
Common bottlenose dolphin	Hawaii Pelagic	5,950	0.1005%	0.0000%	0.1005%
	Kauai/Niihau	184	0.0001%	0.0000%	0.0001%
	4-Islands	191	0.0000%	0.0000%	0.0000%
	Oahu	743	0.0000%	0.0000%	0.0000%
	Hawaii Island	128	0.0000%	0.0000%	0.0000%
Cuvier's beaked whale	Hawaii	1,941	0.1054%	0.0000%	0.1054%
Dwarf sperm whale	Hawaii	17,519	0.1299%	0.0000%	0.1299%
False killer whale	Hawaii Pelagic	1,540	0.1053%	0.0000%	0.1053%
	Main Hawaiian Islands Insular stock and DPS	151	0.0134%	0.0000%	0.0134%
	Northwestern Hawaiian Islands	617	0.0026%	0.0000%	0.0026%
Fraser's dolphin	Hawaii	16,992	0.1298%	0.0000%	0.1298%
Killer whale	Hawaii	101	0.1422%	0.0000%	0.1422%
Longman's beaked whale	Hawaii	4,571	0.1063%	0.0000%	0.1063%
Melon-headed whale	Hawaiian Islands	5,794	0.0560%	0.0000%	0.0560%
	Kohala Resident	447	0.0000%	0.0000%	0.0000%
Pantropical spotted dolphin	Hawaiian Pelagic	15,917	0.0788%	0.0000%	0.0788%
	Hawaii Island	220	0.0000%	0.0000%	0.0000%
	Oahu	220	0.0000%	0.0000%	0.0000%
	4-Islands	220	0.0000%	0.0000%	0.0000%
Pygmy killer whale	Hawaii	3,433	0.1102%	0.0000%	0.1102%
Pygmy sperm whale	Hawaii	7,138	0.1295%	0.0000%	0.1295%
Risso's dolphin	Hawaii	7,256	0.1277%	0.0000%	0.1277%
Rough-toothed dolphin	Hawaii	6,288	0.1436%	0.0000%	0.1436%
Short-finned pilot whale	Hawaii	12,422	0.1129%	0.0000%	0.1129%
Sperm whale	Hawaii	3,354	0.0995%	0.0000%	0.0995%
Spinner dolphin	Hawaii Pelagic	3,351	0.0447%	0.0000%	0.0447%
	Kauai/Niihau	601	0.0013%	0.0000%	0.0013%
	Hawaii Island	631	0.0000%	0.0000%	0.0000%
	Oahu/4-Islands	355	0.0000%	0.0000%	0.0000%
	Kure/Midway Atoll	260	0.0000%	0.0000%	0.0000%
	Pearl and Hermes Reef	300	0.0000%	0.0000%	0.0000%
Striped dolphin	Hawaii	20,650	0.0762%	0.0000%	0.0762%
Hawaiian monk seal	Hawaii	1,112	0.0023%	0.0001%	0.0023%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Mission Area 11: Hawaii South; Fall Season					
Blue whale	CNP	81	0.1105%	0.0832%	0.1937%
Bryde's whale	Hawaii	798	0.1030%	0.0749%	0.1779%
Common minke whale	Hawaii	25,049	0.0023%	0.0016%	0.0040%
Fin whale	Hawaii	58	0.0968%	0.0648%	0.1616%
Humpback whale	Central stock/ Hawaii DPS	10,103	0.0209%	0.0155%	0.0364%
Sei whale	Hawaii	178	0.1539%	0.1120%	0.2659%
Blainville's beaked whale	Hawaii	2,338	0.0919%	0.0000%	0.0919%
Common bottlenose dolphin	Hawaii Pelagic	5,950	0.0922%	0.0000%	0.0922%
	Kauai/Niihau	184	0.0000%	0.0000%	0.0000%
	4-Islands	191	0.0001%	0.0000%	0.0001%
	Oahu	743	0.0007%	0.0000%	0.0007%
	Hawaii Island	128	0.0000%	0.0000%	0.0000%
Cuvier's beaked whale	Hawaii	1,941	0.0886%	0.0000%	0.0886%
Deraniyagala beaked whale	NP	22,799	0.0088%	0.0000%	0.0088%
Dwarf sperm whale	Hawaii	17,519	0.1072%	0.0000%	0.1072%
False killer whale	Hawaii Pelagic	1,540	0.0933%	0.0000%	0.0933%
	Main Hawaiian Islands Insular stock and DPS	151	0.0562%	0.0000%	0.0562%
Fraser's dolphin	Hawaii	16,992	0.1051%	0.0000%	0.1051%
Killer whale	Hawaii	101	0.1125%	0.0000%	0.1125%
Longman's beaked whale	Hawaii	4,571	0.0893%	0.0000%	0.0893%
Melon-headed whale	Hawaiian Islands	5,794	0.0496%	0.0000%	0.0496%
	Kohala Resident	447	0.0112%	0.0000%	0.0112%
Pantropical spotted dolphin	Hawaiian Pelagic	15,917	0.0808%	0.0000%	0.0808%
	Hawaii Island	220	0.1293%	0.0000%	0.1293%
	Oahu	220	0.1027%	0.0000%	0.1027%
	4-Islands	220	0.1438%	0.0000%	0.1438%
Pygmy killer whale	Hawaii	3,433	0.0976%	0.0000%	0.0976%
Pygmy sperm whale	Hawaii	7,138	0.1068%	0.0000%	0.1068%
Risso's dolphin	Hawaii	7,256	0.1025%	0.0000%	0.1025%
Rough-toothed dolphin	Hawaii	6,288	0.1050%	0.0000%	0.1050%
Short-finned pilot whale	Hawaii	12,422	0.0965%	0.0000%	0.0965%
Sperm whale	Hawaii	3,354	0.0799%	0.0000%	0.0799%
Spinner dolphin	Hawaii Pelagic	3,351	0.0458%	0.0000%	0.0458%
	Kauai/Niihau	601	0.0000%	0.0000%	0.0000%
	Hawaii Island	631	0.0016%	0.0000%	0.0016%
	Oahu/4-Islands	355	0.1613%	0.0000%	0.1613%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Striped dolphin	Hawaii	20,650	0.0781%	0.0000%	0.0781%
Hawaiian monk seal	Hawaii	1,112	0.0032%	0.0002%	0.0032%
Mission Area 12: Offshore Southern California; Spring Season					
Blue whale	ENP	1,647	0.0105%	0.0017%	0.0122%
Bryde's whale	ENP	13,000	0.0002%	0.0000%	0.0002%
Common minke whale	C/O/W	478	0.1364%	0.0143%	0.1508%
Eastern North Pacific gray whale	ENP	20,990	0.0318%	0.0000%	0.0318%
Fin whale	C/O/W	3,051	0.0084%	0.0017%	0.0101%
Humpback whale	C/O/W stock/ Mexico DPS	1,918	0.0084%	0.0151%	0.0235%
Sei whale	ENP	126	0.1646%	0.0271%	0.1918%
Western North Pacific gray whale	WNP stock/ Western DPS	140	0.0015%	0.0000%	0.0015%
Baird's beaked whale	C/O/W	847	0.2260%	0.0000%	0.2260%
Blainville's beaked whale	C/O/W	694	0.3495%	0.0000%	0.3495%
Common bottlenose dolphin	C/O/W	1,006	1.5987%	0.0000%	1.5987%
Cuvier's beaked whale	C/O/W	6,590	0.1318%	0.0000%	0.1318%
Dall's porpoise	C/O/W	42,000	0.1760%	0.0000%	0.1760%
Ginkgo-toothed beaked whale	C/O/W	694	0.0699%	0.0000%	0.0699%
Hubb's beaked whale	C/O/W	694	0.3145%	0.0000%	0.3145%
Killer whale	Eastern Pacific Offshore	240	0.3130%	0.0000%	0.3130%
Long-beaked common dolphin	California	107,016	0.1687%	0.0000%	0.1687%
Northern right whale dolphin	C/O/W	21,332	2.2343%	0.0000%	2.2343%
Pacific white-sided dolphin	C/O/W (Northern and Southern)	26,930	0.9424%	0.0000%	0.9424%
Perrin's beaked whale	C/O/W	694	0.3145%	0.0000%	0.3145%
Pygmy beaked whale	C/O/W	694	0.0699%	0.0000%	0.0699%
Pygmy sperm whale	C/O/W	579	0.4494%	0.0000%	0.4494%
Risso's dolphin	C/O/W	6,272	0.3804%	0.0000%	0.3804%
Short-beaked common dolphin	C/O/W	411,211	0.4863%	0.0000%	0.4863%
Short-finned pilot whale	C/O/W	760	0.0595%	0.0000%	0.0595%
Sperm whale	C/O/W	2,106	0.3340%	0.0000%	0.3340%
Stejneger's beaked whale	C/O/W	694	0.2097%	0.0000%	0.2097%
Striped dolphin	C/O/W	10,908	0.1136%	0.0000%	0.1136%
California sea lion	U.S. (Pacific Temperate)	296,750	0.0013%	0.0000%	0.0013%
Guadalupe fur seal	Mexico	7,408	0.0553%	0.0000%	0.0553%
Harbor seal	California	30,968	0.0852%	0.0066%	0.0918%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Northern elephant seal	California Breeding	179,000	0.0002%	0.0000%	0.0002%
Northern fur seal	California	14,050	0.1340%	0.0000%	0.1340%
Mission Area 13: Western North Atlantic (off Florida); Winter Season					
Common minke whale	Canadian East Coast	20,741	0.0451%	0.0583%	0.1034%
Humpback whale	Gulf of Maine stock/West Indies DPS	12,312	0.0015%	0.0026%	0.0041%
North Atlantic right whale	WNA	476	0.0243%	0.0229%	0.0405%
Atlantic spotted dolphin	WNA	44,715	0.0937%	0.0000%	0.0937%
Clymene dolphin	WNA	6,086	1.5192%	0.0000%	1.5192%
Common bottlenose dolphin	Offshore WNA	77,532	0.1781%	0.0000%	0.1781%
	Southern Migratory Coast	9,173	0.0000%	0.0000%	0.0000%
	Northern Florida Coast	1,219	0.0000%	0.0000%	0.0000%
	Central Florida Coast	4,895	0.0000%	0.0000%	0.0000%
Cuvier's beaked whale	WNA	6,532	0.0682%	0.0000%	0.0682%
False killer whale	WNA	442	0.0623%	0.0000%	0.0623%
Killer whale	WNA	67	0.0475%	0.0000%	0.0475%
Kogia spp.	WNA	3,785	0.0836%	0.0000%	0.0836%
Mesoplodon spp.	WNA	7,092	0.0681%	0.0000%	0.0681%
Pantropical spotted dolphin	WNA	3,333	0.6688%	0.0000%	0.6688%
Risso's dolphin	WNA	18,250	0.0750%	0.0000%	0.0750%
Rough-toothed dolphin	WNA	271	0.8154%	0.0000%	0.8154%
Short-beaked common dolphin	WNA	173,486	0.0022%	0.0000%	0.0022%
Short-finned pilot whale	WNA	21,515	0.1034%	0.0000%	0.1034%
Sperm whale	WNA	2,288	0.0903%	0.0000%	0.0903%
Spinner dolphin	WNA	262	0.5597%	0.0000%	0.5597%
Striped dolphin	WNA	54,807	0.0199%	0.0000%	0.0199%
Mission Area 14: Eastern North Atlantic; Summer Season					
Blue whale	ENA	979	0.0219%	0.1729%	0.1948%
Common minke whale	Northeast Atlantic	78,572	0.0516%	0.2664%	0.3180%
Fin whale	ENA	9,019	0.1355%	1.5374%	1.6729%
Humpback whale	Iceland stock/Cape Verdes and West Africa DPS	11,572	0.0017%	0.0141%	0.0157%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Sei whale	Iceland-Denmark Strait	10,300	0.0487%	0.2385%	0.2872%
Atlantic white-sided dolphin	ENA	3,904	0.0024%	0.0000%	0.0024%
Blainville’s beaked whale	ENA	6,992	1.0967%	0.0000%	1.0967%
Common bottlenose dolphin	ENA	35,780	0.1025%	0.0000%	0.1025%
Cuvier’s beaked whale	ENA	6,992	1.0967%	0.0000%	1.0967%
Gervais' beaked whale	ENA	6,992	1.0967%	0.0000%	1.0967%
Harbor porpoise	ENA	375,358	0.1602%	0.0000%	0.1602%
Killer whale	Northern Norway	731	0.0364%	0.0000%	0.0364%
Kogia spp.	ENA	3,785	0.3575%	0.0000%	0.3575%
Long-finned pilot whale	ENA	128,093	0.7065%	0.0000%	0.7065%
Northern bottlenose whale	ENA	19,538	0.2533%	0.0000%	0.2533%
Risso’s dolphin	ENA	18,250	0.1943%	0.0000%	0.1943%
Short-beaked common dolphin	ENA	172,930	0.1426%	0.0000%	0.1426%
Sowerby’s beaked whale	ENA	6,992	1.0967%	0.0000%	1.0967%
Sperm whale	ENA	7,785	0.0837%	0.0000%	0.0837%
Striped dolphin	ENA	67,414	0.0198%	0.0000%	0.0198%
True's beaked whale	ENA	6,992	1.0967%	0.0000%	1.0967%
White-beaked dolphin	ENA	16,536	0.7899%	0.0000%	0.7899%
Gray seal	Northwest Europe	116,800	0.0050%	0.0000%	0.0050%
Harbor seal	Northwest Europe	40,414	1.0046%	0.0000%	1.0046%
Mission Area 15: Mediterranean Sea; Summer Season					
Fin whale	Mediterranean	3,583	0.7794%	0.9256%	1.7050%
Common bottlenose dolphin	WM	1,676	0.6764%	0.0000%	0.6764%
Cuvier’s beaked whale	Alboran Sea	429	0.3687%	0.0000%	0.3687%
Long-finned pilot whale	ENA	21,515	0.2394%	0.0000%	0.2394%
Risso’s dolphin	WM	5,320	0.5147%	0.0000%	0.5147%
Short-beaked common dolphin	WM	19,428	0.2334%	0.0000%	0.2334%
Sperm whale	WM	396	1.4879%	0.0000%	1.4879%
Striped dolphin	WM	117,880	0.3756%	0.0000%	0.3756%
Mission Area 16: Arabian Sea; Summer Season					
Blue whale	NIND	3,432	0.0043%	0.0010%	0.0053%
Bryde's whale	NIND	9,176	0.0170%	0.0031%	0.0201%
Common minke whale	IND	257,500	0.0149%	0.0034%	0.0182%
Fin whale	IND	1,716	0.1652%	0.0332%	0.1985%
Humpback whale	AS stock and	200	0.0620%	0.0100%	0.0720%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
	DPS				
Blainville's beaked whale	IND	16,867	0.0443%	0.0000%	0.0443%
Common bottlenose dolphin	IND	785,585	0.0133%	0.0000%	0.0133%
Cuvier's beaked whale	IND	27,272	0.0306%	0.0000%	0.0306%
Deraniyagala beaked whale	IND	16,867	0.0446%	0.0000%	0.0446%
Dwarf sperm whale	IND	10,541	0.0016%	0.0000%	0.0016%
False killer whale	IND	144,188	0.0004%	0.0000%	0.0004%
Fraser's dolphin	IND	151,554	0.0035%	0.0000%	0.0035%
Ginkgo-toothed beaked whale	IND	16,867	0.0446%	0.0000%	0.0446%
Indo-Pacific bottlenose dolphin	IND	7,850	0.0133%	0.0000%	0.0133%
Killer whale	IND	12,593	0.1890%	0.0000%	0.1890%
Long-beaked common dolphin	IND	1,819,882	0.0000%	0.0000%	0.0000%
Longman's beaked whale	IND	16,867	0.1914%	0.0000%	0.1914%
Melon-headed whale	IND	64,600	0.0338%	0.0000%	0.0338%
Pantropical spotted dolphin	IND	736,575	0.0016%	0.0000%	0.0016%
Pygmy killer whale	IND	22,029	0.0150%	0.0000%	0.0150%
Pygmy sperm whale	IND	10,541	0.0005%	0.0000%	0.0005%
Risso's dolphin	IND	452,125	0.0542%	0.0000%	0.0542%
Rough-toothed dolphin	IND	156,690	0.0013%	0.0000%	0.0013%
Short-finned pilot whale	IND	268,751	0.0302%	0.0000%	0.0302%
Sperm whale	NIND	24,446	0.0841%	0.0000%	0.0841%
Spinner dolphin	IND	634,108	0.0015%	0.0000%	0.0015%
Striped dolphin	IND	674,578	0.0294%	0.0000%	0.0294%
Mission Area 17: Andaman Sea; Summer Season					
Blue whale	NIND	3,432	0.0006%	0.0003%	0.0009%
Bryde's whale	NIND	9,176	0.0038%	0.0038%	0.0076%
Common minke whale	IND	257,500	0.0026%	0.0019%	0.0045%
Fin whale	IND	1,716	–	–	–
Omura's whale	IND	9,176	0.0038%	0.0038%	0.0076%
Blainville's beaked whale	IND	16,867	0.0094%	0.0000%	0.0094%
Common bottlenose dolphin	IND	785,585	0.0084%	0.0000%	0.0084%
Cuvier's beaked whale	IND	27,272	0.0297%	0.0000%	0.0297%
Deraniyagala beaked whale	IND	16,867	0.0097%	0.0000%	0.0097%
Dwarf sperm whale	IND	10,541	0.0008%	0.0000%	0.0008%
False killer whale	IND	144,188	0.0002%	0.0000%	0.0002%
Fraser's dolphin	IND	151,554	0.0016%	0.0000%	0.0016%
Ginkgo-toothed beaked whale	IND	16,867	0.0097%	0.0000%	0.0097%
Indo-Pacific bottlenose dolphin	IND	7,850	0.0157%	0.0000%	0.0157%
Killer whale	IND	12,593	0.0691%	0.0000%	0.0691%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Long-beaked common dolphin	IND	1,819,882	0.0000%	0.0000%	0.0000%
Longman's beaked whale	IND	16,867	0.0459%	0.0000%	0.0459%
Melon-headed whale	IND	64,600	0.0145%	0.0000%	0.0145%
Pantropical spotted dolphin	IND	736,575	0.0006%	0.0000%	0.0006%
Pygmy killer whale	IND	22,029	0.0061%	0.0000%	0.0061%
Pygmy sperm whale	IND	10,541	0.0001%	0.0000%	0.0001%
Risso's dolphin	IND	452,125	0.0288%	0.0000%	0.0288%
Rough-toothed dolphin	IND	156,690	0.0007%	0.0000%	0.0007%
Short-finned pilot whale	IND	268,751	0.0156%	0.0000%	0.0156%
Sperm whale	NIND	24,446	0.0063%	0.0000%	0.0063%
Spinner dolphin	IND	634,108	0.0005%	0.0000%	0.0005%
Striped dolphin	IND	674,578	0.0104%	0.0000%	0.0104%
Mission Area 18: Panama Canal (West Approach); Winter Season					
Blue whale	ENP	1,647	0.0173%	0.0120%	0.0293%
Bryde’s whale	ETP	13,000	0.0077%	0.0063%	0.0140%
Common minke whale	ETP	478	0.2171%	0.1706%	0.3877%
Fin whale	ENP	832	–	–	–
Humpback whale	Southeast Pacific stock /Central America DPS	6,000	0.0005%	0.0004%	0.0010%
Blainville's beaked whale	ETP	25,300	0.0258%	0.0000%	0.0258%
Common bottlenose dolphin	ETP	335,834	0.0344%	0.0000%	0.0344%
Cuvier’s beaked whale	ETP	20,000	0.0084%	0.0000%	0.0084%
Deraniyagala's beaked whale	ETP	25,300	0.0258%	0.0000%	0.0258%
False killer whale	ETP	39,800	0.0030%	0.0000%	0.0030%
Fraser’s dolphin	ETP	289,300	0.0010%	0.0000%	0.0010%
Ginkgo-toothed beaked whale	ETP	25,300	0.0190%	0.0000%	0.0190%
Killer whale	ETP	8,500	0.0051%	0.0000%	0.0051%
Kogia spp.	ETP	11,200	0.3703%	0.0000%	0.3703%
Longman's beaked whale	ETP	25,300	0.0258%	0.0000%	0.0258%
Melon-headed whale	ETP	45,400	0.0202%	0.0000%	0.0202%
Mesoplodon spp.	ETP	25,300	0.0217%	0.0000%	0.0217%
Pantropical spotted dolphin	Northeastern Pacific Offshore	640,000	0.0170%	0.0000%	0.0170%
Pygmy killer whale	ETP	38,900	0.0106%	0.0000%	0.0106%
Pygmy beaked whale	ETP	25,300	0.0268%	0.0000%	0.0268%
Risso’s dolphin	ETP	110,457	0.0470%	0.0000%	0.0470%
Rough-toothed dolphin	ETP	107,633	0.0141%	0.0000%	0.0141%
Short-beaked common dolphin	ETP	3,127,203	0.0005%	0.0000%	0.0005%
Short-finned pilot whale	ETP	160,200	0.0322%	0.0000%	0.0322%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Sperm whale	ETP	22,700	0.0549%	0.0000%	0.0549%
Spinner dolphin	Eastern	1,062,879	0.0101%	0.0000%	0.0101%
Striped dolphin	ETP	964,362	0.0205%	0.0000%	0.0205%
Mission Area 19: Northeast Australian Coast; Spring Season					
Blue whale	WSP	9,250	0.0003%	0.0005%	0.0009%
Bryde’s whale	WSP	20,501	0.0084%	0.0147%	0.0231%
Common minke whale	WSP	25,049	0.0528%	0.0810%	0.1337%
Fin whale	WSP	9,250	0.0063%	0.0119%	0.0182%
Humpback whale	IWC Breeding Stock E1/East Australia DPS	14,500	0.0178%	0.0308%	0.0486%
Omura's whale	WSP	1,800	0.0096%	0.0167%	0.0263%
Sei whale	WSP	7,000	0.0247%	0.0429%	0.0677%
Blainville’s beaked whale	WSP	8,032	0.0150%	0.0000%	0.0150%
Common bottlenose dolphin	WSP	168,791	0.0267%	0.0000%	0.0267%
Cuvier’s beaked whale	WSP	90,725	0.0144%	0.0000%	0.0144%
False killer whale	WSP	16,668	0.0520%	0.0000%	0.0520%
Fraser’s dolphin	WSP	220,789	0.0097%	0.0000%	0.0097%
Gingko-toothed beaked whale	WSP	22,799	0.0053%	0.0000%	0.0053%
Killer whale	WSP	12,256	0.0021%	0.0000%	0.0021%
Kogia spp.	WSP	350,553	0.0026%	0.0000%	0.0026%
Longman's beaked whale	WSP	4,571	0.0132%	0.0000%	0.0132%
Melon-headed whale	WSP	36,770	0.0348%	0.0000%	0.0348%
Pantropical spotted dolphin	WSP	438,064	0.0086%	0.0000%	0.0086%
Pilot whales	WSP	53,608	0.0853%	0.0000%	0.0853%
Pygmy killer whale	WSP	30,214	0.0208%	0.0000%	0.0208%
Risso’s dolphin	WSP	83,289	0.0382%	0.0000%	0.0382%
Rough-toothed dolphin	WSP	145,729	0.0122%	0.0000%	0.0122%
Short-beaked common dolphin	WSP	3,286,163	0.0053%	0.0000%	0.0053%
Sperm whale	WSP	102,112	0.0027%	0.0000%	0.0027%
Spinner dolphin	WSP	1,015,059	0.0002%	0.0000%	0.0002%
Striped dolphin	WSP	570,038	0.0158%	0.0000%	0.0158%
Mission Area 20: Northwest Australia; Winter Season					
Antarctic minke whale	ANT	90,000	–	–	–
Blue whale	SIND	1,657	–	–	–
Bryde's whale	SIND	13,854	0.0112%	0.0035%	0.0147%
Common minke whale	IND	257,500	–	–	–
Fin whale	SIND	38,185	0.0001%	0.0000%	0.0001%
Humpback whale	WAU stock and DPS	13,640	–	–	–

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Omura's whale	IND	13,854	0.0112%	0.0035%	0.0147%
Sei whale	IND	13,854	0.0004%	0.0001%	0.0005%
Blainville's beaked whale	IND	16,867	0.0130%	0.0000%	0.0130%
Common bottlenose dolphin	IND	3,000	2.2106%	0.0000%	2.2106%
Cuvier's beaked whale	IND	76,500	0.0138%	0.0000%	0.0138%
Dwarf sperm whale	IND	10,541	0.0012%	0.0000%	0.0012%
False killer whale	IND	144,188	0.0004%	0.0000%	0.0004%
Fraser's dolphin	IND	151,554	0.0026%	0.0000%	0.0026%
Killer whale	IND	12,593	0.1348%	0.0000%	0.1348%
Longman's beaked whale	IND	16,867	0.0614%	0.0000%	0.0614%
Melon-headed whale	IND	64,600	0.0288%	0.0000%	0.0288%
Pantropical spotted dolphin	IND	736,575	0.0022%	0.0000%	0.0022%
Pygmy killer whale	IND	22,029	0.0118%	0.0000%	0.0118%
Risso's dolphin	IND	452,125	0.0459%	0.0000%	0.0459%
Rough-toothed dolphin	IND	156,690	0.0012%	0.0000%	0.0012%
Short-finned pilot whale	IND	268,751	0.0245%	0.0000%	0.0245%
Southern bottlenose whale	IND	599,300	0.0005%	0.0000%	0.0005%
Spade-toothed beaked whale	IND	16,867	0.0130%	0.0000%	0.0130%
Sperm whale	SIND	24,446	0.0094%	0.0000%	0.0094%
Spinner dolphin	IND	634,108	0.0020%	0.0000%	0.0020%
Striped dolphin	IND	674,578	0.0398%	0.0000%	0.0398%
Mission Area 21: Northeast of Japan; Summer Season					
Blue whale	WNP	9,250	0.0032%	0.0207%	0.0240%
Common minke whale	WNP "O"	25,049	0.2524%	2.0587%	2.3111%
Fin whale	WNP	9,250	0.0663%	0.3923%	0.4586%
Humpback whale	WNP stock and DPS	1,328	0.0990%	3.3158%	3.4148%
North Pacific right whale	WNP	922	0.0248%	0.3640%	0.3888%
Sei whale	NP	7,000	0.0877%	0.5184%	0.6061%
Western North Pacific gray whale	WNP stock/Western DPS	140	0.0086%	0.0040%	0.0126%
Baird's beaked whale	WNP	8,000	1.6190%	0.0000%	1.6190%
Cuvier's beaked whale	WNP	90,725	0.1015%	0.0000%	0.1015%
Dall's porpoise	WNP	173,638	0.9080%	0.0000%	0.9080%
Killer whale	WNP	12,256	1.4834%	0.0000%	1.4834%
Pacific white-sided dolphin	NP	931,000	0.0180%	0.0000%	0.0180%
Short-beaked common dolphin	WNP	3,286,163	0.1428%	0.0000%	0.1428%
Sperm whale	NP	102,112	0.0289%	0.0000%	0.0289%
Stejneger's beaked whale	WNP	8,000	0.1066%	0.0000%	0.1066%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Northern fur seal	Western Pacific	503,609	0.0712%	0.0000%	0.0712%
Ribbon seal	NP	61,100	1.5390%	0.0118%	1.5509%
Spotted seal	Alaska stock/Bering Sea DPS	460,268	–	–	–
Steller sea lion	Western-Asian stock and Western DPS	68,218	0.0004%	0.0000%	0.0004%
Mission Area 22: Gulf of Alaska; Summer Season					
Blue whale	ENP	1,647	0.0000%	0.0000%	0.0000%
Common minke whale	AK	1,233	1.5012%	6.8905%	8.3917%
Eastern North Pacific gray whale	ENP	20,990	0.0259%	0.1815%	0.2074%
Fin whale	AK/Northeast Pacific	1,368	1.1227%	6.4168%	7.5395%
Humpback whale	WNP and CNP stocks/Hawaii, Mexico, and WNP DPSs	10,103	0.0025%	0.0020%	0.0044%
North Pacific right whale	ENP	31	1.9699%	1.0916%	3.0615%
Sei whale	ENP	126	1.4725%	1.6000%	3.0725%
Baird's beaked whale	AK	847	0.7937%	0.0000%	0.7937%
Cuvier's beaked whale	AK	6,590	0.6249%	0.0000%	0.6249%
Dall's porpoise	AK	173,638	0.7273%	0.0000%	0.7273%
Killer whale	ENP AK Resident	2,347	0.0141%	0.0000%	0.0141%
	ENP Gulf of Alaska, Aleutian Islands, and Bering Sea Transient	587	1.4685%	0.0000%	1.4685%
Pacific white-sided dolphin	NP	26,880	1.9308%	0.0000%	1.9308%
Sperm whale	NP	102,112	0.0148%	0.0000%	0.0148%
Stejneger's beaked whale	AK	694	2.0343%	0.0000%	2.0343%
Northern elephant seal	California Breeding	179,000	0.0513%	0.0003%	0.0515%
Northern fur seal	EP	648,534	0.0824%	0.0000%	0.0824%
Ribbon seal	AK	184,000	0.0000%	0.0000%	0.0000%
Stellar Sea Lion	Eastern U.S. stock/Eastern DPS	60,131	0.0017%	0.0000%	0.0017%
	Western U.S.	49,497	0.3218%	0.0000%	0.3218%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
	stock/Western DPS				
Mission Area 23: Norwegian Basin; Summer Season					
Blue whale	ENA	979	0.0108%	0.0047%	0.0154%
Common minke whale	Northeast Atlantic	78,572	0.3117%	0.0514%	0.3631%
Fin whale	North-West Norway	6,409	0.2578%	0.2126%	0.4705%
Humpback whale	Iceland stock/ Cape Verdes-West Africa and West Indies DPSs	11,572	0.0066%	0.0011%	0.0077%
Sei whale	Iceland-Denmark Strait	10,300	0.0007%	0.0001%	0.0008%
Atlantic white-sided dolphin	ENA	3,904	0.0006%	0.0000%	0.0006%
Cuvier's beaked whale	ENA	6,992	0.8572%	0.0000%	0.8572%
Harbor porpoise	ENA	375,358	0.0059%	0.0000%	0.0059%
Killer whale	Northern Norway	731	0.0073%	0.0000%	0.0073%
Long-finned pilot whale	ENA	128,093	0.1955%	0.0000%	0.1955%
Northern bottlenose whale	ENA	19,538	0.0928%	0.0000%	0.0928%
Sowerby's beaked whale	ENA	6,992	0.8572%	0.0000%	0.8572%
Sperm whale	ENA	7,785	0.2627%	0.0000%	0.2627%
White-beaked dolphin	ENA	16,536	0.1567%	0.0000%	0.1567%
Hooded seal	West Ice	84,020	0.0660%	0.0008%	0.0660%
Mission Area 24: Western North Atlantic (off Norfolk, VA); Summer Season					
Common minke whale	Canadian East Coast	20,741	0.0023%	0.0005%	0.0029%
Fin whale	WNA	1,618	0.1852%	0.0640%	0.2491%
Humpback whale	Gulf of Maine stock/West Indies DPS	12,312	0.0015%	0.0001%	0.0016%
North Atlantic right whale	WNA	476	0.0000%	0.0000%	0.0000%
Atlantic spotted dolphin	WNA	44,715	0.3088%	0.0000%	0.3088%
Clymene dolphin	WNA	6,086	0.3355%	0.0000%	0.3355%
Common bottlenose dolphin	Offshore WNA	77,532	0.0973%	0.0000%	0.0973%
	Northern Migratory Coastal	11,548	0.0000%	0.0000%	0.0000%
	Southern Migratory	9,173	0.0000%	0.0000%	0.0000%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
	Coastal				
Cuvier’s beaked whale	WNA	6,532	0.3596%	0.0000%	0.3596%
False killer whale	WNA	442	0.0357%	0.0000%	0.0357%
Killer whale	WNA	67	0.0337%	0.0000%	0.0337%
Kogia spp.	WNA	3,785	0.0494%	0.0000%	0.0494%
Mesoplodon spp.	WNA	7,092	0.3599%	0.0000%	0.3599%
Pantropical spotted dolphin	WNA	3,333	0.2215%	0.0000%	0.2215%
Risso’s dolphin	WNA	18,250	0.2879%	0.0000%	0.2879%
Rough-toothed dolphin	WNA	271	0.5222%	0.0000%	0.5222%
Short-beaked common dolphin	WNA	173,486	0.0877%	0.0000%	0.0877%
Short-finned pilot whale	WNA	21,515	0.2680%	0.0000%	0.2680%
Sperm whale	WNA	2,288	1.5558%	0.0000%	1.5558%
Spinner dolphin	WNA	262	0.1861%	0.0000%	0.1861%
Striped dolphin	WNA	54,807	0.3491%	0.0000%	0.3491%
Mission Area 25: Labrador Sea; Winter Season					
Blue whale	WNA	440	0.0973%	0.6610%	0.7583%
Common minke whale	Canadian East Coast	20,741	0.0158%	0.1374%	0.1532%
Fin whale	Canadian East Coast	1,352	0.0998%	0.5490%	0.6488%
Humpback whale	Newfoundland-Labrador stock/West Indies DPS	12,312	0.0383%	0.4193%	0.4576%
North Atlantic right whale	WNA	476	0.0000%	0.0000%	0.0000%
Sei whale	Labrador Sea	965	0.0467%	0.3367%	0.3834%
Atlantic white-sided dolphin	Labrador Sea	24,422	0.2859%	0.0000%	0.2859%
Harbor porpoise	Newfoundland	3,326	0.0715%	0.0000%	0.0715%
Killer whale	WNA	67	0.5844%	0.0000%	0.5844%
Long-finned pilot whale	Canadian East Coast	6,134	0.0000%	0.0000%	0.0000%
Northern bottlenose whale	Davis Strait	50	0.6543%	0.0000%	0.6543%
Short-beaked common dolphin	WNA	173,486	0.0227%	0.0000%	0.0227%
Sowerby's beaked whale	WNA	50	0.3187%	0.0000%	0.3187%
Sperm whale	WNA	2,288	0.8136%	0.0000%	0.8136%
White-beaked dolphin	Canadian East Coast	15,625	0.1721%	0.0000%	0.1721%
Harp seal	WNA	7,411,000	0.0405%	0.0024%	0.0428%
Hooded seal	WNA	592,100	0.0458%	0.0004%	0.0461%
Ringed seal	Arctic	787,000	0.3948%	0.0230%	0.4178%

Table 4-7. Percentage of marine mammal stocks potentially affected by 24 hr of SURTASS LFA sonar transmissions estimated for one season in 26 representative mission areas; percent stock affected (with mitigation applied) at MMPA Level A is 0.0000 percent for all marine mammal stocks in all representative mission areas.

Marine Mammal Species	*Stock[1] Name*	*Stock Abundance*	*Percent Stock Affected—Behavioral Risk*	*Percent Stock Affected—TTS*	*Percent Stock Affected—Total Level B Harassment*
Mission Area 26: Sea of Okhotsk; Spring Season					
Bowhead whale	Okhotsk Sea	247	0.0005%	0.0186%	0.0191%
Common minke whale	WNP "O"	25,049	0.0068%	0.4192%	0.4260%
	WNP "J"	893	0.0069%	0.4221%	0.4290%
Fin whale	WNP	9,250	0.0004%	0.0139%	0.0143%
Humpback whale	WNP stock and DPS	1,328	0.0058%	0.3833%	0.3892%
North Pacific right whale	WNP	922	–	–	–
Western North Pacific gray whale	WNP stock/Western DPS	140	–	–	–
Baird's beaked whale	WNP	8,000	0.0604%	0.0000%	0.0604%
Beluga	Okhotsk Sea	12,226	0.1523%	0.0000%	0.1523%
Dall's porpoise	WNP *dalli*-type	111,402	0.3907%	0.0000%	0.3907%
	WNP *truei*-type	101,173	0.3907%	0.0000%	0.3907%
Harbor porpoise	WNP	31,046	0.1916%	0.0000%	0.1916%
Killer whale	Okhotsk-Kamchatka-Western Aleutians Transient	12,256	0.0968%	0.0000%	0.0968%
Pacific white-sided dolphin	NP	931,000	0.0016%	0.0000%	0.0016%
Sperm whale	NP	102,112	0.0023%	0.0000%	0.0023%
Bearded seal	Okhotsk stock and DPS	200,000	0.0215%	0.0005%	0.0220%
Northern fur seal	Western Pacific	503,609	0.0385%	0.0000%	0.0385%
Ribbon seal	Sea of Okhotsk	124,000	0.2941%	0.0029%	0.2970%
Ringed seal	Okhotsk	676,000	0.1425%	0.0014%	0.1439%
Spotted seal	Sea of Okhotsk stock and DPS	180,000	0.6207%	0.0062%	0.6269%
Steller sea lion	Western stock and DPS	82,516	0.0815%	0.0000%	0.0815%

4.3.1 No Action Alternative

Under the No Action Alternative, the Proposed Action would not occur and there would be no change to economic resources. Therefore, no significant impacts to economic resources would occur with implementation of the No Action Alternative.

Economic Resource Potential Impacts:

- Commercial fisheries: minimal potential to affect individual fish or fish species; therefore, negligible impacts on commercial fisheries.
- Subsistence harvesting of marine mammals: geographic restrictions results in no overlap in time or space with subsistence hunts; therefore, no unmitigable adverse impacts.
- Recreational marine activities primarily occur within the coastal geographic restriction of SURTASS LFA sonar and therefore will not be affected.

4.3.2 Alternative 1/Alternative 2

The study area for the analysis of impacts to economic resources associated with Alternative 1 and Alternative 2/Preferred Alternative includes the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea. SURTASS LFA sonar will not operate in polar regions. Additional geographical restrictions include maintaining received levels for SURTASS LFA sonar below established levels within OBIA boundaries and recreational and commercial dive sites, as described in Chapter 2. The only difference between Alternatives 1 and 2 is the maximum number of hours of LF sound transmision per vessel, i.e., 432 hrs per vessel per year under Alternative 1 and 255 hrs per vessel per year under Alternative 2.

4.3.2.1 Potential Impacts to Commercial Fisheries

SURTASS LFA sonar operations are geographically restricted such that received levels are less than 180 dB re 1 µPa (rms) SPL within 12 nmi (22 km) from coastlines where fisheries productivity is generally high. If SURTASS LFA sonar operations occur in proximity to fish stocks, members of some fish species could potentially be affected by the low frequency sounds, but there is no potential for fitness level consequences. Given the studies of sound exposure to fishes, the potential for impacts is restricted to within close proximity of LFA sonar while it is transmitting. A summary of the thresholds defined by Popper et al. (2014), and modified by NMFS (2015) to account for the signal duration of exposure, shows that the probability of an impact is low to moderate and would require fishes to be within close proximity (<0.54 nmi [<1 km]) of the LFA sonar (Table 4-1). Since this would represent a minimal to negligible portion of any fish stock, there is minimal potential for LFA sonar to affect fish species. Due to the negligible impacts on fish from the operation of LFA sonar within the required guidelines and restrictions, there will be negligible impacts on commercial fisheries.

4.3.2.2 Potential Impacts to Subsistence Harvest of Marine Mammals

The impact of the operation of LFA sonar on subsistence harvesting of marine mammals was discussed in Subchapter 4.6.2 of the 2012 SEIS/SOEIS (DoN, 2012). The information presented remains pertinent and valid to the discussion of impact on subsistence harvesting going forward and is therefore incorporated herein by reference. In summary, with the geographic restrictions associated with operations near coastal waters (within 12 nmi [22 km] of any coastline) and OBIAs, there would be no overlap in time or space with subsistence hunts of marine mammals. In addition, the current and potential future employment of LFA sonar would not lead to unmitigable adverse impacts on the availability of marine mammal species or stocks for subsistence use, particularly in the Gulf of Alaska and off the coasts of Washington or Oregon.

4.3.2.3 Potential Impacts to Recreational Marine Activities

4.3.2.3.1 Recreational Diving, Swimming, Snorkeling

There will be no significant impacts on recreational divers, swimmers, or snorkelers that submerge themselves below the ocean's surface due to the operation of LFA sonar. This is due to the geographic restrictions imposed on LFA sonar operations that limit the received level at known recreational and commercial dive sites to no greater than 145 dB re 1 µPa (rms). Received levels at or below this limit will not have an adverse impact on recreational or commercial divers.

The vast majority of recreational swimming, snorkeling and diving occurs within 12 nmi (22 km) of shore. Since LFA sonar operations are restricted from transmitting received levels of greater than 180 dB re 1 µPa (rms) within 12 nmi (22 km) from shore there is no reasonably foreseeable likelihood that operation of SURTASS LFA sonar will affect recreational diving, snorkeling or swimming.

4.3.2.3.2 Whale Watching

There will be no significant impacts on whale watching activities as a result of the employment of SURTASS LFA sonar due to the imposed geographic restrictions. These geographic restrictions were designed such that LFA operations would avoid areas that may contain high concentrations of marine mammals, which correlate to prime whale watching areas. Therefore SURTASS LFA sonar operations will have no impact on whale watching activities since they will not transpire in areas where these activities occur.

4.4 Summary of Significant Environmental Impacts of the Alternatives

A summary of the potential impacts associated with each of the action alternatives and the No Action Alternative is presented in Table 4-8.

4.5 Cumulative Impacts

This section 1) defines the scope of the cumulative impacts analysis, 2) describes past, present, and reasonably foreseeable future actions relevant to cumulative impacts, 3) analyzes the incremental interaction the Proposed Action may have with other actions, and 4) evaluates cumulative impacts potentially resulting from these interactions.

The approach taken in the analysis of cumulative impacts follows the objectives of NEPA, CEQ regulations, and CEQ guidance. Cumulative impacts are defined in 40 CFR section 1508.7 as the following:

> "The impact on the environment that results from the incremental impact of the action when added to the other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

Table 4-8. Summary of Potential Impacts to Resource Areas[12]

Resource Area	*No Action Alternative*	*Alternative 1*	*Alternative 2*
Water Resources			
	No impact	Intermittent increase in ambient noise level during LFA sonar transmissions for a maximum of 432 hr per vessel per year	Intermittent increase in ambient noise level during LFA sonar transmissions for a maximum of 255 hr per vessel per year
Biological Resources			
Marine Invertebrates	No impact	Using the best available science, the Navy concludes that it is unlikely that biologically meaningful responses will occur due to high hearing thresholds and low potential of being exposed to SURTASS LFA transmissions make it unlikely that biologically meaningful responses will occur	
Marine Fishes	No impact	The Navy concludes after evaluating potential impacts using the best available science that a low to moderate probability of non-auditory, auditory, behavioral, masking, or physiological stress impacts may result when fish are in close proximity (<0.54 nmi [<1 km]) of the LFA sonar	
Sea turtles	No impact	Low to moderate potential of non-auditory, auditory, behavioral, masking, or physiological stress impacts when turtles are in close proximity (<0.54 nmi [<1 km]) of the transmitting SURTASS LFA sonar based on use of the best available science	
Marine mammals	No impact	Potential for auditory or behavioral impacts evaluated quantitatively with the best available science; low to moderate probability of non-auditory, masking, or physiological stress assessed with best available scientific information and data	
Marine Habitats	No impact	Small, intermittent, and transitory increase in overall acoustic environment of marine habitats resulting in a negligible impact	Vanishingly small, intermittent, and transitory increase in overall acoustic environment of marine habitats resulting in an negligible impact
Economic Resources			
Commercial fisheries	No impact	Minimal potential for impacts to fish species and no potential for fitness level consequences resulting in negligible impacts on commercial fisheries	
Subsistence harvest of marine mammals	No impact	Geographic restrictions would result in no overlap in time or space with subsistence hunts of marine mammals, therefore no adverse impacts on the availability of marine mammal species or stocks for subsistence use	
Recreational marine activities	No impact	Geographic restrictions limit the received level at known recreational and commercial dive sites to no greater than 145 dB re 1 µPa (rms) (SPL), resulting in no impact; the geographic restrictions were developed to limit the sonar levels in coastal waters in which higher concentrations of marine mammals may occur, which correlates to areas of prime whale watching and thus, would result in no impact to whale watching activities; additionally the same geographic restrictions would protect human swimmers in nearshore waters	

12 If the conclusions for Alternative 1 and 2 were the same, one conclusion was presented for both alternatives.

To determine the scope of environmental impact statements, agencies shall consider cumulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement.

In addition, CEQ and USEPA have published guidance addressing implementation of cumulative impact analyses—Guidance on the Consideration of Past Actions in Cumulative Effects Analysis (CEQ, 2005) and Consideration of Cumulative Impacts in EPA Review of NEPA Documents (U.S. EPA, 1999). CEQ guidance entitled *Considering Cumulative Impacts Under NEPA* (1997) states that cumulative impact analyses should

> "…determine the magnitude and significance of the environmental consequences of the Proposed Action in the context of the cumulative impacts of other past, present, and future actions...identify significant cumulative impacts…[and]…focus on truly meaningful impacts."

Cumulative impacts are most likely to arise when a relationship or synergism exists between a Proposed Action and other actions expected to occur in a similar location or during a similar time period. Actions overlapping with or in close proximity to the Proposed Action would be expected to have more potential for a relationship than those more geographically separated. Similarly, relatively concurrent actions would tend to offer a higher potential for cumulative impacts. To identify cumulative impacts, the analysis needs to address the following three fundamental questions.

- Does a relationship exist such that affected resource areas of the Proposed Action might interact with the affected resource areas of past, present, or reasonably foreseeable actions?
- If one or more of the affected resource areas of the Proposed Action and another action could be expected to interact, would the Proposed Action affect or be affected by impacts of the other action?
- If such a relationship exists, then does an assessment reveal any potentially significant impacts not identified when the Proposed Action is considered alone?

4.5.1 Scope of Cumulative Impacts Analysis

The scope of the cumulative impacts analysis involves both the geographic extent of the impacts and the time frame in which the impacts could be expected to occur. For this SEIS/SOEIS, the study area delimits the geographic extent of the cumulative impacts analysis. In general, the study area will include those areas previously identified in Chapter 4 for the respective resource areas. The time frame for cumulative impacts centers on the timing of the Proposed Action.

Another factor influencing the scope of cumulative impacts analysis involves identifying other actions to consider. Beyond determining that the geographic scope and time frame for the actions interrelate to the Proposed Action, the analysis employs the measure of "reasonably foreseeable" to include or exclude other actions. For the purposes of this analysis, public documents prepared by federal, state, and local government agencies form the primary sources of information regarding reasonably foreseeable actions. Documents used to identify other actions include notices of intent for EISs and EAs, management plans, land use plans, and other planning related studies.

4.5.2 Past, Present, and Reasonably Foreseeable Actions

This section will focus on past, present, and reasonably foreseeable future projects in the Pacific, Atlantic and Indian oceans and the Mediterrean Sea. In determining which projects to include in the cumulative impacts analysis, a preliminary determination was made regarding the past, present, or reasonably foreseeable action. Specifically, using the first fundamental question included in Section 4.5, it was determined if a relationship exists such that the affected resource areas of the Proposed Action might interact with the affected resource areas of a past, present, or reasonably foreseeable action. If no such potential relationship exists, the project was not carried forward into the cumulative impacts analysis. In accordance with CEQ guidance (CEQ, 2005), these actions considered but excluded from further cumulative impacts analysis are not catalogued here as the intent is to focus the analysis on the meaningful actions relevant to inform decision-making. Chapter 3 describes current resource conditions and trends and discusses how past and present human activities influence each resource. Projects included in this cumulative impacts analysis are briefly described in the following subsections (Table 4-9).

Table 4-9. Cumulative Impacts Evaluation

Action	*Location*	*Timeframe*
Maritime traffic	All of study area	Past, present, and future
Seismic exploration	All of study area	Past, present, and future
Alternative energy developments	All of study area	Past, present, and future
Naval and other sonar activity	All of study area	Past, present, and future

4.5.2.1 Maritime Traffic

The dominate source of anthropogenic sound in the ocean stems from the propulsion of ships (Tyack, 2008). At the lower frequencies, the dominant source of this noise is the cumulative impact of ships that are too far away to be heard individually, but because of their great number, contribute substantially to the average noise background. Shipping noise centers in the 20 to 200 Hz frequency band and is increasing yearly (Ross, 2005). Ross (1976) estimated that between 1950 and 1975 shipping had caused a rise of 10 dB in ambient ocean noise levels, and he predicted that the level would increase by another 5 dB by the beginning of the 21st century. Andrew et al. (2002) collected ocean ambient sound data from 1994 to 2001 using a receiver on the continental slope off Point Sur, California. These data were compared to measurements made from 1963 to 1965 by an identical receiver. The data demonstrated an increase in ambient noise over the 33-year period of approximately 10 dB in the frequency range of 20 to 80 Hz primarily due to commercial shipping; there were also increases as large as 9 dB in the frequency ranges 100 Hz up to 400 Hz, for which the cause was less obvious (Andrew et al., 2002).

4.5.2.2 Seismic Exploration

Seismic surveys are performed to obtain information on subsurface geologic formations to identify potential oil and gas reserves. Deep seismic surveys are used to more accurately assess potential hydrocarbon reservoirs. High-resolution seismic surveys are used in the initial site evaluation for drill rig emplacement and platform design. Seismic surveying operations are conducted from ships towing an array of acoustic instruments, including air guns, which release compressed air into the water, creating acoustic energy that penetrates the sea floor. The acoustic signals are reflected off the subsurface sedimentary layers and recorded near the ocean surface on hydrophones spaced along streamer cables. Alternatively, cable grids are laid on the ocean floor to act as receivers and are later retrieved. In addition to air guns, seismic surveys utilize numerous other MF and HF acoustic instruments including multi-beam bathymetric sonar, side-scan sonar, and sub-bottom profilers.

Major offshore oil and gas production regions include the continental shelf of the U.S., the coasts of Venezuela, Mexico, and Brazil, the Persian Gulf, the North Sea, and the waters off Africa. Deepwater (greater than 1,000 ft [305 m]) oil and gas exploration activities are on the rise due to improved technology spurred by the discovery of high production reservoirs in deeper waters. As such, oil and gas production activities are extending to greater depths and associated greater distances from the coastline.

4.5.2.3 Alternative Energy Developments

As offshore wind energy generation increases, the underwater noise levels generated from the operation of the wind farms would need further investigation. The first offshore wind facility was constructed in Rhode Island waters, with additional siting surveys occurring off New England and the mid-Atlantic. While other anthropogenic noises such as seismic exploration are more transient in nature, the lifetime of an offshore wind farm is expected to be twenty to thirty years. The associated noises from the operation of the wind farm would result in an almost permanent source of noise in the area of the wind farm (Tougaard et al., 2009). The Bureau of Ocean Energy Management (BOEM) is supporting research to understand the potential impacts associated with alternative energy developments (http://www.boem.gov/Environmental-Studies-Planning/).

4.5.2.4 Naval and other sonar activity

The NMFS has issued incidental take authorizations for U.S. Navy activities within identified training and testing ranges. The Atlantic Fleet Training and Testing and Hawaii Southern California Training and Testing authorizations occur from 2013 to 2018. The Mariana Islands Training and Testing and the Northwest Training and Testing authorizations occur from 2015 to 2020. Training Activities in the Gulf of Alaska Temporary Maritime Activities Area were authorized from 2011 to 2016, with a follow-on authorization for 2016 to 2021. Each of these authorizations includes the use of naval sonar to support and conduct current, emerging, and future training and testing activities.

Marine acoustic surveys are fundamental tools guiding explorations of this planet. Sound can be used to measure bathymetry and to map geology, ocean temperatures, and currents. Numerous scientific research vessels from around the world are engaged in studying all of the Earth's oceans and the underlying seafloor. The data that are being collected are critical to informed decision making regarding our future. Researchers use ship-mounted equipment and unmanned and manned submersible vehicles. For example, several U.S. institutions, including the Woods Hole Oceanographic Institution, Scripps Institution of Oceanography at the University of California-San Diego, Lamont-Doherty Earth Observatory at Columbia University, and several science centers operated by NMFS, conduct research each year over the world's oceans.

4.5.3 Cumulative Impacts Analysis

Where feasible, the cumulative impacts were assessed using quantifiable data; however, for many of the resources included for analysis, quantifiable data are not available and a review of the best available information was undertaken. In addition, where an analysis of potential environmental impacts for future actions has not been completed, assumptions were made regarding cumulative impacts related to this SEIS/SOEIS where possible. The analytical methodology presented in Chapter 4, which was used to determine potential impacts to the various resources analyzed in this document, was also used to determine cumulative impacts. In general, long-term rather than short-term impacts and widespread rather than localized impacts were considered more likely to contribute to cumulative impacts. For example, for biological resources, population-level impacts were considered more likely to contribute to cumulative impacts than were individual-level impacts. Negligible impacts were not considered further in the cumulative impacts analysis. The vast majority of impacts expected from sonar exposure and underwater detonations are behavioral in nature, temporary and comparatively short in duration, relatively infrequent, and not of the type or severity that would be expected to be additive for the small portion of the stocks and species likely to be exposed either annually or in the reasonably foreseeable future.

4.5.3.1 Marine Water Resources

Cumulative water resources impacts from past, present, and future actions would be less than significant because of the operational profile of LFA sonar. As described in Chapter 2, LFA sonar will transmit 60-sec signals at up to a 20 percent duty cycle, but more often at a 7.5-10 percent duty cycle. With the maximum number of transmission hours of Alternative 1 (432 hr per vessel per year), the percentage of the total anthropogenic acoustic energy budget added by each LFA source is estimated to be 0.21 percent per system (or less), when other man-made sources are considered (Hildebrand, 2005); this would be approximately 40 percent less with Alternative 2 (255 hr per vessel per year). Therefore, implementation of the Proposed Action combined with the past, present, and reasonably foreseeable future projects, would not result in significant impacts. Cumulative water resources impacts that would occur with implementation of either alternative would include elevation in level of ambient noise. Since the impact of elevated ambient noise increase would be transitory of a very brief duration, no cumulative impacts on water resources will result from the implementation of the proposed action.

4.5.3.2 Biological Resources

Cumulative biological resources impacts from past, present, and future actions would not be significant since the contribution of potential impacts anticipated from SURTASS LFA sonar operations are not estimated to result in significant impacts to the biological environment. The potential impacts on any marine animal species or stock from non-auditory impacts is vanishingly small. TTS and behavioral change to marine mammals exposed to SURTASS LFA sonar transmissions may result but the impacts are not anticipated to be of biological significance to any stock or result in population level consequences. No mortality or injury is expected due to marine mammal, sea turtle, or fish exposure to SURTASS LFA sonar transmissions. For seismic exploration, direct impacts may include auditory impacts, behavioral change, and masking. In U.S. waters, seismic exploration efforts are primarily focused in the Gulf of Mexico, for which a programmatic EIS and associated authorizations is ongoing. BOEM is supporting research to quantify the potential impacts that may occur with alternative energy facilities, but it is expected that impact would include auditory impacts and behavioral change during construction and masking at short ranges during operation. For the U.S. Navy training and testing activities, the vast majority of impacts expected from sonar exposure and underwater detonations are behavioral in nature, temporary and comparatively short in duration, relatively infrequent, and not of the type or severity that would be expected to be additive for the small portion of the stocks and species likely to be exposed either annually or over the remaining period of the 5-year MMPA regulations or in the reasonably foreseeable future. Therefore, implementation of the Proposed Action combined with the past, present, and reasonably foreseeable future projects, would not result in significant impacts.

4.5.3.3 Economic Resources

Cumulative economic resource impacts from past, present, and future actions would be less than significant because of the negligible impact of LFA sonar on economic resources. There is a negligible potential for impacts on fishes from the operation of LFA sonar, which results in negligible impacts on commercial fisheries. There is no potential to impact subsistence harvest of marine mammals. The geographic restrictions associated with LFA sonar operation would limit impacts to recreational marine activities. Therefore, implementation of the Proposed Action combined with the past, present, and reasonably foreseeable future projects, would not result in significant impacts within the potential operating areas for SURTASS LFA sonar.

4.6 Literature Cited

Aguilar de Soto, N., N. Delorme, J. Atkins, S. Howard, J. Williams, & M. Johnson. (2013). Anthropogenic noise causes body malformations and delays development in marine larvae. *Scientific Reports,* 3, 2831.

André, M., M. Solé, M. Lenoir, M. Durfort, C. Quero, A. Mas, A. Lombarte, M. van der Schaar, M. López-Bejar, M. Morell, S. Zaugg, & L. Houégnigan. (2011). Low-frequency sounds induce acoustic trauma in cephalopods. *Frontiers in Ecology and the Environment, 9*, 489-493.

Andrew, R. K., B. M. Howe, J. A. Mercer, & M. A. Dzieciuch. (2002). Ocean ambient sound: Comparing the 1960s with the 1990s for a receiver off the California coast. *Acoustics Research Letters Online, 3*(2), 65-70.

Andriguetto-Filho, J. M., A. Ostrensky, M. R. Pie, U. A. Silva, & W. A. Boeger. (2005). Evaluating the impact of seismic prospecting on artisanal shrimp fisheries. C*ontinental Shelf Research, 25*(14), 1720-1727.

Antunes, R., P. H. Kvadsheim, F. P. Lam, P. L. Tyack, L. Thomas, P. J. Wensveen, & P. J. Miller. (2014). High thresholds for avoidance of sonar by free-ranging long-finned pilot whales (*Globicephala melas*). *Marine Pollution Bulletin, 83*(1), 165-180.

Atkinson, S., D. E. Crocker, D. Houser, & K. Mashburn. (2015). Stress physiology in marine mammals: how well do they fit the terrestrial model? *Journal of Comparative Physiology B Biochemical Systemic and Environmental Physiology, 185*(5), 463-486.

Bartol, S. M., & J. A. Musick. (2003). Sensory biology of sea turtles. In P. Lutz, J. A. Musick, and J. Wyneken (Eds.), *The Biology of Sea Turtles: Volume II* (pp. 79-102). Boca Raton, Florida: CRC Press.

Bernaldo de Quirós, Y., O. Gonzalez-Diaz, M. Arbelo, E. Sierra, S. Sacchini, & A. Fernandez. (2012). Decompression vs. decomposition: Distribution, amount, and gas composition of bubbles in stranded marine mammals. *Frontiers in Physiology, 3,* 177.

Bernaldo de Quiros, Y., O. Gonzalez-Diaz, A. Mollerlokken, A. O. Brubakk, A. Hjelde, P. Saavedra, & A. Fernandez. (2013). Differentiation at autopsy between in vivo gas embolism and putrefaction using gas composition analysis. *International Journal of Legal Medicine, 127*(2), 437-445.

Calambokidis, J., G. H. Steiger, C. Curtice, J. Harrison, M. C. Ferguson, E. A. Becker, M. DeAnglis, & S. M. Van Parijs. (2015). Biologically important areas for selected cetaceans within U.S. waters – West coast region. *Aquatic Mammals, 41*(1), 39-53.

Clark, C. W., W. T. Ellison, B. L. Southall, L. T. Hatch, S. M. Van Parijs, A. S. Frankel, & D. Ponirakis. (2009). Acoustic masking in marine ecosystems: intuitions, analysis, and implication. *Marine Ecology Progress Series, 395*, 201-222.

Clark, C. W., P. Tyack, & W. T. Ellison. (1999). *Responses of four species of whales to sounds of SURTASS LFA sonar transmissions.* Technical Report 1: Low frequency sound scientific research program technical report. Overseas environmental impact statement and environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar, Vol. 2. (Revised 2001). Washington, D.C.: Chief of Naval Operations, Department of the Navy.

Council on Environmental Quality (CEQ). (1997). *Considering cumulative effects under the National Environmental Policy Act.* Retrieved from <http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/G-CEQ-ConsidCumulEffects.pdf>.

CEQ. (2005). *Guidance on the consideration of past actions in cumulative effects analysis.* Retrieved from <http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/G-CEQ-PastActsCumulEffects.pdf>.

Cunningham, K. A., B. L. Southall, & C. Reichmuth. (2014). Auditory sensitivity of seals and sea lions in complex listening scenarios. *The Journal of the Acoustical Society of America, 136*(6), 3410.

D'Amico, A., R. C. Gisiner, D. R. Ketten, J. A. Hammock, C. Johnson, P. L. Tyack, & J. G. Mead. (2009). Beaked whale strandings and naval exercises. *Aquatic Mammals, 35*(4), 452-472.

Deguignet, M., D. Juffe-Bignoli, J. Harrison, B. MacSharry, N. Burgess, & N. Kingston. (2014). *United Nations list of protected areas*. Cambridge, UK: United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC).

Dennison, S., M. J. Moore, A. Fahlman, K. Moore, S. Sharp, C. T. Harry, J. Hoppe, M. Niemeyer, B. Lentell, & R. S. Wells. (2012). Bubbles in live-stranded dolphins. *Proceedings of the Royal Society B: Biological Sciences, 279*(1732), 1396-1404.

Department of the Navy (DoN). (2001). *Final overseas environmental impact statement and environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar*. Washington, D.C.: Chief of Naval Operations, Department of the Navy.

DoN. (2007). *Final supplemental environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar*. Washington, D.C.: Chief of Naval Operations, Department of the Navy.

DoN. (2012). *Final supplemental environmental impact statement/supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar*. Washington, D.C.: Chief of Naval Operations, Department of the Navy.

DeRuiter, S. L., & K. L. Doukara. (2012). Loggerhead turtles dive in response to airgun sound exposure. *Endangered Species Research, 16*, 16:55-63.

Deruiter, S. L., B. L. Southall, J. Calambokidis, W. M. Zimmer, D. Sadykova, E. A. Falcone, A. S. Friedlaender, J. E. Joseph, D. Moretti, G. S. Schorr, L. Thomas, & P. L. Tyack. (2013). First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. *Biology Letters, 9*(4), 20130223.

Doksaeter, L., N. O. Handegard, O. R. Godo, P. H. Kvadsheim, & N. Nordlund. (2012). Behavior of captive herring exposed to naval sonar transmissions (1.0-1.6 kHz) throughout a yearly cycle. *Journal of the Acoustical Society of America, 131*(2), 1632-1642.

Dunlop, R. A., D. H. Cato, & M. J. Noad. (2014). Evidence of a Lombard response in migrating humpback whales (*Megaptera novaeangliae*). *The Journal of the Acoustical Society of America, 136*(1), 430.

Ellison, W. T., B. L. Southall, C. W. Clark, & A. S. Frankel. (2012). A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. *Conservation Biology, 26*(1), 21-28.

Erbe, C., C. Reichmuth, K. Cunningham, K. Lucke, and R. Dooling. (2016). Communication masking in marine mammals: A review and research strategy. *Marine Pollution Bulletin, 103*(1-2), 15-38.

Finneran, J. J. (2015). *Auditory weighting functions and TTS/PTS exposure functions for cetaceans and marine carnivores. Appendix A: Draft guidance for assessing the effects of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts.* Silver Spring, MD: National Oceanic and Atmospheric Administration.

Goldbogen, J. A., B. L. Southall, S. L. DeRuiter, J. Calambokidis, A. S. Friedlaender, E. L. Hazen, E. A. Falcone, G. S. Schorr, A. Douglas, D. J. Moretti, C. Kyburg, M. F. McKenna, & P. L. Tyack. (2013). Blue whales respond to simulated mid-frequency military sonar. *Proceedings of the Biological Society B, 280*(1765), 20130657.

Gregory, L. F., T. S. Gross, A. B. Bolten, K. A. Bjorndal, & J. Guillette, Louis J. (1996). Plasma corticosterone concentrations associated with acute captivity stress in wild loggerhead sea turtles (*Caretta caretta*). *General and Comparative Endocrinology, 104*(3), 312-320.

Gregory, L. F., & J. R. Schmid. (2001). Stress responses and sexing of wild Kemp's ridley sea turtles (*Lepidochelys kempii*) in the northeastern Gulf of Mexico. *General and Comparative Endocrinology, 124*(1), 66-74.

Halvorsen, M. B., D. Zeddies, D. R. Chicoine, & A. N. Popper. (2013). Effects of low frequency naval sonar exposure on three species of fish. *JASA Express Letters, 134*(2), EL206-210.

Hawkins, A. D., A. E. Pembroke, & A. N. Popper. (2015). Information gaps in understanding the effects of noise on fishes and invertebrates. *Reviews in Fish Biology and Fisheries, 25*(1), 39-64.

Henderson, E. E., M. H. Smith, M. Gassmann, S. M. Wiggins, A. B. Douglas, & J. A. Hildebrand. (2014). Delphinid behavioral responses to incidental mid-frequency active sonar. *The Journal of the Acoustical Society of America, 136*(4), 2003.

Hildebrand, J. A. (2005). Impacts of anthropogenic sound. In J. E. Reynolds, III., W. F. Perrin, R. R. Reeves, S. Montgomery, and T. J. Ragen (Eds.), *Marine mammal research: conservation beyond crisis* (Vol. Baltimore, pp. 101-124): Johns Hopkins University Press.

Hildebrand, J. A. (2009). Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology Progress Series, 395*, 5-20.

Holt, M. M., D. P. Noren, R. C. Dunkin, & T. M. Williams. (2015). Vocal performance affects metabolic rate in dolphins: implications for animals communicating in noisy environments. *The Journal of Experimental Biology, 218*(Pt 11), 1647-1654.

Holt, M. M., D. P. Noren, & C. K. Emmons. (2011). Effects of noise levels and call types on the source levels of killer whale calls. *The Journal of the Acoustical Society of America, 130*(5), 3100-3106.

Houser, D. S., S. W. Martin, & J. J. Finneran. (2013a). Behavioral responses of California sea lions to mid-frequency (3250-3450 Hz) sonar signals. *Marine Environmental Research, 92,* 268-278.

Houser, D. S., S. W. Martin, & J. J. Finneran. (2013b). Exposure amplitude and repetition affect bottlenose dolphin behavioral responses to simulated mid-frequency sonar signals. *Journal of Experimental Marine Biology and Ecology, 443*, 123-133.

Hoyt, E. (2005). *Marine protected areas for whales, dolphins and porpoises: A worldwide handbook for cetacean habitat conservation*. London: Earthscan.

Hoyt, E. (2011). *Marine protected areas for whales, dolphins and porpoises: A world handbook for cetacean habitat conservation and planning, 2nd Edition*. London: Earthscan.

International Union for Conservation of Nature and Natural Resources (IUCN). (2012). *Guidelines for applying the IUCN protected area management categories to marine protected areas.* Gland, Switzerland: IUCN.

IUCN & United Nations Environmental Programme (UNEP). 2016. World database on protected areas. Access from <http://www.protectedplanet.net/>.

IUCN WCPA-SSC Joint Task Force on Biodiversity and Protected Areas, and IUCN WCPA-SSC Joint Task Force on Marine Mammal Protected Areas. (2015). *Joint statement by the IUCN WCPA/SSC Task Forces: Defining the relationship between IMMAs, KBAs, and other area-based marine conservation initiatives.* Retrieved from <http://icmmpa.org/iucn-task-force/>.

Irvine, L. M., B. R. Mate, M. H. Winsor, D. M. Palacios, S. J. Bograd, D. P. Costa, & H. Bailey. (2014). Spatial and temporal occurrence of blue whales off the U.S. west coast, with implications for management. *PLoS ONE, 9*(7), e102959.

Isojunno, S., C. Curé, P. H. Kvadsheim, F.-P. A. Lam, P. L. Tyack, P. J. Wensveen, & P. J. O. m. Miller. (2016). Sperm whales reduce foraging effort during exposure to 1–2 kHz sonar and killer whale sounds. *Ecological Applications, 26*(1), 77–93.

Johnson, M., & P. L. Tyack. (2003). A digital acoustic recording tag for measuring the response of wild marine mammals to sound. *IEEE Journal of Oceanic Engineering, 28*(1), 3-12.

Kane, A. S., J. Song, M. B. Halvorsen, D. L. Miller, J. D. Salierno, L. E. Wysocki, D. Zeddies, & A. N. Popper. (2010). Exposure of fish to high-intensity sonar does not induce acute pathology. *Journal of Fish Biology, 76*(7), 1825–1840.

Kastelein, R. (2013). Brief behavioral response threshold levels of a harbor porpoise (*Phocoena phocoena*) to five helicopter dipping sonar signals (1.33 to 1.43 kHz). *Aquatic Mammals, 39*(2), 162-173.

Kastelein, R. A., N. Steen, R. Gransier, P. J. Wensveen, & C. A. de Jong. (2012). Threshold received sound pressure levels of single 1-2 kHz and 6-7 kHz up-sweeps and down-sweeps causing startle responses in a harbor porpoise (*Phocoena phocoena*). *The Journal of the Acoustical Society of America, 131*(3), 2325-2333.

Lavender, A. L., S. M. Bartol, & I. K. Bartol. (2014). Ontogenetic investigation of underwater hearing capabilities in loggerhead sea turtles (*Caretta caretta*) using a dual testing approach. *Journal of Experimental Biology, 217*, 2580-2589.

Lyamin, O. I., S. M. Korneva, V. V. Rozhnov, & L. M. Mukhametov. (2011). Cardiorespiratory changes in beluga in response to acoustic noise. *Doklady Biological Sciences, 440* 275-278.

Maresh, J. L., S. E. Simmons, D. E. Crocker, B. I. McDonald, T. M. Williams, and D. P. Costa. (2014). Free-swimming northern elephant seals have low field metabolic rates that are sensitive to an increased cost of transport. *The Journal of Experimental Biology, 217*(Pt 9), 1485-1495.

Marine Conservation Institute. (2015). *MPAtlas www.mpatlas.org.* Retrieved 22 January 2016.

Martin, K. J., S. C. Alessi, J. C. Gaspard, A. D. Tucker, G. B. Bauer, & D. A. Mann. (2012). Underwater hearing in the loggerhead turtle (*Caretta caretta*): a comparison of behavioral and auditory evoked potential audiograms. *Journal of Experimental Biology, 215*, 3001-3009.

Mate, B., D. M. Palacios, L. M. Irvine, B. Lagerquist, T. Follett, M. Winsor, & C. Hayslip. (2015). *Baleen (blue & fin) whale tagging in Southern California in support of marine mammal monitoring across multiple Navy training areas (SOCAL, NWTRC, GOA).* Final report. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Pacific, Pearl Harbor, Hawaii under Contract No. N62470-10-D-3011, Task Orders JP03 and KB27 issued to HDR, Inc., San Diego, California. 31 July 2015. San Diego, CA: HDR, Inc.

Mate, B. R., D. M. Palacios, C. S. Baker, B. A. Lagerquist, L. M. Irvine, T. Follett, D. Steel, C. Hayslip, & M. H. Winsor. (2016). *Baleen (blue & fin) whale tagging and analysis in support of marine mammal monitoring across multiple Navy training areas.* Preliminary summary. Prepared for Commander, U.S. Pacific Fleet. Submitted to Naval Facilities Engineering Command Pacific, Pearl Harbor, Hawaii under Contract No. N62470-10-D-3011, Task Order KB29 and Contract No. N62470-15-8006, Task Order KB01 issued to HDR, Inc., San Diego, California. 15 January 2016. San Diego, CA: HDR, Inc.

McCauley, R. D., & J. Fewtrell. (2008). Marine invertebrates, intense anthropogenic noise, and squid response to seismic survey pulses. *Bioacoustics, 17*(1-3), 315-318.

McCauley, R. D., J. Fewtrell, A. J. Duncan, C. Jenner, M.-N. Jenner, J. Penrose, R. I. T. Prince, A. Adhitya, J. Murdoch, & K. McCabe. (2000). Marine seismic surveys: A study of environmental implications. *APPEA Journal, May*, 692-708.

McCay, B. J., & P. J. S. Jones. (2011). Marine protected areas and the governance of marine ecosystems and fisheries. *Conservation Biology, 25*(6), 1130-1133.

Miksis, J. L., R. C. Connor, M. D. Grund, D. P. Nowacek, A. R. Solow, & P. L. Tyack. (2001). Cardiac responses to acoustic playback experiments in the captive bottlenose dolphin (*Tursiops truncatus*). *Journal of Comparative Psychology, 115(*3), 227-232.

Miller, P. J., P. H. Kvadsheim, F. P. Lam, P. L. Tyack, C. Cure, S. L. DeRuiter, L. Kleivane, L. D. Sivle, I. S. P. van, F. Visser, P. J. Wensveen, A. M. von Benda-Beckmann, L. M. Martin Lopez, T. Narazaki, & S. K. Hooker. (2015). First indications that northern bottlenose whales are sensitive to behavioural disturbance from anthropogenic noise. *Royal Society Open Science 2*(6), 140484.

Miller, P. J. O., R. N. Antunes, P. J. Wensveen, F. I. P. Samarra, A. Catarina Alves, P. L. Tyack, P. H. Kvadsheim, L. Kleivane, F.-P. A. Lam, M. A. Ainslie, & L. Thomas. (2014). Dose-response relationships for the onset of avoidance of sonar by free-ranging killer whales. *The Journal of the Acoustical Society of America, 135*(2), 975-993. 6

Miller, P. J. O., P. H. Kvadsheim, F. P. Lam, P. J. Wensveen, R. Antunes, A. C. Alves, F. Visser, L. Kleivane, P. L. Tyack, & L. D. Sivle. (2012). The severity of behavioral changes observed during experimental exposures of killer (*Orcinus orca*), long-finned pilot (*Globicephala melas*), and sperm (*Physeter macrocephalus*) whales to naval sonar. *Aquatic Mammals, 38*(4), 362-401.

Mooney, T., R. Hanlon, J. Christensen-Dalsgaard, P. Madsen, D. Ketten, & P. Nachtigall. (2012). The potential for sound sensitivity in cephalopods. In A. Popper & A. Hawkins (Eds.), *The effects of noise on aquatic life* (pp. 125-128). New York: Springer Science+Business Media, LLC.

Mooney, T. A., R. T. Hanlon, J. Christensen-Dalsgaard, P. T. Madsen, D. R. Ketten, & P. E. Nachtigall. (2010). Sound detection by the longfin squid (*Loligo pealeii*) studied with auditory evoked potentials: sensitivity to low-frequency particle motion and not pressure. *The Journal of Experimental Biology, 213*(Pt 21), 3748-3759.

Moretti, D., L. Thomas, T. Marques, J. Harwood, A. Dilley, B. Neales, J. Shaffer, E. McCarthy, L. New, S. Jarvis, and R. Morrissey. (2014). A Risk Function for Behavioral Disruption of Blainville's Beaked Whales (*Mesoplodon densirostris*) from Mid-Frequency Active Sonar. *PLoS ONE, 9*(1), e85064.

National Marine Fisheries Service (NMFS). (2012). *ESA section 7 biological opinion and conference report.* Silver Spring, MD: National Marine Fisheries Service.

NMFS. (2015). *ESA section 7 biologial opinion and conference report on Navy Northwest training and testing (NWTT) activities and NMFS' MMPA incidental take authorization*. (FPR-2015-9110). Silver Spring, MD.

National Oceanic and Atmospheric Administration (NOAA). (2002). Taking and importing marine mammals: taking marine mammals incidental to Navy operations of Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar; Final Rule. National Marine Fisheries Service. National Oceanic and Atmospheric Administration. *Federal Register 67*(136):46712-46789. <http://www.surtass-lfa-eis.com/docs/LFA%20Final%20Rule7-16-2002.pdf>.

NOAA. (2007). Taking and importing marine mammals: Taking marine mammals incidental to U.S. Navy operations of Surveillance Towed Array Sensor System Low Frequency Active sonar: Final rule. *Federal Regsister, 72*(161), 46846-46893. <http://www.nmfs.noaa.gov/pr/pdfs/fr/fr72-46846.pdf>.

NOAA. (2012). Taking and Importing Marine Mammals: Taking Marine Mammals Incidental to U.S. Navy Operations of Surveillance Towed Array Sensor System Low Frequency Active Sonar: Final Rule, 50 CFR Part 218. *Federal Register, 77*(161), 50290-50322. < http://www.surtass-lfa-eis.com/docs/LFA%20Final%20MMPA%20Rule_2012_Federal%20Register.pdf>.

NOAA. (2015). *Biologically important areas* Retrieved 11 November 2015 from *<http://cetsound.noaa.gov/important>*.

NOAA. (2016a). *Guidance for assessing the effect of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts*. Silver Spring, MD: National Oceanic and Atmospheric Administration.

NOAA. (2016b). Takes of marine mammals incidental to specified activities; U.S. Navy training activities in the Gulf of Alaska temporary maritime activities area, Proposed rule. National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Federal Register 81*(38), 9950-10023.

National Research Council. (2005). *Marine mammal populations and ocean noise: Determining when noise causes biologically significant effects.* Washington, D.C.: National Research Council.

Nedelec, S. L., A. N. Radford, S. D. Simpson, B. Nedelec, D. Lecchini, and S. C. Mills. (2014). Anthropogenic noise playback impairs embryonic development and increases mortality in a marine invertebrate. *Scientific Reports, 4,* 5891.

Neo, Y. Y., J. Hubert, L. Bolle, H. V. Winter, C. Ten Cate, and H. Slabbekoorn. (2016). Sound exposure changes European seabass behaviour in a large outdoor floating pen: Effects of temporal structure and a ramp-up procedure. Environmental Pollution*,* 214, 26-34.

New, L. F., J. S. Clark, D. P. Costa, E. Fleishman, M. A. Hindell, T. Klanjšček, D. Lusseau, S. Kraus, C. R. McMahon, P. W. Robinson, R. S. Schick, L. K. Schwarz, S. E. Simmons, L. Thomas, P. Tyack, and J. Harwood. (2014). Using short-term measures of behaviour to estimate long-term fitness of southern elephant seals. *Marine Ecology Progress Series, 496*, 99-108.

Nichols, T. A., T. W. Anderson, and A. Širović. (2015). Intermittent noise induces physiological stress in a coastal marine fish. *PLoS ONE, 10*(9), e0139157.

Nowacek, D. P., L. H. Thorne, D. W. Johnston, and P. L. Tyack. (2007). Responses of cetaceans to anthropogenic noise. *Mammal Review, 37*(2), 81-115.

O'Hara, J., and J. R. Wilcox. (1990). Avoidance responses of loggerhead turtles, *Caretta caretta*, to low frequency sound. *Copeia, 1990*(2), 564-567.

Popper, A. N., M. B. Halvorsen, A. Kane, D. L. Miller, M. E. Smith, J. Song, P. Stein, & L. E. Wysocki. (2007). The effects of high-intensity, low-frequency active sonar on rainbow trout. J*ournal of the Acoustical Society of America, 122*(1), 623-635.

Popper, A. N., A. D. Hawkins, R. R. Fay, D. A. Mann, S. M. Bartol, T. J. Carlson, S. Coombs, W. T. Ellison, R. L. Gentry, M. B. Halvorsen, S. Lokkeborg, P. H. Rogers, B. L. Southall, D. G. Zeddies, & W. N. Tavolga. (2014). *Sound exposure guidelines for fishes and sea turtles: A technical report prepared by the ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI.* Springer briefs in oceanography. New York, NY: ASA Press.

Popper, A. N., M. E. Smith, P. A. Cott, B. W. Hanna, A. O. MacGillivray, M. E. Austin, & D. A. Mann. (2005). Effects of exposure to seismic airgun use on hearing of three fish species. *Journal of the Acoustical Society of America, 117*(6), 3958-3971.

Richardson, W. J., J. Charles R. Greene, C. I. Malme, & D. H. Thomson. (1995). *Marine mammals and noise*. San Diego, CA: Academic Press.

Robinson, P. W., D. P. Costa, D. E. Crocker, J. P. Gallo-Reynoso, C. D. Champagne, M. A. Fowler, C. Goetsch, K. T. Goetz, J. L. Hassrick, L. A. Huckstadt, C. E. Kuhn, J. L. Maresh, S. M. Maxwell, B. I. McDonald, S. H. Peterson, S. E. Simmons, N. M. Teutschel, S. Villegas-Amtmann, & K. Yoda. (2012). Foraging behavior and success of a mesopelagic predator in the northeast Pacific Ocean: insights from a data-rich species, the northern elephant seal. *PLoS ONE, 7*(5), e36728.

Rolland, R. M., S. E. Parks, K. E. Hunt, M. Castellote, P. J. Corkeron, D. P. Nowacek, S. K. Wasser, & S. D. Kraus. (2012). Evidence that ship noise increases stress in right whales. *Proceedings of the Royal Society B, 279*(1737), 2363-2368.

Romano, T. A., M. J. Keogh, C. Kelly, P. Feng, L. Berk, C. E. Schlundt, D. A. Carder, & J. J. Finneran. (2004). Anthropogenic sound and marine mammal health: Measures of the nervous and immune systems before and after intense sound exposure. *Canadian Journal of Fisheries and Aquatic Sciences, 61,* 1124-1137.

Ross, D. (1976). *Mechanics of underwater noise*. New York: Pergamon.

Ross, D. (2005). Ship sources of ambient noise. *IEEE Journal of Oceanic Engineering, 30*(2), 257-261.

Samson, J. E., T. A. Mooney, S. W. Gussekloo, & R. T. Hanlon. (2014). Graded behavioral responses and habituation to sound in the common cuttlefish *Sepia officinalis*. *The Journal of Experimental Biology, 217*(24), 4347-4355.

Scheifele, P. M., S. Andrew, R. A. Cooper, M. Darre, F. E. Musiek, & L. Max. (2005). Indication of a Lombard vocal response in the St. Lawrence River beluga. *The Journal of the Acoustical Society of America, 117*(3), 1486-1492.

Seminoff, J. A., Eguchi, T., Carretta, J., Allen, C. D., Prosperi, D., Rangel, R., Gilpatrick, J. W., Forney, K., & Peckham, S. H. (2014). Loggerhead sea turtle abundance at a foraging hotspot in the eastern Pacific Ocean: implications for at-sea conservation. *Endangered Species Research, 24*(3), 207-220. doi:10.3354/esr00601.

Sivle, L. D., P. H. Kvadsheim, C. Curé, S. Isojunno, P. J. Wensveen, F.-P. A. Lam, F. Visser, L. Kleivane, P. L. Tyack, C. M. Harris, & P. J. O. Miller. (2015). Severity of expert-identified behavioural responses of humpback whale, minke whale, and northern bottlenose whale to naval sonar. *Aquatic Mammals, 41*(4), 469-502.

Smith, M. E., A. S. Kane, & A. N. Popper. (2004). Noise-induced stress response and hearing loss in goldfish (*Carassius auratus*). *Journal of Experimental Biology, 207,* 427-435.

Smith, M. E., Wysocki, L. E., & Popper, A. N. (2006). Effects of background sound on fish. *Journal of the Acoustical Society of America 119*(5 Part 2):3283-3284.

Solan, M., C. Hauton, J. A. Godbold, C. L. Wood, T. G. Leighton, & P. White. (2016). Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties. *Scientific Reports, 6,* 20540.

Solé, M., M. Lenoir, M. Durfort, M. López-Bejar, A. Lombarte, & M. André. (2013). Ultrastructural damage of *Loligo vulgaris* and *Ilex coindetii* statocysts after low frequency sound exposure. *PLoS ONE, 8*(10), e78825.

Song, J., D. A. Mann, P. A. Cott, B. W. Hanna, & A. N. Popper. (2008). The inner ears of Northern Canadian freshwater fishes following exposure to seismic air gun sounds. *Journal of the Acoustical Society of America, 124*(2), 1360-1366.

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene, Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, & P. L. Tyack. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals, 33*(4), 411-522.

Southall, B. L., D. Moretti, B. Abraham, J. Calambokidis, & P. L. Tyack. (2012). Marine mammal behavioral response studies in Southern California: Advances in technology and experimental methods. *Marine Technology Society Journal, 46,* 46-59.

St. Aubin, D. J., & J. R. Geraci. (1989). Adaptive changes in hematologic and plasma chemical constituents in captive beluga whales, *Delphinapterus leucas*. *Canadian Journal of Fisheries and Aquatic Sciences, 46,* 796-803.

Thomas, J. A., R. A. Kastelein, & F. T. Awbrey. (1990). Behavior and blood catecholamines of captive belugas during playbacks of noise from an oil drilling platform. *Zoo Biology, 9*(5), 393-402.

Tougaard, J., O. D. Henriksen, & L. A. Miller. (2009). Underwater noise from three types of offshore wind turbines: estimation of impact zones for harbor porpoises and harbor seals. *The Journal of the Acoustical Society of America, 125(*6), 3766-3773.

Tougaard, J., A. J. Wright, & P. T. Madsen. (2015). Cetacean noise criteria revisited in the light of proposed exposure limits for harbour porpoises. *Marine Pollution Bulletin, 90*(1-2), 196-208.

Tyack, P. L. (2008). Implications for marine mammals of large-scale changes in the marine acoustic environment. *Journal of Mammalogy, 89*(32), 549-558.

U.S. Environmental Protection Agency (U.S. EPA). (1999). Consideration Of Cumulative Impacts In EPA Review of NEPA Documents. < https://www.epa.gov/sites/production/files/2014-08/documents/cumulative.pdf>.

Van Parijs, S. M., C. Curtice, & M. C. Ferguson (Eds.). (2015). *Biologically Important Areas for cetaceans within U.S. waters*: *Aquatic Mammals (Special Issue)*, 41(1).

Voellmy, I. K., J. Purser, D. Flynn, P. Kennedy, S. D. Simpson, & A. N. Radford. (2014). Acoustic noise reduces foraging success in two sympatric fish species via different mechanisms. *Animal Behaviour, 89*, 191-198.

Wale, M. A., S. D. Simpson, & A. N. Radford. (2013). Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise. Biology Letters*,* 9(2), 121194.

Wartzok, D., A. N. Popper, J. Gordon, & J. Merrill. (2003/04). Factors affecting the responses of marine mammals to acoustic disturbance. *Marine Technology Society Journal, 37*(4), 6-15.

Wood, L. J. (2007). *MPA Global: A database of the world's marine protected areas. Sea Around Us Project, UNEP-WCMC & WWF. <www.mpaglobal.org>*.

Wysocki, L. E., J. P. Dittami, & F. Ladich. (2006). Ship noise and cortisol secretion in European freshwater fishes. *Biological Conservation, 128*(4), 501-508.

Wysocki, L. E., J. W. D. III, M. E. Smith, A. S. Frankel, W. T. Ellison, P. M. Mazik, A. N. Popper, & J. Bebak. (2007). Effects of aquaculture production noise on hearing, growth, and disease resistance of rainbow trout *Oncorhynchus mykiss*. Aquaculture*,* 272, 687-697.

Yamato, M., K. Khidas, N. D. Pyenson, R. E. Fordyce, & J. G. Mead. (2016). Extensively remodeled, fractured cetacean tympanic bullae show that whales can survive traumatic injury to the ears. *Journal of Anatomy 228*, 125-136. doi: 10.1111/joa.12385.

5 MITIGATION, MONITORING, AND REPORTING

5.1 Mitigation

Mitigation includes measures to minimize impacts by limiting the degree or magnitude of a proposed action and its implementation. Three alternatives for the operation of SURTASS LFA sonar are presented in this SEIS/SOEIS (No Action Alternative, Alternative 1, and Alternative 2), two of which would meet the Navy's purpose and need and include mitigation measures that would reduce potential impacts. These mitigation measures are discussed in this section.

The objective of mitigation for the employment of SURTASS LFA sonar is to reduce or avoid the effects of potential exposures of SURTASS LFA sonar transmissions on the marine environment. These objectives will be met by:

- Ensuring that coastal waters within 12 nmi (22 km) of shore (including islands) will not be exposed to SURTASS LFA sonar signal received levels (RL) ≥180 dB re 1 µPa (rms) (sound pressure level [SPL]);
- Ensuring that no offshore biologically important areas (OBIA) will be exposed to SURTASS LFA sonar signal RLs ≥180 dB re 1 µPa (rms) (SPL) during biologically important seasons;
- Minimizing exposure of marine mammals and sea turtles to SURTASS LFA sonar signal RLs below 180 dB re 1 µPa (rms) (SPL) by monitoring for their presence and delaying/suspending LFA sonar transmissions when one of these animals enters the LFA mitigation zone; and
- Ensuring that no known recreational or commercial dive sites will be subjected to SURTASS LFA sonar signal RLs >145 dB re 1 µPa (rms) (SPL).

Due to the application of different criteria and methodology to assess potential injury to marine mammals in this SEIS/SOEIS, the Navy reassessed the protective mitigation measures employed whenever SURTASS LFA sonar is transmitting. The basis for the existing suite of mitigation measures is the 180 dB re 1 µPa (rms) isopleth. In previous SURTASS LFA analyses marine animals exposed at or above this level were treated as though they were injured (DoN, 2001, 2007, 2012, 2015). The following is a description of the re-evaluation of the 180-dB isopleth as the basis for SURTASS LFA sonar mitigation.

5.1.1 Re-evaluation of Mitigation Basis

The 180 dB re 1 µPa (rms) threshold for the onset of potential injury has been used for SURTASS LFA sonar since 2001 (DoN, 2001, 2007, 2012, 2015). However, the NOAA (2016) guidance specifies auditory weighted (SEL_{cum}) values for the onset of PTS, which is considered as the onset of injury. The NOAA guidance (2015, 2016) also categorized marine mammals into five generalized hearing groups, with the LF cetacean group including all mysticete or baleen whales.

- <u>Low-frequency (LF) Cetaceans</u>—mysticetes (baleen whales)
- <u>Mid-frequency (MF) Cetaceans</u>—includes most dolphins, all toothed whales except *Kogia* spp., and all beaked and bottlenose whales
- <u>High-frequency (HF) Cetaceans</u>—consists of all true porpoises, river dolphins, *Kogia* spp., *Cephalorhynchid* spp. (genus in the dolphin family Delphinidae), and two species of *Lagenorhynchus* (Peale's and hourglass dolphins)

- Phocids Underwater (PW)—consists of true seals
- Otariids Underwater (OW)—includes sea lions and fur seals

NOAA's (2016) guidance presents the auditory weighting functions developed for each of these generalized hearing groups that reflect the best available data on hearing, impacts of noise on hearing, and data on equal latency. When estimating the onset of injury (PTS), the NOAA guidance (2016) defines weighted thresholds as sound exposure levels (SELs) (Table 4-3). To determine what the SEL for each hearing group would be when exposed to a 60-sec (length of a nominal LFA transmission or 1 ping), 300 Hz (the center frequency in the possible transmission range of 100 to 500 Hz) SURTASS LFA sonar transmission, and the auditory weighting functions must be applied to account for each functional hearing group's sensitivity. Applying the auditory weighting functions to the nominal LFA sonar signal results in the thresholds increasing by approximately 1.5, 56, 56, 15, and 20 dB for LF, MF, HF, PW, and OW groups, respectively. Based on simple spherical spreading (i.e., TL based on 20 × $\log_{10}$ [range {m}]), all functional hearing groups except LF cetaceans would need to be within 22 ft (7 m) for an entire LFA sonar ping (60 sec) to potentially experience PTS. LF cetaceans would be at the greatest distance from the transmitting sonar before experiencing the onset of injury, 135 ft (41 m) for this example (see Section 4.2.4 for additional details). Consequently, the distance at which SURTASS LFA sonar transmissions should be mitigated for marine mammals would be the distance associated with LF cetaceans (baleen whales), as the mitigation ranges would be greatest for this group of marine mammals. Any mitigation measure developed for LF cetaceans would be highly conservative for any other marine mammals potentially exposed to SURTASS LFA sonar transmissions.

The following illustrate what SPL RL would be at the distance an LF cetacean would begin to experience PTS from transmitting LFA sonar. Per NOAA (2016) acoustic guidance, the LF cetacean threshold is 199 dB re 1 μPa^2-sec (weighted). The magnitude of the auditory weighting function at 300 Hz for SURTASS LFA sonar is 1.5 dB, with the equivalent unweighted SEL_{cum}[1] value of 200.5 dB re 1 μPa^2-sec. To convert this value into an SPL value, total duration of sound exposure is needed:

$$SPL = SEL_{cum} - 10 \times \log_{10}(T)$$

Where *T* is the duration in seconds.

Applying the duration of a single ping of SURTASS LFA sonar, or 60 sec, would result in 17.8 dB being subtracted from the unweighted CSEL value of 200.5 dB, for an SPL of 182.7 dB re 1 μPa (rms). The mitigation distance to the 182.7-dB re 1 μP (rms) isopleth would be somewhat smaller than that associated with the previously used 180 dB re 1 μPa (rms) isopleth. If an LF cetacean was exposed to two full pings of SURTASS LFA sonar, the resulting SPL would be 179.7 dB re 1 μPa (rms). This exposure is unlikely, as a marine mammal would have to be close to the LFA sonar array for an extended period, approximately 20 minutes, to experience two full pings. Although the RL in this unlikely scenario (179.7 dB re 1 μP [rms]) is so close to the 180 dB re 1 μP (rms) RL level on which previous mitigation measures for SURTASS LFA sonar have been based, for the purpose of this SEIS/SOEIS, the Navy proposes to retain the current mitigation basis for SURTASS LFA sonar transmissions as the distance to the 180 dB re 1 μPa (rms) isopleth.

1 SEL_{cum}=cumulative sound exposure level

5.1.2 Mitigation Measures

5.1.2.1 Operational Parameters

The Navy proposes to employ up to four SURTASS LFA sonar systems onboard up to four U.S. Navy surveillance ships for routine training, testing, and military operations in the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea. The sound signals transmitted by the SURTASS LFA sonar source will be maintained between 100 and 500 Hz with a SL for each of the 18 projectors of no more than 215 dB re 1 µPa m) (rms) and a maximum duty cycle of 20 percent.

Annually, each SURTASS LFA sonar vessel will be expected to spend approximately 54 days in transit and about 240 days performing LFA sonar operations, although the actual number and length of the individual missions within the 240 days are difficult to predict. The Navy is currently authorized to transmit the maximum number of 432 hours of LFA sonar transmission hours per vessel per year. Under Alternative 1, the Navy would retain this maximum number of 432 hours of LFA sonar transmissions per year, while under Alternative 2, the Navy would only transmit the maximum number of 255 hours of LFA sonar per vessel per year.

5.1.2.2 Mitigation Zone

Prior to commencing SURTASS LFA sonar transmissions and during LFA sonar transmissions, the propagation of LFA sonar signals in the mission area and the distance from the SURTASS LFA sonar source to the 180 dB re 1 µPa isopleth will be determined. A mitigation zone around the LFA sonar array that is equal in size to the 180 dB re 1 µPa isopleth (i.e., the volume subjected to sound pressure levels of 180 dB or greater) will be established. Monitoring for marine animals will be conducted within the mitigation zone.

5.1.2.3 Ramp-up of High Frequency Marine Mammal Monitoring (HF/M3) Sonar

The ramp up procedure will be implemented to ensure that there will be no inadvertent exposures of marine animals in close proximity to the sonar system to RLs ≥180 dB re 1 µPa (rms) from the HF/M3 active sonar system. Prior to full-power operations, the HF/M3 sonar power level will be ramped up over a period of no less than 5 minutes from a source level of 180 dB re 1 µPa @ 1 m (rms) (SPL) in 10 dB increments until full power (if required) is attained. This ramp up procedure will be implemented at least 30 minutes prior to any SURTASS LFA sonar transmissions, prior to any sonar calibrations or testing that are not part of the regularly planned transmissions, and any time after the HF/M3 sonar has been powered down for more than two minutes. The HF/M3 active sonar system’s sound pressure level may not increase once a marine mammal is detected. The ramp up may resume once marine mammals are no longer detected.

5.1.2.4 LFA Sonar Suspension/Delay

SURTASS LFA sonar transmissions will be delayed or suspended if the Navy detects a marine animal entering or within the LFA sonar mitigation zone (i.e., the 180 dB re 1 µPa isopleth). The suspension or delay of LFA sonar transmissions will occur if the marine animal is detected by any of the employed monitoring methods: visual, passive acoustic, or active acoustic monitoring. During the delay/suspension, the Navy would still operate the HF/M3 active sonar system to monitor for the presence of marine mammals in addition to conducting visual and passive acoustic monitoring for marine animals. Operations will be allowed to commence/resume no sooner than 15 minutes after all marine mammals/animals are no longer detected within the SURTASS LFA sonar mitigation zone and no further detections of marine animals by visual, passive acoustic, and active acoustic monitoring have occurred within the mitigation zone.

5.1.2.5 Geographic Sound Field Operational Constraints

The Navy intends to continue applying the following geographic restrictions to the employment of SURTASS LFA sonar:

- SURTASS LFA sonar-generated sound field will be below RLs of 180 dB re 1 µPa (rms) (SPL) within 12 nmi (22 km) of any land (including islands);
- SURTASS LFA sonar-generated sound field will be below RLs of 180 dB re 1 µPa (rms) (SPL) from the outer boundary of OBIAs that have been determined by NMFS and the Navy ;
- When in the vicinity of known recreational or commercial dive sites, SURTASS LFA sonar will be operated such that the sound fields at those sites would not exceed RLs of 145 dB re 1 µPa (rms) (SPL); and
- SURTASS LFA sonar operators will estimate LFA sound field RLs (SPL) prior to and during active sonar operations so that the distance from the LFA sonar system to the 180 dB re 1 µPa (rms) and 145 dB re 1 µPa (rms) isopleths are known.

LFA sonar transmissions would be suspended or delayed to ensure that received levels above 180 dB re 1 µPa (rms) or 145 dB re 1 µPa (rms) would not enter the standoff range from land, OBIAs, or dive sites.

5.1.2.5.1 Coastal Standoff Distance

The coastal standoff distance or range refers to the distance of 12 nmi (22 km) from any land wherein the sound field generated by SURTASS LFA sonar will not exceed 180 dB re 1 µPa (rms) SPL. This distance and sound field measure were established to lower the risk to many marine animals such as marine mammals and especially sea turtles, which aggregate in coastal waters. The Navy will continue to employ the 12 nmi (22 km) coastal standoff distance while using SURTASS LFA sonar.

5.1.2.5.2 OBIAs

Since certain areas of biological importance to marine mammals lie outside the coastal standoff range for SURTASS LFA sonar, the Navy and NMFS developed the concept of OBIAs to ensure exposure of marine mammals to LFA sonar transmissions is minimized in areas where marine mammals conduct biologically significant behaviors (i.e., OBIAs) (see Section 3.3.5.5 and Chapter 4 for more information on OBIAs). Accordingly, the Navy will conduct SURTASS LFA sonar operations such that the LFA sound field will be below RLs of 180 dB re 1 µPa (rms) at the outer (seaward) boundary of designated marine mammal OBIAs during the biologically important season specified for each OBIA.

5.1.2.5.3 Dive Sites

SURTASS LFA sonar operations will be constrained in the vicinity of known recreational and commercial dive sites to ensure that the sound field at such sites does not exceed RLs of 145 dB re 1 µPa (rms). Recreational dive sites are generally located in coastal/island areas in waters from the shoreline out to a water depth of about 130 ft (40 m); it is recognized that there are other dive sites that may be outside this boundary.

5.1.2.6 Sound Field Modeling

SURTASS LFA sonar operators will 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, so that the sound field criteria referenced in this chapter are not exceeded. Sound field limits will be 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 will help determine the sound field by predicting the SPLs, or RLs, at various distances from the SURTASS LFA sonar source. Acoustic model updates will nominally be made every 12 hours or more frequently, depending upon the variance in meteorological or oceanographic conditions.

5.1.2.7 Annual Take Limit on Marine Mammal Stocks

The operation of SURTASS LFA in military readiness activities may incidentally take marine mammals present within the Navy's mission areas by exposing them to sound from LFA sonar sources. The Navy annually requests authorization to take marine mammals by Level A and Level B harassment in the marine areas in which it anticipates operating LFA sonar during that annual period. The take estimates for the proposed operational or mission areas will be calculated annually using various inputs such as mission location, mission duration, and season of operation.

The Navy will limit operation of SURTASS LFA sonar to ensure that no more than 12 percent of any marine mammal stock would be taken by Level B harassment annually from transmissions of all SURTASS LFA sonar vessels. The Navy will use the 12 percent cap to guide its mission planning and selection of potential operational mission areas within each annual authorization application.

The Navy plans to avoid takes of marine mammals by Level A incidental harassment through implementing the complete suite of mitigation and monitoring measures described in this chapter. With the application of mitigation, the acoustic analyses results presented herein and in previous documentation for SURTASS LFA sonar translate into estimates of zero individuals taken by Level A for any species' stock. While the probability of detecting a sea turtle and especially a marine mammal with the Navy's active HF/M3 sonar system within the SURTASS LFA sonar mitigation zone is high, it is not 100 percent. For that reason, a small number of Level A harassment (non-lethal) takes of marine mammals and sea turtles have been requested by the Navy and authorized by NMFS (NMFS, 2012; NOAA, 2012).

5.2 Monitoring

The Navy is required to cooperate with NMFS and other Federal agencies to monitor impacts on marine mammals, to designate qualified on-site personnel to conduct mitigation monitoring and reporting activities. The Navy will continue to conduct the following monitoring to prevent injury to marine animals when SURTASS LFA sonar is employed:

- **Visual monitoring** for marine mammals and sea turtles from the SURTASS LFA sonar vessels during daylight hours by personnel trained to detect and identify marine mammals and sea turtles;
- **Passive acoustic monitoring** using the passive SURTASS towed 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.

5.2.1 Visual Monitoring

Visual monitoring will include daytime observations for marine mammals and sea turtles from the SURTASS LFA sonar vessel. Daytime is defined as 30 minutes before sunrise until 30 minutes after sunset. Visual monitoring will begin 30 minutes before sunrise or 30 minutes before the SURTASS LFA sonar is deployed and will continue until 30 minutes after sunset or until the SURTASS LFA sonar is recovered aboard the vessel. Observations will be made by personnel trained in detecting and identifying marine mammals and sea turtles from the ship's bridge using standard binoculars (7x) and the naked eye. The objective of visual monitoring will be to ensure that no marine mammal or sea turtle approaches close enough to enter the LFA mitigation zone.

The trained visual observers will maintain a topside watch for marine mammals and sea turtles at the sea surface and observation log during operations that employ SURTASS LFA sonar transmissions. The numbers and identification of observed marine mammals or sea turtles, as well as any unusual behavior, will be entered into the log. A designated ship's officer will monitor the conduct of the visual watches and will periodically review the log entries. If a potentially affected marine mammal or sea turtle would be sighted anywhere within the LFA mitigation zone , the visual observer will notify the military crew (MILCREW) officer-in-charge (OIC), who will order the immediate delay or suspension of SURTASS LFA sonar transmissions. Similarly, if a marine mammal or sea turtle were sighted outside the LFA mitigation zone, the bridge officer would notify the MILCREW OIC of the estimated range and bearing of the observed marine mammal or sea turtle. The MILCREW OIC will notify the HF/M3 sonar operator to verify or determine the range and projected track of the detected marine mammal/sea turtle. If the sonar operator would determine that the animal will pass into the LFA mitigation zone, the MILCREW OIC would order the immediate delay or suspension of SURTASS LFA sonar transmissions when the animal enters the LFA mitigation zone. The visual observer would continue visual monitoring and recording until the marine mammal/sea turtle is no longer observed. SURTASS LFA sonar transmissions would only commence/resume 15 minutes after there would be no further detection of marine mammals or sea turtles by visual, active acoustic (HF/M3 sonar), or passive acoustic monitoring within the LFA mitigation zone. If a detected marine mammal were exhibiting abnormal behavior, visual monitoring would continue until the behavior returns to normal or conditions did not allow monitoring to continue.

5.2.2 Passive Acoustic Monitoring

Passive acoustic monitoring will be conducted when SURTASS is deployed, using the SURTASS towed HLA to listen for vocalizing marine mammals as an indicator of their presence. If a detected sound were estimated to be from a vocalizing marine mammal that may be potentially affected by SURTASS LFA sonar, the sonar technician will notify the MILCREW OIC, who would alert the HF/M3 sonar operator and visual observers (during daylight). The delay or suspension of SURTASS LFA sonar transmissions would be ordered when the HF/M3 sonar and/or visual observation indicates the marine mammal's range is within the LFA mitigation zone. Passive acoustic sonar technicians identify the detected vocalizations to marine mammal species whenever possible. As with the other types of monitoring, passive acoustic monitoring would begin 30 min prior to the first LFA sonar transmission, continue throughout all LFA sonar transmissions, and end at least 15 minutes after LFA sonar transmissions would no longer be broadcast.

5.2.3 Active Acoustic/HF/M3 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 sonar monitoring would begin 30 minutes before the first SURTASS LFA sonar transmission is scheduled to commence and continue until 15 minutes after LFA sonar transmissions are terminated. Prior to full-power operations, the HF/M3 sonar power level would be ramped up over a period of 5 minutes from the SL of 180 dB re 1 µPa @ 1 m (rms) (SPL) in 10 dB increments until full power (if required) would be attained to ensure that there are no inadvertent exposures of marine mammals or sea turtles to RLs ≥180 dB re 1 µPa (rms) from the HF/M3 sonar.

If a contact would be detected during HF/M3 monitoring within the LFA mitigation zone, the sonar operator would notify the MILCREW OIC, who would order the immediate delay or suspension of LFA sonar transmissions. Likewise, if HF/M3 monitoring were to detect a possible marine mammal or sea turtle outside the LFA mitigation zone, the HF/M3 sonar operator would determine the range and projected track of the marine mammal or sea turtle and notify the MILCREW OIC that a detected animal would pass within the LFA mitigation zone. The MILCREW OIC would notify the bridge and passive sonar operator of the potential presence of a marine animal projected to enter the mitigation zone. The MILCREW OIC would order the delay or suspension of LFA sonar transmissions when the marine mammal/sea turtle would be predicted to enter the LFA mitigation zone. SURTASS LFA sonar transmissions would commence/resume 15 minutes after there are no further detections by the HF/M3 sonar, visual, or passive acoustic within the LFA mitigation zone.

The effectiveness of the HF/M3 sonar system to monitor and detect marine mammals has been described in the Navy's 2001 FOEIS/EIS (Chapter 2 and 4) for SURTASS LFA sonar (DoN, 2001) in addition to technical report by Ellison and Stein (1999/2001). The information presented therein remains valid and is incorporated herein by reference. To summarize the effectiveness of the HF/M3 sonar system, the Navy's testing and analysis of the HF/M3 sonar system's capabilities indicated that the system substantially increased the probability of detecting a marine mammal within the LFA mitigation zone and provides a superior monitoring capability especially for medium to large-sized marine mammals to a distance of 1.1 to 1.3 nmi (2 to 2.5 km) from the system (DoN, 2001). Additionally, qualitative and quantitative assessments of the HF/M3 system's ability to detect marine mammals of various sizes were verified in 170 hr of at-sea testing. The sea testing showed that several detections of a marine mammal by the HF/M3 sonar system would occur before a marine mammal entered the LFA mitigation zone (DoN, 2001). Ellison and Stein (2001) reported that the detection probability would be near 100% for a moderately-sized (~33 ft [10 m]) marine mammal swimming towards the system.

5.2.4 Visual and Passive Acoustic Observer Training

The ship's lookouts will conduct the visual monitoring for marine animals at the sea surface. Training of these at-sea visual observers onboard the SURTASS LFA sonar vessels is a requirement of the MMPA Final Rule and annual LOAs. A marine mammal biologist qualified in conducting at-sea visual monitoring of marine mammals from surface vessels will train and qualify designated personnel of the four SURTASS LFA sonar vessels to conduct at-sea visual monitoring. Training also will include means of achieving effective and swift communication within the observer's command structure to facilitate quick execution of protective measures if marine mammals or other marine animals are observed at the sea surface (NOAA, 2012).

Although not currently required by the MMPA rulemaking for SURTASS LFA sonar, the Navy routinely conducts training of the MILCREWs stationed aboard SURTASS LFA sonar vessels to augment their sonar detection capabilities. Senior marine acousticians and a senior marine biologist conduct passive acoustic training of the MILCREWs to increase their ability as sonar operators to distinguish biological sounds from those of mission-directed sounds.

5.2.5 Monitoring To Increase Knowledge of Marine Mammals

The MMPA requires that entities authorized to take marine mammals conduct monitoring that increases our understanding of the species as well as the impacts of the activity on the affected marine mammals. As such, the Navy has undertaken several monitoring efforts designed to increase knowledge of the marine mammal species potentially affected during employment of SURTASS LFA sonar.

5.2.5.1 Beaked Whale and Harbor Porpoise Research on LFA Sonar Impacts

The impetus for investigating the effect of SURTASS LFA sonar on beaked whales and the harbor porpoise is the result of research that indicated these taxa may be particularly sensitive to a range of underwater sound exposures. As a result, the potential sensitivity of beaked whales and the harbor porpoise to LF sonar systems has arisen as a monitoring and research need. NMFS made increasing the understanding of the potential effects of SURTASS LFA sonar on beaked whales and harbor porpoises a condition of the 2012 MMPA rulemaking and the current LOAs for SURTASS LFA sonar employment. The Navy convened an independent Scientific Advisory Group (SAG), whose purpose was to investigate and assess different types of research and monitoring methods that could increase the understanding of the potential effects to beaked whales and harbor porpoises from exposure to SURTASS LFA sonar transmissions. The SAG was composed of six scientists who are affiliated with two universities, one Federal agency (NMFS), and three private research and consultancy firms. The SAG was responsible for preparing and submitting a report, *Potential Effects of SURTASS LFA Sonar on Beaked Whales and Harbor Porpoises*, which described the SAG's monitoring and research recommendations. The SAG report was submitted to the Navy, NMFS, and the Executive Oversight Group (EOG) for SURTASS LFA sonar in August 2013.

The EOG is comprised of representatives from the U.S. Navy (Chair, OPNAV N2/N6F24), Office of the Deputy Assistant Secretary of the Navy for the Environment, Office of Naval Research, Navy Living Marine Research Program, and the NMFS Office of Protected Resources (OPR) (Permits, Conservation, and Education Division). Representatives of the Marine Mammal Commission have also attended EOG meetings as observers. The EOG for SURTASS LFA sonar met twice in 2014 to review and further discuss the research recommendations put forth by the SAG, the feasibility of implementing any of the research efforts, and existing budgetary constraints. In addition to the research and monitoring efforts recommended by the SAG, additional promising research/monitoring suggestions were recommended for consideration by the EOG. The EOG is considering which research/monitoring efforts are the most efficacious given existing budgetary constraints and will provide the Navy with a ranked list of research recommendations. The EOG also determined that a study should be conducted to determine the extent of the overlap between potential LFA sonar operations and the distributional range of harbor porpoises; the Navy is in the process of finalizing this study. Following completion of all EOG consideration and evaluation, the Navy will prepare a research action plan for submittal to the NMFS Office of Protected Resources outlining the way forward (DoN, 2015). The Navy is committed to completing its assessment of the validity, need, and recommendations for field and/or laboratory research on the potential effects of SURTASS LFA sonar on beaked whales and harbor porpoises.

5.2.5.2 Marine Mammal Monitoring (M3) Program

The Navy's Integrated Undersea Surveillance System's (IUSSs) Marine Mammal Monitoring (M3) program uses the Navy's fixed and mobile passive acoustic monitoring systems to enhance the Navy's collection of long-term data on individual and population levels of acoustically active marine mammals, principally of baleen whales. At present, the M3 program's data are classified, as are the data reports created by M3 analysts. In the past, however, researchers have based unclassified research and the resulting scientific papers on information from classified M3 program data or other Navy passive acoustic assets.

The Navy (OPNAV N2/N6F24) continues to assess and analyze M3 data collected from Navy passive acoustic monitoring systems and is working toward making some portion of that data, after appropriate security reviews, available to scientists with appropriate clearances and ultimately made publicly available (DoN, 2015). Progress has been achieved on addressing security concerns and declassifying the results of a specific dataset pertinent to a current area of scientific inquiry for which a peer-reviewed scientific paper is being prepared for submission to a scientific journal.

5.2.5.3 SURTASS Passive Sonar—Marine Mammal Detection

One of the types of mitigation monitoring required during SURTASS LFA sonar transmissions is the use of the SURTASS passive HLA to monitor for marine mammal vocalizations, which are indicative of the presence of marine mammals in the surrounding marine environment. In recognition of the monitoring value of the SURTASS LFA passive towed HLA, NMFS has asked the Navy to explore the feasibility of coordinating with other Navy fleet assets to use the SURTASS passive sonar to augment the collection of marine mammal vocalizations during Navy exercises and/or as an adjunct to Navy range monitoring programs.

However, considerable constraints are entailed in using the SURTASS passive sonar array to participate in Navy range or joint exercises. These constraints include the sizeable lead time required in the operational planning process to involve any of the SURTASS LFA sonar vessels in a joint or Range exercise and the length of time, and associated considerable operational costs, required to transit one of the vessels to a Navy Range Complex or joint exercise area due to the low speeds at which the SURTASS LFA vessels are capable of traveling. Nevertheless, the Navy's Warfare Integration for Information Dominance Undersea Capabilities Division (OPNAV N2/N6F24) has requested that Navy planners consider including the SURTASS passive HLA in the advanced planning of Navy exercises in the western and central North Pacific (DoN, 2015).

5.2.5.4 Ambient Noise

The Navy collects ambient noise data on the marine environment when the SURTASS passive towed HLA is deployed. However, because the collected ambient noise data may also contain sensitive acoustic information, the Navy classifies the data, and thus, does not make these data publicly available. The ambient noise data, especially from areas of the ocean for which marine ambient noise data may be lacking, would be a beneficial addition to the comprehensive ocean noise budget (i.e., an accounting of the relative contributions of various underwater sources to the ocean noise field) that is being developed for the world's oceans. Ocean noise budgets are an important component of varied marine environmental analyses, including studies of masking in marine animals, marine habitat characterization, and marine animal impact analyses.

In acknowledgement of the valuable data the Navy routinely collects, NMFS has recommended that the Navy continue to explore the feasibility of declassifying and archiving the ambient noise data for incorporation into appropriate ocean noise budget efforts. Due to national security concerns, these data are currently classified. The Navy continues to study the feasibility of declassifying portions of these data after all related security concerns have been resolved. The M3 program is working to compile information on the ambient noise data that have been collected from various systems as a starting point for further discussions on data dissemination, either at a classified or unclassified level.

5.2.6 Other Mitigation and Monitoring Measures Considered

In previous documentation for SURTASS LFA sonar, other mitigation measures, including the use of small boats and aircraft for pre-operational surveys were considered, but not carried forward (DoN, 2007 and 2012). The Navy concluded that boat or aircraft pre-operational 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 (DoN, 2007). Therefore, under the revisions to the MMPA by the NDAA of fiscal year 2004, pre-operational surveys were not considered as a viable mitigation option. Other discussions of recommended mitigation measures may be found in Chapter 10 of the 2007 FSEIS (DoN, 2007) and Chapter 7 of the 2012 SEIS/SOEIS (DoN, 2007 and 2012).

5.2.6.1 Underwater Gliders

Unmanned underwater gliders are increasingly being utilized in marine research, including the study of marine mammals. Acoustic and other sensors can be attached to underwater gliders to collect data on the presence of marine mammals and potentially on some types of marine mammal behavior. The efficacy of using underwater gliders affixed with passive acoustic sensors to monitor marine mammals during SURTASS LFA sonar operations has been part of the Adaptive Management review process and further assessed for this SEIS/SOEIS.

The Navy considered some of the issues associated with the potential use of underwater gliders as a mitigation measure for SURTASS LFA sonar. These issues included but were not limited to the cost of purchasing and maintaining underwater gliders, including associated operational personnel; transportation of underwater gliders to mission areas aboard SURTASS LFA sonar vessels; and deployment and recovery of underwater gliders from SURTASS LFA sonar vessels. The Navy evaluated these logistical and practicability issues in conjunction with the potential efficacy of using underwater gliders to collect real-time information on the locations and ranges of marine mammals relative to transmitting SURTASS LFA sonar systems. The principal issue associated with the use of underwater gliders is their capability of providing localized, real-time acoustic data on marine mammals.

The current suite of mitigation monitoring, including the use of passive acoustic monitoring, provides real-time data on the presence and location of marine animals in the vicinity of transmitting LFA sonar. In that context, the Navy concluded that until issues of practicability, logistics, and the fundamental capability to provide real-time data can be resolved, it is currently not feasible to employ underwater gliders as a mitigation measure for SURTASS LFA sonar.

5.3 Reporting

The Navy will continue reporting the details of the at-sea missions conducted by SURTASS LFA sonar in addition to other program information on a quarterly, annual, and five-year schedule

5.3.1 Quarterly Mission Reports

Within 30 days following the end of each quarter beginning with the LOAs' effective date, the Navy will submit unclassified and classified quarterly mission reports to NMFS for each SURTASS LFA sonar vessel. The quarterly mission reports will include a summary of all missions during which LFA sonar was transmitted, marine mammal observation/detections during missions, and estimations of the percentages of marine mammals stocks affected by the actual LFA sonar transmissions for the quarter and cumulatively for the annual period. The Navy will submit a report for each vessel even if no LFA sonar was transmitted during that quarterly period.

5.3.2 Annual Report

The Navy will submit an unclassified annual report to the NMFS Office of Protected Resources Director no later than 45 days after the end of the annual LOA effective period. The annual report on SURTASS LFA sonar operations will contain summaries of the unclassified quarterly mission reports, estimations of total percentages of each marine mammal stock affected by SURTASS LFA sonar transmissions, analysis of the effectiveness of mitigation measures, cumulative impacts, and long-term effects from SURTASS LFA sonar operations.

5.3.3 Five-Year Comprehensive Report

A final comprehensive report, which is an unclassified assessment of any impacts of SURTASS LFA sonar on marine mammal stocks during the five-year period of the MMPA regulations, will be submitted by the Navy to NMFS and be made available for public review at least 240 days prior to expiration of the MMPA Final Rule regulations.

5.4 Literature Cited

Department of the Navy (DoN). (2001). Final overseas environmental impact statement and environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/FEIS%20Vol%20I.pdf>.

DoN. (2007). Final supplemental environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS.pdf>.

DoN. (2012). Final supplemental environmental impact statement/supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Washington, D.C.: Department of the Navy, Chief of Naval Operations. <http://www.surtass-lfa-eis.com/docs/SURTASS_LFA_FSEIS-SOEIS.pdf>.

DoN. (2015). *Annual report No. 3: Navy operations of the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar onboard the USNS VICTORIOUS (T-AGOS 19), USNS ABLE (T-AGOS 20), USNS EFFECTIVE (T-AGOS 21), and USNS IMPECCABLE (T-AGOS 23) under the National Marine Fisheries Service 15 August 2014 Letters of Authorization and 2012 Final Rule.* Washington, DC: U.S. Department of the Navy, Chief of Naval Operations. 66 pages.

Ellison, W.T., & P.J. Stein. (1999, updated 2001). *SURTASS LFA high frequency marine mammal monitoring (HF/M3) system: System description and test and evaluation*. Marine Acoustics, Inc. and Scientific Solutions, Inc., 26 Nov 99. Retrieved from <http://www.surtass-lfa-eis.com/docs/HF-M3%20Ellison%20Report%202-4a.pdf>.

National Marine Fisheries Service (NMFS). 2012). *Endangered Species Act section 7 biological opinion on U.S. Navy's proposed use of the Surveillance Towed Array Sensor System Low Frequency Active sonar from August 2012 through August 2017 and NMFS Office of Protected Resources promulgation of regulations pursuant to the Marine Mammal Protection Act and subsequent issuance of Letters of Authorization pursuant to the MMPA regulations for the U.S. Navy to ''take'' marine mammals incidental to its employment ofthe Surveillance Towed Array Sensor System Low Frequency Active sonar in areas of the Atlantic, Pacific, and Indian Oceans and the Mediterranean Sea.* Silver Spring, Maryland: NMFS Office of Protected Resources Endangered Species Act Interagency Cooperation Division.

National Oceanic & Atmospheric Administration (NOAA). (2012). Taking and importing marine mammals: Taking marine mammals incidental to U.S. Navy operations of Surveillance Towed Array Sensor System Low Frequency Active Sonar; Final rule. *Federal Resister, 77*(161), 50290-50322.

NOAA. (2015). *Draft guidance for assessing the effect of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts*. Revised version for second public comment period. Silver Spring, MD: National Marine Fisheries Service, National Oceanic and Atmospheric Administration.

NOAA. (2016). *Guidance for assessing the effect of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts*; Proposed changes. Silver Spring, MD: National Marine Fisheries Service, National Oceanic and Atmospheric Administration. <http://www.nmfs.noaa.gov/pr/acoustics/Acoustic%20Guidance%20Files/opr-55_acoustic_guidance_tech_memo.pdf>.

6 OTHER CONSIDERATIONS REQUIRED BY NEPA

6.1 Consistency with Other Applicable Federal, State, and Local Plans, Policies, and Regulations

In accordance with 40 CFR section 1502.16(c), analysis of environmental consequences shall include discussion of possible conflicts between the Proposed Action and the objectives of Federal, regional, state, and local policies, and control (Table 6-1). SURTASS LFA sonar is currently operating under a Final Rule pursuant to the MMPA (NOAA, 2012) and a Biological Opinion under the statutes of the ESA (NMFS, 2012). All permits, approvals, and authorizations required for the operation of SURTASS LFA sonar have been obtained and are current.

Table 6-1. Summary of this SEIS/SOEISs Environmental Compliance With Applicable Federal, State, Regional, and Local Laws, Policies, and Regulations.

Federal, State, Local, and Regional Policies, and Controls	Status of Compliance
National Environmental Policy Act (NEPA) (42 USC §§4321, et. seq.) Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (40 CFR §§1500-1508) DoN Procedures for Implementing NEPA (32 CFR §775)	This SEIS/SOEIS has been prepared in accordance with NEPA, CEQ regulations, and the Navy's NEPA implementation procedures. Public participation and review of the Draft SEIS/SOEIS is being conducted in accordance with NEPA. The proposed action would not result in significant impacts to the marine environment.
EO 12114, Environmental Effects Abroad of Major Federal Actions	This SEIS/SOEIS has been prepared in accordance with EO 12114, which requires environmental consideration for major Federal actions that may affect the environment outside of U.S. territorial waters. The proposed action would not result in significant harm to the marine environment.
Endangered Species Act (ESA) (16 USC §§1531, et seq.)	This SEIS/SOEIS analyzes potential effects to marine species listed under the ESA as well as designated critical habitats of those species. The Navy has initiated consultation under ESA's Section 7 with NMFS on the potential of the proposed action to affect listed species and critical habitat.
Marine Mammal Protection Act (16 USC §§1431, et seq.)	This SEIS/SOEIS analyzes the potential effects to marine mammals, some of which are also listed under the ESA. The Navy is requesting rulemaking under the MMPA for the five year period from 2017 through 2022 in addition to annual Letters of Authorization.

Table 6-1. Summary of this SEIS/SOEISs Environmental Compliance With Applicable Federal, State, Regional, and Local Laws, Policies, and Regulations.

Federal, State, Local, and Regional Policies, and Controls	Status of Compliance
The National Marine Sanctuaries Act (16 USC §§1431, et seq.)	The Navy will initiate consultation with the Office of National Marine Sanctuaries (ONMS) under Section 304(d) of the NMSA. The Navy and NMFS intend to submit a joint Sanctuary Resource Statement to ONMS. When the Sanctuary Resource Statement is deemed complete, ONMS will have 45 days to respond with conservative recommendations for the agencies to consider.
Coastal Zone Management Act (16 USC section 1451 et seq.)	Under the Coastal Zone Management Program Regulations and CFR 930, *Federal Consistency with Approved Coastal Management Programs*, the Navy submitted negative determinations in conjunction with the 2001 DOEIS/EIS that determined that the employment of the SURTASS LFA sonar would be consistent to the maximum extent practicable with the relevant enforceable policies of 23 coastal states' and five territories' Coastal Zone Management Plans, with the exception of California where the consistency determination was not completed. Nothing in the current regulatory process changes the Navy's conclusion. If there is a need to operate LFA sonar in U.S. waters in the future, the Navy will review and address any coastal zone consistency issues in conjunction with the annual LOAs and ITS application process.
Act to Prevent Pollution from Ships (APPS) (33 USC §§1901, et seq.)	The Navy and all SURTASS LFA sonar vessels comply with the discharge regulations set forth under the requirements of the APPS.
EO 12962, Recreational Fisheries	EO 12962 requires the fulfillment of certain duties to promote the health and access of the public to recreational fishing areas. The proposed action complies with these duties.
EO 13158, Marine Protected Areas (MPAs)	EO 13158 requires the avoidance of harm to the natural or cultural resources protected as MPAs and the identification of any actions that may affect those resources. The proposed action complies with these requirements.
EO 13175, Consultation and Coordination with Indian Tribal Governments	EO 13175 establishes the requirement for consultation and collaboration with tribal officials regarding development of Federal policy that has tribal implications. The Navy currently has no plans to operate SURTASS LFA sonar in the Gulf of Alaska or off the coast of Washington, Oregon, or California. The Navy will continue to keep native groups

Table 6-1. Summary of this SEIS/SOEISs Environmental Compliance With Applicable Federal, State, Regional, and Local Laws, Policies, and Regulations.

Federal, State, Local, and Regional Policies, and Controls	Status of Compliance
	informed of the timeframes of any future SURTASS LFA sonar exercises planned for the Gulf of Alaska or off the coast of Washington, Oregon, and California. Letters notifying the representatives of the Indian or Alaskan Native tribal governments from the Gulf of Alaska and coastal Washington and Oregon of the availability of this Draft SEIS/SOEIS have been sent in conjunction with the filing of this document with the U.S. EPA.
EO 13547, Stewardship of the Ocean, Our Coasts, and the Great Lakes	EO 13547 requires the development of coastal and marine spatial plans that build upon and improve existing Federal, state, tribal, local, and regional decision-making and planning processes. This and other mandates of EO 13547 have been met in this SEIS/SOEIS by using the best available data for all analyses, by conducting an analysis of potential and cumulative effects, and by defining OBIAs. Analyses of potential effects have been conducted in an integrated, systematic manner that incorporates cumulative effects from potential additional sound sources in the marine environment. In addition, OBIAs were defined within a marine spatial planning framework.

6.2 Irreversible or Irretrievable Commitment of Resources

Section 102(c)(v) of NEPA requires that an EIS identify any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented. Resources that are irreversibly or irretrievably committed to a project are those that are used on a long-term or permanent basis, including the use of non-renewable resources.

Although operating SURTASS LFA sonar immeasurably enhances national security by allowing the Navy to ascertain submarine threats at long-range, implementation of the Proposed Action would involve the use of nonrenewable resources such as petroleum-based fuel and steel, used in SURTASS LFA sonar vessels and sonar systems and the use of human labor. Implementation of the Proposed Action would not result in significant irreversible or irretrievable commitment of resources.

6.3 Relationship between Short-Term Use of the Environment and Maintenance and Enhancement of Long-Term Productivity

The NEPA requires analysis of the relationship between a proposed action's short-term effects on the environment and any effects on the maintenance and enhancement of the long-term productivity of the affected environment. The Navy supports research that increases knowledge about marine mammals, sea turtles, and marine fishes and helps to develop methods to reduce or eliminate the potential for effects on these species that may be associated with the operation of SURTASS LFA sonar. While some short-term environmental effects may be associated with the use of SURTASS LFA sonar, no long-term environmental effects that would lead to decreased productivity, permanently reduce the range of beneficial environmental uses, or pose long-term risk to the health, safety, or general welfare of the public are reasonably expected.

6.4 Unavoidable Adverse Environmental Impacts

Unavoidable adverse impacts associated with the proposed action include potential effects on marine mammals, sea turtles, and fish stocks. Nearly all potential effects on these marine taxa can be avoided due to the mitigation and monitoring methods implemented to prevent injury or harm to marine mammals and sea turtles. Additionally, the geographic restrictions on SURTASS LFA sonar employment would result in negligible impacts to fish stocks on an annual basis and no impacts to commercial or recreational non-pelagic fisheries.

7 PUBLIC INVOLVEMENT AND DISTRIBUTION

CEQ regulations implementing the NEPA (40 CFR §1503.1) as well as Navy guidance on environmental readiness require that Navy agencies solicit comments on Draft SEISs from the public as well as from Federal and appropriate state agencies. This chapter describes the distribution, review, and comment process on the Draft SEIS/SOEIS for SURTASS LFA sonar.

7.1 Public Review Process

7.1.1 Public Notification

In the Notice of Intent (NOI), published in the *Federal Register* on June 5, 2015 (DoN, 2015), the Navy, with NMFS as a cooperating agency, announced its intention to prepare a SEIS/SOEIS for the worldwide employment of SURTASS LFA sonar. In the NOI, the Navy proposed the likely timelines for the 45-day public comment period for availability and access to the Draft SEIS/SOEIS and availability of the Final SEIS/SOEIS as June 2016 and June 2017, respectively.

7.1.2 Public Review Period

Per CEQ regulation (40 CFR §1506.10), a 45-day comment and review period will commence when the U.S. Environmental Protection Agency (EPA) publishes its Notice of Availability for the Draft SEIS/SOEIS for SURTASS LFA sonar employment in the *Federal Register*. The Navy will accept comments on the Draft SEIS/SOEIS from Federal and state agencies and organizations as well as interested members of the public only for the duration of this comment period.

7.2 Distribution and Filing of SEIS/SOEIS

The CEQ regulations implementing the NEPA (40 CFR §1503.1) as well as Navy guidance on environmental readiness require that Navy agencies solicit comments on Draft SEISs from Federal and appropriate state agencies in addition to the members of the public.

7.2.1 Filing of the Draft SEIS/SOEIS

Pursuant to Section 102(2) of the NEPA of 1969 as implemented by the CEQ regulations (40 CFR §§ 1500 to 1508) and EO 12114, the Navy has prepared and plans to file the Draft SEIS/SOEIS for SURTASS LFA sonar employment with the EPA in August 2016 to document the supplemental analyses and information associated with the employment of SURTASS LFA sonar.

7.2.2 Distribution of SEIS/SOEIS

In conjunction with filing this Draft SEIS/SOEIS with the EPA and announcing its public availability, correspondence notifying appropriate Federal and state government agencies and officials, Native Alaskan and tribal governments and organizations, as well as other interested parties in accordance with NEPA requirements and EPA guidelines that the Draft SEIS/SOEIS is available on the SURTASS LFA sonar website will be sent, as follows.

7.2.2.1 Federal Organizations

Horst Greczmiel
Associate Director of NEPA Oversight
Executive Office of the President
Council on Environmental Quality
722 Jackson Place, N.W.
Washington, DC 20503

U.S. EPA
OECA (2201A)
Dawn Roberts, EIS Filing Section
1200 Pennsylvania Avenue, NW
Washington, DC 20460

U.S. EPA, Region 1
Office of Environmental Review
5 Post Office Square, Suite 100
(Mail code: ORA-17-1)
Boston, MA 02109-3912

U.S. EPA, Region 2
Environmental Review Section

290 Broadway
New York, NY 10007-1866

U.S. EPA, Region 3
NEPA Team Leader
Office of Environmental Programs (3EA30)
1650 Arch Street
Philadelphia, PA 19103-2029

U.S. EPA, Region 4
NEPA Program Office
61 Forsyth Street, SW
Atlanta, GA 30303-8960

U.S. EPA Region 5
NEPA Implementation Section
(Mail Code E-19J)
77 W. Jackson Blvd.
Chicago, IL 60604

U.S. EPA, Region 6
1445 Ross Avenue, Suite 1200
Mail Code: 6EN
Dallas, TX 75202-2733

U.S. EPA, Region 9
Environmental Review Section
(Mail Code: ENF-4-2)
75 Hawthorne Street
San Francisco, CA 94105

U.S. EPA, Region 10
EIS Review Coordinator
1200 Sixth Avenue, Suite 900
(ETPA-202)
Seattle, WA 98101

U.S. Department of Justice
Environment and Natural Resources Division
Law and Policy Section
Attn: John C. Cruden, Asst. Attorney General
950 Pennsylvania Avenue, NW
Washington, DC 20530-0001

Director, Office of Environmental Policy and Compliance
U.S. Department of the Interior
1849 C Street, NW, MS 2462
Washington, DC 20240

Patricia Sanderson Port
Regional Environmental Officer, Office of Environmental Policy and Compliance
U.S. Department of the Interior
San Francisco, Region IX
333 Bush Street, Suite 515
San Francisco, CA 94104

U.S. Fish and Wildlife Service
Division of Engineering
5275 Leesburg Pike, MS: BMO
Falls Church, VA 22041-3803

Mary Abrams
Field Supervisor, Pacific Islands Fish and Wildlife Office
U.S. Fish and Wildlife Service
300 Ala Moana Boulevard, Room 3-122
Honolulu, HI 96850

Cathy Tortorici
Office of Protected Resources F/PR5
Chief, Endangered Species Act Interagency Cooperation Division
NMFS, NOAA
1315 East-West Highway
Silver Spring, MD 20910

Jolie Harrison
Office of Protected Resources F/PR1

Chief, Permits and Conservation Division
NMFS, NOAA
1315 East-West Highway
Silver Spring, MD 20910

Patricia Montanio
Director, Office of Habitat Conservation
NMFS, NOAA
1315 East West Highway SSMC3 F/HC
Silver Spring, MD 20910

Rebecca Lent
Executive Director, Marine Mammal Commission
4340 East West Highway, Suite 700
Bethesda, MD 20814

NOAA National Marine Sanctuaries Program
Acting Director
1305 East-West Highway, 11th Floor
Silver Spring, MD 20910

Dr. Leila Hatch
NOAA National Marine Sanctuaries Program
Gerry E. Studds Stellwagen Bank National
Marine Sanctuary
175 Edward Foster Road
Scituate, MA 02066

Craig MacDonald
Superintendent, Stellwagen Bank National
Marine Sanctuary
175 Edward Foster Road
Scituate, MA 02066

Mary Tagliareni
Deputy Superintendent
Florida Keys National Marine Sanctuary
P.O. Box 1083
Key Largo, FL 33037

Billy Causey
Regional Director
Florida Keys National Marine Sanctuary
South East Region
33 East Quay Road
Key West, FL 33040

G. P. Schmahl
Superintendent, Flower Garden Banks National
Marine Sanctuary
4700 Avenue U, Bldg 216
Galveston, TX 77551

Allen Tom
Director, Pacific Islands Region
Office of National Marine Sanctuaries
726 South Kihei Road
Kihei, HI 96753

Elia Y. K. Herman
State Co-Manager, Hawaiian Islands Humpback
Whale National Marine Sanctuary
Division of Aquatic Resources
Department of Land and Natural Resources
1151 Punchbowl St., #330
Honolulu, HI 96813

Malia Chow
Superintendent, Hawaiian Islands Humpback
Whale National Marine Sanctuary
NOAA / DKIRC
Attn: NOS/HIHWNMS
1845 Wasp Boulevard, Building 176
Honolulu, HI 96818-5007

Maria Brown
Superintendent
NOAA Greater Farallones National Marine
Sanctuary
991 Marine Drive, The Presidio
San Francisco, CA 94129

Chris Mobley
Superintendent
Channel Islands National Marine Sanctuary
University of California Santa Barbara
Ocean Science Education Building 514, MC 6155
Santa Barbara, CA 93106-6155

Gene Brighouse
Superintendent
National Marine Sanctuary of American Samoa
P.O. Box 4318
Pago Pago, AS 96799

Sarah Fangman
Superintendent
Gray's Reef National Marine Sanctuary
10 Ocean Science Circle
Savannah, GA 31411

Paul Michel
Superintendent
Monterey Bay National Marine Sanctuary
99 Pacific Street, Bldg. 455A
Monterey, CA 93940

David Alberg
Superintendent
Monitor National Marine Sanctuary
c/o Mariners' Museum
100 Museum Drive
Newport News, VA 23606

Carol Bernthal
Superintendent
Olympic Coast National Marine Sanctuary
115 East Railroad Ave. Suite 301
Port Angeles, WA 98362

Commanding Officer (MSC) Environmental
Protection Branch
U.S. Coast Guard, Stop 7430
Department of Homeland Security
2703 Martin Luther King Jr. Ave SE
Washington, DC 20593-7430

Dr. Jerome Montague
Alaskan Command, U.S. Navy
Native Affairs and Natural Resources Advisor
Building 10471
Suite 301A
Elmendorf Air Force Base, Alaska 99506-2100

7.2.2.2 Native Alaskan and Native Tribal Governments and Organizations

The Honorable Stella M. Krumrey
President, Alutiiq Tribe of Old Harbor
P.O. Box 62
Old Harbor, AK 99643

The Honorable Tom Johnson, Jr.
Chairman, Sun'aq Tribe of Kodiak
312 West Marine Way
Kodiak, AK 99615

The Honorable David Totemoff
President, Native Village of Tatitlek
P.O. Box 171
Tatitlek, AK 99677

The Honorable Elizabeth Pennington
President, Native Village of Port Lions
P.O. Box 69
Port Lions, AK 99550

The Honorable Patrick Norman
First Chief, Native Village of Port Graham
P.O. Box 5510
Port Graham, AK 99603

The Honorable Robert Boskofsky
President, Native Village of Ouzinkie
P.O. Box 130
Ouzinkie, AK 99644

The Honorable Robert Henrichs
President, Native Village of Eyak
P.O. Box 1388
Cordova, AK 99574

The Honorable Larry Evanoff
Chairman, Native Village of Chenega
P.O. Box 8079
Chenega Bay, AK 99574

The Honorable Loretta Nelson
Chairperson, Native Village of Afognak
323 Carolyn Street
Kodiak, AK 99615

The Honorable Andy Teuber
President, Tangirnaq Native Village
3449 E. Rezanof Drive
Kodiak, AK 99615

The Honorable Phyllis Amado
President, Kaguyak Village
P.O. Box 5078
Akhiok, AK 99615

The Honorable Warren Brainard
Chief, Confederated Tribes of Coos, Lower Umpqua, and Siuslaw Indians
1245 Fulton Avenue
Coos Bay, OR 97420

The Honorable Delores Pigsley
Chairwoman, Confederated Tribes of Siletz Indians of Oregon
P.O. Box 549
Siletz, OR 97380

The Honorable Reyn Leno
Chairman, Confederated Tribes of Grand Ronde Community of Oregon
9615 Grand Ronde Road
Grand Ronde, OR 97347

The Honorable Austin Greene, Jr.
Chairman, Confederated Tribes of the Warm Springs
1233 Veterans Street
P.O. Box C
Warm Springs OR 97761

The Honorable Brenda Meade
Chairwoman, Coquille Indian Tribe
3050 Tremont Street
North Bend, OR 97459

The Honorable Dan Courtney
Chairman, Cow Creek Band of Umpqua Tribe of Indians
2371 North East Stephens Street, Suite 100
Roseburg, OR 97470

The Honorable Don Gentry
Chairman, Klamath Tribes
P.O. Box 436
Chiloquin, OR 97624

The Honorable Don Secena
Chairman, Confederated Tribes of the Chehalis Reservation
P.O. Box 536
Oakville, WA 98568

The Honorable William "Bill" Iyall
Chairman, Cowlitz Indian Tribe
P.O. Box 2547
Longview, WA 98632

The Honorable Maria Lopez
Chairwoman, Hoh Indian Tribe
P.O. Box 2196
Forks, WA 98331

The Honorable Marla Tolliver
Chairwoman, Makah Indian Tribe of the Makah Reservation
P.O. Box 115
Neah Bay, WA 98357

The Honorable Charles Woodruff
Chairman, Quileute Tribe of the Quileute Reservation
P.O. Box 279
La Push, WA 98350

The Honorable Fawn Sharp
President, Quinault Indian Nation
P.O. Box 189
Taholah, WA 98587

The Honorable Charlene Nelson
Chairwoman, Shoalwater Bay Tribe of the Shoalwater Bay Reservation
P.O. Box 130
Tokeland, WA 98590

7.2.2.3 State Organizations

Larry Simon
Federal Consistency Coordinator, California Coastal Commission
45 Fremont, Suite 2000
San Francisco, CA 94105-2219

Frazer McGilvray
Administrator, Division of Aquatic Resources
State of Hawaii
1151 Punchbowl Street, Room 330
Honolulu HI 96813

Tony Van DenBossche
Director, State of Maine
Executive Department
Maine State Planning Office
19 Union Street
Augusta, ME 04333-0038

Leo R. Asuncion, Jr.
Acting Director, Hawaii Office of Planning
State of Hawaii
P.O. Box 2359
Honolulu, HI 96804

William J. Aila, Jr.
State of Hawaii
Department of Land and Natural Resources
P.O. Box 1879
Honolulu, HI 96805

Kim Kruse
Deputy Director, Division of Coastal and Ocean Management
550 West 7th Avenue, Suite 1100
Anchorage, AK 99501-3559

7.2.2.4 Other Organizations and Interested Parties

Michael Jasny
Natural Resources Defense Council
1314 Second Street
Santa Monica, CA 90401

Joel R. Reynolds
Natural Resources Defense Council
1314 Second Street
Santa Monica, CA 90401

The Humane Society of the United States
Animal Protection Litigation
2100 L Street NW
Washington, DC 20037

David Kaplan
Cetacean Society International
65 Redding Road-0953
Georgetown, CT 06829-0953

League for Coastal Protection
212 La Espiral
Orinda, CA 94563-1813

Jean-Michel Cousteau
Ocean Futures Society
513 De La Vina Street
Santa Barbara, CA 93101

Michael Stocker
Ocean Conservation Research
P.O. Box 559
Lagunitas, CA 94938

7.3 Literature Cited

Department of the Navy (DoN). (2015). Notice of intent to prepare a supplemental environmental impact statement/supplemental overseas environmental impact statement for employment of Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar. Department of the Navy, Department of Defense. *Federal Register 80*(108):32097. <http://www.surtass-lfa-eis.com/docs/NOI_FR_2015.pdf>.

8 LIST OF PREPARERS

This SEIS/SOEIS was prepared collaboratively among the Navy, the National Marine Fisheries Service, and contractor preparers.

U.S. Department of the Navy

CAPT Scott A. Minium, U.S. Navy (Chief of Naval Operations, Warfare Integration for Information Dominance Division, OPNAV N2/N6F24)
M.A. National Security and Strategic Studies
M.A. Engineering Management
B.S. Computer Science
Years of Experience: 28
Responsible for: SEIS/SOEIS review and approval

LCDR Mark Murnane, U.S. Navy (Chief of Naval Operations, Warfare Integration for Information Dominance Division, OPNAV N2/N6F24)
M.S. Meteorology and Oceanography
B.S. Geological Sciences
Years of Experience: 17
Responsible for: SEIS/SOEIS review and endorsement

Danielle Buonantony (Chief of Naval Operations, Energy and Environmental Readiness Division OPNAV N454)
M.E.M. Coastal Environmental Management
B.S. Biological Sciences
Years of Experience: 8
Responsible for: SEIS/SOEIS MMPA requirements review

Ronald Carmichael (Chief of Naval Operations, Energy and Environmental Readiness Division OPNAV N454)
M.S. Program Management
B.S. Ocean Engineering
Years of Experience: 30
Responsible for: SEIS/SOEIS NEPA requirements review

National Marine Fisheries Service

Jolie Harrison (Office of Protected Resources, Permits and Conservation Division)
M.S., Environmental Science
B.S. Biology
Years of Experience: 14
Responsible for: SEIS/SOEIS Collaboration and Review

Dale Youngkin (Office of Protected Resources, Permits and Conservation Division)
M.S. Biology/Marine Science
B.S. Ecology
Years of Experience: 19
Responsible for: SEIS/SOEIS Collaboration and Review

Contractors

Kathleen J. Vigness-Raposa (Marine Acoustics, Inc.)
Ph.D. Environmental Sciences
M.S. Biological Oceanography
B.S. Education
Years of Experience: 20
Responsible for: SEIS/SOEIS Program Manager, Editor in Chief; marine mammal population data derivation; OBIAs; marine mammal impact derivation; SEIS preparer (Chapter 4, Appendix B)

Clayton H. Spikes (Marine Acoustics, Inc.)
M.S. Physical Oceanography
B.S. Engineering
Years of Experience: 39
Responsible for: SEIS/SOEIS preparer (Chapters 1, 2, 8) and SEIS/SOEIS review

Cheryl L. Schroeder (Marine Acoustics, Inc.)
M.S. Biological Oceanography
B.S. Marine Biology
Years of Experience: 35
Responsible for: SEIS/SOEIS preparer (Chapters 1, 2, 3, 4, 5, 6, Appendix A, Appendix C); marine biology; marine mammal population data derivation; document preparation and editing; OBIAs; GIS analysis and map preparer; document preparation

Adam S. Frankel (Marine Acoustics, Inc.)
Ph.D. Oceanography
M.S. Zoology
B.S. Biology
Years of Experience: 30
Responsible for: SEIS/SOEIS preparer (Chapters 3, 4); acoustic impact modeling and analysis

Jennifer L. Giard (Marine Acoustics, Inc.)
M.S. Ocean Engineering
B.S. Ocean Engineering
Years of Experience: 8
Responsible for: SEIS/SOEIS preparer (Chapters 3, 4, 5, 6)

Andrew W. White (Marine Acoustics, Inc.)
Ph.D. Geophysics
B.S. Physics/Astronomy
Years of Experience: 9
Responsible for: SEIS/SOEIS preparer (Chapters 1, 2, Appendix B)

Brian Ward, Marine Biologist (Science Applications International Corporation, contracted under OPNAV N454)
M.S. Fisheries
B.S. Biology
Years of Experience: 4
Responsible for: SEIS/SOEIS ESA requirements review

APPENDIX A: CORRESPONDENCE

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
2000 NAVY PENTAGON
WASHINGTON, DC 20350-2000

5090
Ser N45/15U132387
May 28, 2015

Ms. Jolie Harrison
Chief, Division of Permits and Conservation
National Marine Fisheries Service
1315 East West Highway
Silver Spring, MD 20910

Dear Ms. Harrison:

SUBJECT: COOPERATING AGENCY REQUEST FOR THE SUPPLEMENTAL ENVIORNMENTAL IMPACT STATEMENT/SUPPLEMENTAL OVERSEAS ENVIRONMENTAL IMPACT STATEMENT (SEIS/SOEIS) FOR THE SURVEILLANCE TOWED ARRAY SENSOR SYSTEM (SURTASS) LOW FREQUENCY ACTIVE (LFA) SONAR

In accordance with the National Environmental Policy Act (NEPA) and to support a new 5-Year Final Rule under the Marine Mammal Protection Act (MMPA) and Incidental Take Statement-Biological Opinion under the Endangered Species Act for employment of SURTASS LFA sonar, the Department of the Navy is initiating the preparation of a SEIS/SOEIS.

Navy requests that the National Marine Fisheries Service (NMFS) Office of Protected Resources (OPR) continue to serve as a cooperating agency in accordance with NEPA regulations (40 CFR 1501.6) and the Council on Environmental Quality cooperating agency guidance, issued on 30 January 2002. The respective responsibilities of Navy and NMFS OPR will be consistent with those described in and agreed upon in the cooperative agency correspondence between the two agencies for the 2012 SURTASS LFA Sonar SEIS/SOEIS (dated 24 November 2008 and 6 February 2009) and the 2015 SURTASS LFA Sonar SEIS/SOEIS (dated 30 June 2014 and 3 November 2014).

Navy, as lead agency, will be responsible for overseeing preparation of the SEIS/SOEIS that will include, but not be limited to, the following:

- Gathering the necessary background information and preparing the SEIS/SOEIS and the necessary rulemaking and permit applications associated with the employment of SURTASS LFA sonar.
- Working with NMFS personnel in determining the best available science in the analysis of potential effects to protected marine species, including threatened and endangered species.
- Determining the scope and alternatives of the SEIS/SOEIS.
- Responding to NMFS requests for information in a timely manner.
- Circulating the appropriate NEPA/Executive Order 12114 documentation to the general public and other interested parties.

5090
Ser N45/15U132387
May 28, 2015

- Maintaining the SEIS/SOEIS schedule and supervising meetings held in support of the NEPA/Executive Order 12114 process. A notional schedule for the preparation of the 2017 SEIS/SOEIS for SURTASS LFA sonar as well as the associated MMPA and ESA documentation has been included in enclosure (1).
- Compiling and drafting responses to comments received on the Draft SEIS/SOEIS.
- Maintaining an administrative record and responding to any Freedom of Information Act requests related to the SEIS/SOEIS.

As a cooperating agency, Navy requests NMFS provide support as follows:

- Provide timely comments on working drafts of the SEIS/SOEIS.
- Coordinate closely with the Navy to analyze potential additional new or modified marine mammal Offshore Biologically Important Areas (greater than 12 NM offshore) for SURTASS LFA sonar.
- Respond to Navy requests for information in a timely manner.
- Coordinate, to the maximum extent practicable, any public comment periods required by the MMPA permitting process, with the Navy's NEPA public comment periods on the SEIS/SOEIS.
- Assist Navy in responding to public comments.
- Participate in meetings hosted by the Navy for discussions on the SEIS/SOEIS and permitting-related issues.
- Adhere, to the maximum extent possible, to the overall schedule, as agreed upon by Navy and NMFS.

Navy views this agreement as important to the successful completion of the SEIS/SOEIS for SURTASS LFA sonar employment. NMFS participation as a cooperating agency will be invaluable in this endeavor. A formal, written response is requested.

NEPA point of contact for this action is Dawn Schroeder (OPNAV N454), (703) 695-5219, email: dawn.schroeder@navy.mil and the technical point of contact is LCDR Mark Murnane (OPNAV N2/N6F24), (703) 695-8266, email: mark.murnane2@navy.mil.

Sincerely,

Karnig Ohannessian

K. H. OHANNESSIAN
Deputy Director, Energy and
Environmental Readiness Division

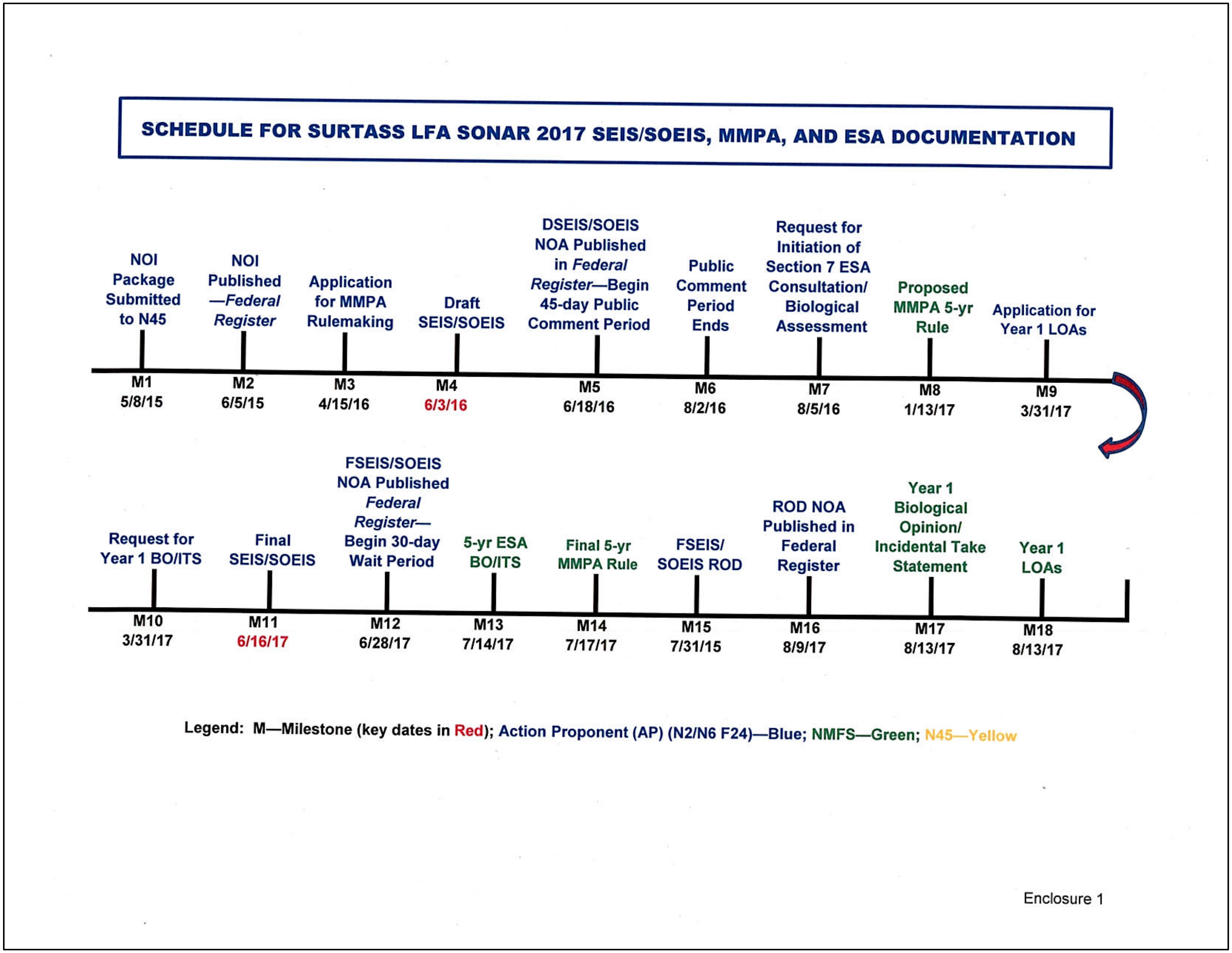
2

5090
Ser N45/15U132387
May 28, 2015

Enclosure: 1. Notional schedule for SURTASS LFA sonar 2017 SEIS/SOEIS, MMPA, and ESA documentation

Copy to: OPNAV (N2/N6F24)

3


SCHEDULE FOR SURTASS LFA SONAR 2017 SEIS/SOEIS, MMPA, AND ESA DOCUMENTATION
NOI Package Submitted to N45
M1 5/8/15
NOI Published —Federal Register
M2 6/5/15
Application for MMPA Rulemaking
M3 4/15/16
Draft SEIS/SOEIS
M4 6/3/16
DSEIS/SOEIS NOA Published in Federal Register—Begin 45-day Public Comment Period
M5 6/18/16
Public Comment Period Ends
M6 8/2/16
Request for Initiation of Section 7 ESA Consultation/ Biological Assessment
M7 8/5/16
Proposed MMPA 5-yr Rule
M8 1/13/17
Application for Year 1 LOAs
M9 3/31/17
Request for Year 1 BO/ITS
M10 3/31/17
Final SEIS/SOEIS
M11 6/16/17
FSEIS/SOEIS NOA Published Federal Register—Begin 30-day Wait Period
M12 6/28/17
5-yr ESA BO/ITS
M13 7/14/17
Final 5-yr MMPA Rule
M14 7/17/17
FSEIS/ SOEIS ROD
M15 7/31/15
ROD NOA Published in Federal Register
M16 8/9/17
Year 1 Biological Opinion/ Incidental Take Statement
M17 8/13/17
Year 1 LOAs
M18 8/13/17
Legend: M—Milestone (key dates in Red); Action Proponent (AP) (N2/N6 F24)—Blue; NMFS—Green; N45—Yellow
Enclosure 1

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Silver Spring, MD 20910

SEP 2 1 2015

K. H. Ohannessian
Deputy Director,
Energy and Environmental Readiness Division
United States Navy
Office of the Chief of Naval Operations
2000 Navy Pentagon
Washington, D.C. 20350-2000

Dear Mr. Ohannessian,

Thank you for inviting the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service, Office of Protected Resources (OPR), Permits and Conservation Division to participate as a cooperating agency in the development of a Supplemental Environmental Impact Statement/Supplemental Overseas Environmental Impact Statement (Supplemental EIS/OEIS) for the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar.

We support.the Navy's decision to prepare this Supplemental EIS/OEIS on this activity and agree to be a cooperating agency, due, in part, to our responsibilities under section 101(a)(5)(A) of the Marine Mammal Protection Act and section 7 of the Endangered Species Act.

We agree with the list of responsibilities itemized in the Navy's letter and request that that the Navy work with NMFS OPR staff to discuss updating the proposed scheduled milestones shown in the Navy's Enclosure 1 to ensure successful and timely completion of the 2017 Supplemental SEIS/OEIS.

If you need any additional information, please contact Jolie Harrison or Jeannine Cody, (301-427-8401), who will be the NOAA OPR points of contact for this SEIS/OEIS.

Sincerely,

PERRY GAYALDO
for Donna S. Wieting
Director, Office of Protected Resources

1

APPENDIX B: MARINE MAMMAL IMPACT ANALYSIS

This appendix documents the elements of the acoustic impact analysis for marine mammals presented in Chapter 4 of this SEIS/SOEIS. The acoustic impact analysis represents an evolution that builds upon the analysis, methodology, and impact criteria documented in previous SURTASS LFA sonar NEPA efforts (DoN, 2001, 2007, 2012, 2015), which are incorporated by reference, but also includes updates of the most current acoustic impact criteria and methodology to assess acoustic impacts on marine mammal species.

The acoustic impact analysis of SURTASS LFA sonar transmissions is a multi-step process based on using the Acoustic Integration Model© (AIM) to integrate the acoustic field created from the underwater transmissions of LFA sonar with the four-dimensional (4D) movement of marine mammals to estimate their potential sonar exposure. AIM is the foundation for the impact analyses presented herein as it has been for all previous analyses of acoustic impacts on marine mammals associated with SURTASS LFA sonar.

Descriptions of the proposed action, including the operating characteristics of LFA sonar, are included in Chapter 2, while Chapter 3 includes information on the distribution and population estimates of the marine mammal species and stocks that occur in the 26 potential mission areas for SURTASS LFA sonar and are assessed in this SEIS/SOEIS.

References to Underwater Sound Levels

- References to underwater sound pressure level (SPL) in this SEIS/SOEIS 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).
- In this SEIS/SOEIS, underwater sound exposure level (SEL) is a measure of energy, specifically the squared instantaneous pressure integrated over time; 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) used herein is an intermediate calculation for input to the behavioral risk continuum used in the acoustic impact analysis for SURTASS LFA sonar. SPE accounts for the energy of all LFA sonar transmissions that a modeled animal ("animat") receives during a 24-hr period of a SURTASS LFA sonar mission as well as an approximation of the manner in which the effect of repeated exposures accumulate. As such, the SPE metric incorporates both physics and biology. SPE is a function of SPL, not SEL. SPE levels will be expressed as "dB SPE" in this document, as they have been presented in preceding environmental compliance documentation for SURTASS LFA sonar: FOEIS/FEIS (DoN, 2001); FSEIS (DoN, 2007); FSEIS/SOEIS (DoN, 2012); and FSEIS/SOEIS (DoN, 2015).
- Briefly, SPE accounts for the increased potential for behavioral response due to repeated exposures by adding 5 x log10 (number of pings) to each 1-dB RL increment (Kryter, 1985; Richardson et al., 1995; Ward, 1968). This calculation is done for each dB level of RL and then summed across all dB levels to determine the dB SPE for that animal. A more generalized formula is provided in the original FOEIS/FEIS (DoN, 2001).

B-1 Introduction to AIM

AIM is described in detail and has been used in the impact analyses in these preceding environmental compliance documentation for SURTASS LFA sonar: FOEIS/FEIS (DoN, 2001); FSEIS (DoN, 2007); FSEIS/SOEIS (DoN, 2012); and FSEIS/SOEIS (DoN, 2015). While the information and details on AIM and its use in the analysis of marine mammal acoustic impacts are incorporated by reference, the following summary of AIM is provided for context.

AIM is a Monte Carlo based statistical model in which multiple iterations of realistic predictions of acoustic source operations as well as animal distribution and movement patterns are conducted to provide statistical predictions of estimated impacts from exposure to acoustic source transmissions. Each acoustic source and receiver is modeled via the “animat” concept. Animats are computationally simulated animals or objects. When an animat represents an object such as an acoustic source, the speed, direction, and depth are usually specified. When an animat represents an animal, movement is defined by specifying behavioral variables, such as dive parameters, swimming speed, and course/direction changes. This results in a realistic representation of animal movements such as diving patterns that mimic real-world diving patterns of that species. The movement of an animat can also be programmed to respond to environmental factors (e.g., water depth) so that a marine species that normally inhabits a specific environment (e.g., shallow, coastal waters) can be constrained to stay within a specified habitat.

A model run consists of a user-specified number of steps forward in time. During each 30-sec time step, each animat is moved according to the programmed rules describing its behavior and the received sound level at each receiver animat is recorded (in the same units that are used to specify the source level, e.g., dB rms). At the end of each time step, each animat evaluates its environment including its three-dimensional (3D) location. If an environmental variable has exceeded the user-specified boundary value (e.g., the animat has moved into water that is too deep), then the animat will alter its course to respond to the environment. These environmental responses are called “aversions”. There are many aversion variables that can be used to specify an animat’s reactions and to program realistic behavior, such as bathymetry, geographic boundaries, water temperature, and density of prey species.

B-2 AIM Modeling Inputs

Twenty-six representative mission areas in the Pacific, Atlantic, and Indian oceans as well as the Mediterranean Sea were selected for analysis to represent the acoustic regimes and marine mammal species that may be encountered during LFA sonar operations (Table B-1). The spatial extent of each simulation area was defined as the range at which the receive level from LFA sonar transmissions was down at least 100 dB from the array SL (i.e., transmission loss was at least 100 dB). Due to the large number of potential mission areas and seasons to be considered in the impact analysis, a seasonal sensitivity study was conducted to determine the optimal modeling season for each mission area. The modeling season was chosen based on an analysis of the sound velocity profiles and resulting sound propagation and transmission loss fields, with the season with the longest range acoustic propagation typically being selected.

The marine mammal species potentially occurring in a modeling area were determined, along with any seasonal differences in their occurrence. Species were listed as occurring in the mission area, but species were only modeled if they would be present during the selected modeling season. Modeled species were simulated by creating animats programmed with behavioral values describing their dive behavior,

Table B-1. Locations of the 26 Representative Mission Areas Modeled for SURTASS LFA Sonar Global Operations and the Season Modeled for Each Area.

Mission Area	*Mission Area Name*	*Season*	*Location of Modeling Area Center*	*Notes*
1	East of Japan	Summer	38°N, 148°E	Adjacent to Navy Japan Complex OPAREA
2	North Philippine Sea	Fall	29°N, 136°E	Adjacent to Navy Japan/Okinawa Complex OPAREA
3	West Philippine Sea	Fall	22°N/124°E	
4	Offshore Guam	Summer	11°N, 145°E	Navy Mariana Islands Testing and Training Area
5	Sea of Japan	Fall	39°N, 132°E	
6	East China Sea	Summer	26°N, 125°E	Navy Japan/Okinawa Complex OPAREA
7	South China Sea	Fall	14°N, 114°E	
8	Offshore Japan 25° to 40°N	Summer	30°N, 165°E	
9	Offshore Japan 10° to 25°N	Winter	15°N, 165°E	
10	Hawaii North	Summer	25°N, 158°W	Navy Hawaii-Southern California Testing and Training Area; Hawaii Operating Area
11	Hawaii South	Fall	19.5°N, 158.5°W	Navy Hawaii-Southern California Testing and Training Area; Hawaii Operating Area
12	Offshore Southern California	Spring	32°N, 120°W	Navy Hawaii-Southern California Testing and Training Area; Southern California Operating Area
13	Western North Atlantic (off Florida)	Winter	29°N, 76°W	Navy Atlantic Fleet Testing and Training Area; Jacksonville Operating Area
14	Eastern North Atlantic	Summer	56.4N, 10W	Northwest Approaches
15	Mediterranean Sea / Ligurian Sea	Summer	39°N, 6°E	
16	Arabian Sea	Summer	14°N, 65°E	
17	Andaman Sea	Summer	7.5°N, 96°E	
18	Panama Canal	Winter	5°N, 81°W	Western Approach
19	Northeast Australia	Spring	23°S, 155°E	
20	Northwest of Australia	Winter	18°S, 110°E	
21	Northeast of Japan	Summer	52°N, 163°E	
22	Southern Gulf of Alaska	Summer	51°N, 150°W	

Table B-1. Locations of the 26 Representative Mission Areas Modeled for SURTASS LFA Sonar Global Operations and the Season Modeled for Each Area.

Mission Area	*Mission Area Name*	*Season*	*Location of Modeling Area Center*	*Notes*
23	Southern Norwegian Basin (between Iceland and Norway)	Summer	65°N, 0°	
24	Western North Atlantic (off Virginia/Maryland)	Summer	36.9°N, 71.6°W	Navy Atlantic Fleet Testing and Training Area; Virginia Capes Operating Area
25	Labrador Sea	Winter	57°N, 50°W	
26	Sea of Okhotsk	Spring	51°N, 150°E	

including dive depth, surfacing time, dive duration, swimming speed, and direction change. Animats were randomly distributed over the model simulation area.

The modeled marine mammal animats were set to populate the simulation area with densities of 0.025, 0.05, and 0.1 animats/km^2, densities often higher than those estimated in the marine environment. This "over population" of the modeling environment ensures that the result of the simulation is not unduly influenced by the chance placement of a few simulated marine mammals. To obtain final harassment estimates, the modeled results are normalized by the ratio of the modeled animat density to the real-world marine mammal density estimate. This allows for greater statistical power without overestimating risk.

During AIM modeling, the animats were programmed to "reflect" off the boundaries of the area to remain within the simulation area. This reflection maintains the appropriate density of animats since no animats are allowed to diffuse out of the simulation area. It is also a conservative factor in the modeling results since it keeps animats within the simulation area and available for additional acoustic exposure during the 24-hr simulation period. In reality, an animat that reflects off the simulation boundary would actually leave the simulation area, whereas the animat reflecting into the simulation boundary would actually be a new animal with no acoustic exposure entering the simulation area. Since acoustic exposure accumulates over the 24-hr modeling period, the reflected animat may have a higher acoustic exposure than if it were considered as two separate animals.

B-2.1 Acoustic Propagation

B-2.1.1 Sound Source Waypoints

Each simulated mission area is defined by geographic coordinates in which the simulated SURTASS LFA sonar ship travels in a triangular pattern (Figure B-1). For modeling purposes, the center of each mission area is the center of the ship track. For all modeled mission areas, the ship speed was modeled at 4 kt (7.4 kph), and in all cases, the time on each bearing was 8 hr (480 min). The duration of LFA sonar transmissions was modeled as 24 hr at each mission area, with a signal duration of 60 sec and a duty cycle of 10 percent (i.e., the source transmitted for 60 sec every 10 mi for 24 hr).

B-2.1.2 Transmission Loss and Modeling Area

The LFA sonar source was modeled as a vertical line array using the actual element spacing of the LFA sonar array, with transmissions at a nominal frequency and nominal SL. For this modeling effort, a single frequency of 300 Hz (i.e., the middle of the 100 to 500 Hz band of the system), and an individual element SL of 215 dB re 1 µPa @ 1 m (rms) (SPL) (or an array source level of about 235 dB re 1 µPa @ 1 m (rms) (SPL) in the far-field) were used as these nominal values.

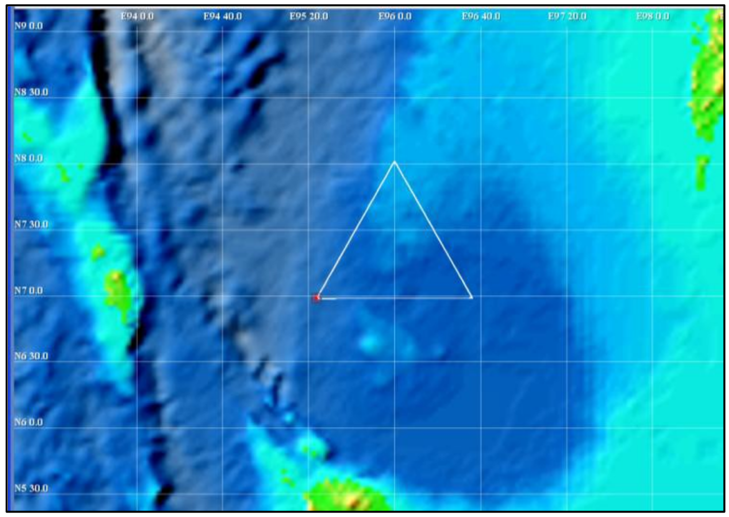


Figure B-1. Modeled Ship Movement Pattern of SURTASS LFA Sonar Vessel during Simulated Sonar Operations.

To model the sound fields created by the SURTASS LFA sonar source, the Navy standard parabolic equation (PE) model was used. The bathymetry used was the 2-minute Gridded Global Relief Data set (ETOPO2), with an adjustment to the data that corrects the existing indexing error in the ETOPO2 dataset (NGDC, 2006). The sound velocity profiles for each location and season were obtained from the Generalized Digital Environmental Model, Version 3.0 (Carnes, 2009), a standard U.S. Navy OAML database. A wind speed of 15 kt (27.8 kph) was used to calculate surface losses using the Bechmann-Spezzichino formula modified by Leibiger (1978). For bottom loss, province 5 and curve 5 from the consolidated bottom loss upgrade (CBLUG) database (Renner and Spofford, 1985) were used for all sites. Four bearings were modeled per location and a nominal vertical half-beam width of 45° was used. Spherical spreading was assumed within 0.054 nmi (0.1 km) of the LFA sonar source.

B-2.2 Parameters that Define Animat Movement in AIM

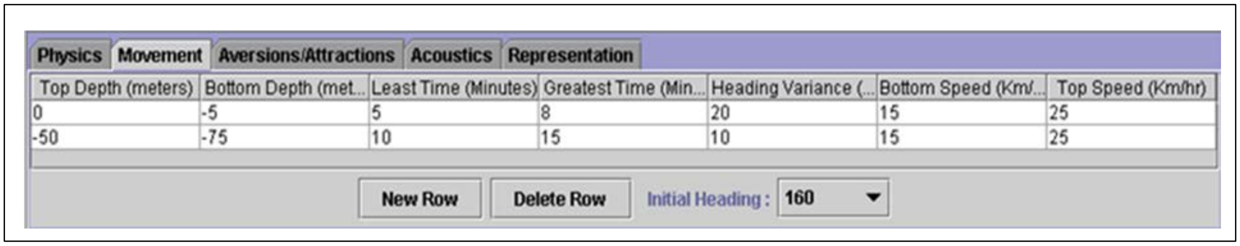
Animals move through four dimensions: 3D space and time. Several parameters are used in AIM to produce simulated movements that accurately represent expected real animal movement patterns. This section provides short descriptions of the various parameters, with nominal values as examples of how the parameters are implemented in AIM. The actual values used in the impact analysis and the literature from which that information was obtained are detailed in Chapter B-2.3.

B-2.2.1 Marine Mammal Diving Patterns

Diving parameters, such as time limits, depth limits, heading variance, and speed, are specified for each animat in the AIM model (Figure B-2). As an example, a dive pattern is presented that consists of a shallow, respiratory sequence (top row of Figure B-2) followed by a deeper, longer dive (bottom row of Figure B-2). The horizontal component of the dive is handled with the “heading variance” term, which allows the animal to change course up to a certain number of degrees at each movement step. For this example, the animal can change course 20° during a shallow dive and 10° during a deep dive (Figure B-2). Using the defined diving parameters, AIM generates realistic dive patterns (Figure B-3).

B-2.2.2 Aversions

In addition to movement patterns, animats can be programmed to avoid certain environmental characteristics (Figure B-4). For example, aversions can be used to constrain an animal to a particular



Top Depth (meters)	Bottom Depth (met...	Least Time (Minutes)	Greatest Time (Min...	Heading Variance (...	Bottom Speed (Km/...	Top Speed (Km/hr)
0	-5	5	8	20	15	25
-50	-75	10	15	10	15	25

Figure B-2. Example of AIM Marine Mammal Movement Parameters, With the Top Row Showing the Parameters of a Shallow, Respiratory Dive (Diving from Surface to 5 M For 5 to 8 Min) and the Bottom Row Showing a Deeper, Longer Dive (Diving Between 50 and 75 M for 10 to 15 Min).

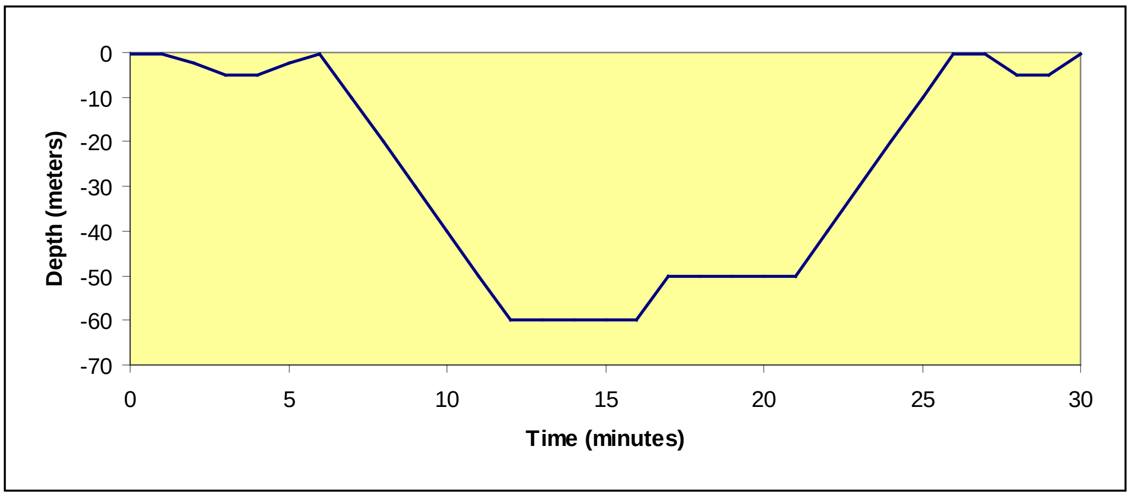
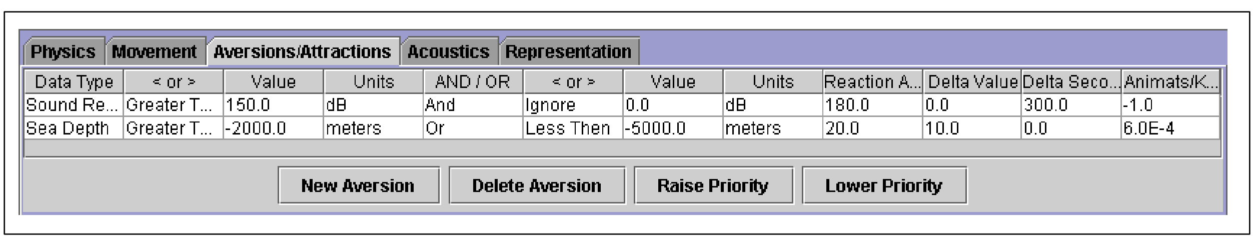


Figure B-3. Marine Mammal Dive Pattern Based on Animat Data in Figure B-2. The Animat Makes a Shallow Dive from the Surface to 5 M for Approximately 6 Min, Surfaces, and then Makes a Deep Dive to 60 M for About 5 Min, Changes Depth to 50 M for Another 5 Min, and then Surfaces.



Data Type	< or >	Value	Units	AND / OR	< or >	Value	Units	Reaction A...	Delta Value	Delta Seco...	Animats/K...
Sound Re...	Greater T...	150.0	dB	And	Ignore	0.0	dB	180.0	0.0	300.0	-1.0
Sea Depth	Greater T...	-2000.0	meters	Or	Less Then	-5000.0	meters	20.0	10.0	0.0	6.0E-4

Figure B-4. Example of Depth Aversion Parameters for Modeling of Marine Mammal Movements.

depth regime. (e.g., an animat can be constrained to waters between 2,000 and 5,000 m deep). An animat will continue to turn until the aversion is satisfied. In this example, animat makes 20° turns in water depths shallower than 6,562 ft (2,000 m) or deeper than 16,404 ft (5,000 m) to remain within that depth range.

B-2.3 Parameters of Marine Mammal Movement Behaviors Used in Impact Analysis

Dive and swim speed information for each marine mammal or marine mammal group is a critical component of accurately and realistically modeling marine mammal movements when assessing potential exposure to underwater acoustic transmissions. Dive and swim parameters for marine mammals potentially occurring in the representative mission areas (Table B-1) are summarized (Table B-2). Narrative information, including the literature from which these values were obtained, is included in Chapter B-2.4 or incorporated by reference from the 2012 SEIS/SOEIS as described below.

Some marine mammal species were modeled as representative groups rather than individual species. Beaked whale species are one example, where all potentially occurring beaked whales were divided into two functional modeling groups, the large and small beaked whales (see Table B-2 for the breakdown of species each grouping represents). Additionally, some species such as the bottlenose and common dolphins, for which more than one species has been identified in the representative mission areas for SURTASS LFA sonar global operations, were modeled as an inclusive generic group rather than by the individual species (e.g., bottlenose dolphins vice common and Indo-Pacific bottlenose dolphins) since the dive and swim parameters are similar. Likewise, congener species that inhabit the same type of habitat and have similar dive and swim behaviors, such as the *Phoca* ice-loving (pagophilic) seals (ribbon, spotted, and ringed), are modeled as a group.

The dive and swim data for many of the marine mammal species modeled for this SEIS/SOEIS (Table B-2) remain unchanged from the data and information presented previously (Appendix C, 2012 SEIS/SOEIS [DoN, 2012]); thus, the narrative information on diving and swimming behavior for some species are incorporated by reference herein and are not repeated in this appendix. Dive and swim data and descriptions for the following marine mammal species are included by reference from the 2012 SEIS/SOEIS:

- Humpback Whale (*Megaptera novaeangliae*) (Winter Grounds: Singer)
- Humpback Whale (*Megaptera novaeangliae*) (Calf)
- North Atlantic Right Whale (*Eubalaena glacialis*)
- Common Dolphins (*Delphinus* spp.)
- Dall's Porpoise (*Phocaenoides dalli*)
- Fraser's Dolphin (*Lagenodelphis hosei*)
- Killer Whale (*Orcinus orca*)
- *Kogia* spp. (Dwarf and Pygmy Sperm Whales)
- *Lagenorhynchus* Species: Atlantic and Pacific White-Sided, Peale's, White-Beaked, and Hourglass Dolphins
- Right Whale Dolphins (*Lissodelphis* spp*).*
- Risso 's Dolphin (*Grampus griseus*)
- Rough-toothed Dolphin (*Steno bredanensis*)
- *Stenella* spp.: Pantropical Spotted, Atlantic Spotted, Spinner, Spotted, Striped, and Clymene Dolphins

Table B-2. Dive and Swim Parameters of all the Potentially Occurring Marine Mammal Species Modeled to Assess the Potential Impact of Exposure to SURTASS LFA Sonar Transmissions in 26 Representative Mission Areas.

Modeled Species	*Min/Max Surface Time (Min)*	*Surface/ Dive Angle*	*Dive Depth (m) Min/Max (Percentage)*	*Min/Max Dive Time (Min)*	*Heading Variance (Angle/Time)*	*Min/ Max Speed (kph)*	*Speed Distribution*	*Depth Limit (M)/ Reaction Angle*
Blue Whale (non-foraging) (including pygmy blue whale)	1/4		20/100	2/18	30/300(50%) 90/300(50%)	3/14	Normal	100/reflect
Blue Whale (foraging) (including pygmy blue whale)	1/4		20/100 (50) 100/300 (50)	2/18 4/18	30/300 90/90	3/14	Normal	100/reflect
Bowhead Whale (migrating)	1/2		5/16 (60) 17/151 (25%) 152/416 (15%)	1/5 5/15 15/30		1/8	Normal	
Common Minke Whale	1/3		20/100	2/6	Surf 45/Dive 20	1/18	Gamma (3.25,2)	10/reflect
Fin Whale	1/1		50/250 (45) 50/250 (45) 250/470 (10)	5/8 1/2	20	1/16	Normal	30/reflect
Gray Whale (migrating)	1/2		10/40	3/12	10/300	2/9	Normal	10/reflect
Gray Whale (summering)	1/2		10 / bottom	1/7	90/90	1/5	Normal	
Gray Whale (Mating)	1/2		10/40	1/7	90/90	1/5	Normal	
Humpback Whale (migrating)	1/2		10/40 (100)	5/10	10	2/12	Normal	(Min =100)/reflect
Humpback Whale (feeding)	1/2		10/60 (20%) 40/100(75%) 100/150(5%)	5/10	45/30	2/10	Normal	(Min =100)/reflect
Humpback Whale (winter grounds, singing)	1/1		15/30 (100)	10/25	10/30	0/1	Normal	>1000/reflect
Humpback Whale (calf)	1/2		5/30 (100)	2/5	45	1/3	Normal	>200/reflect
Humpback Whale (winter grounds and migrating adults)	1/1		10/50	5/20	20	1/6	Gamma	1000/reflect
Right Whale (feeding)	4/5	75	113/130 (50) 113/130 (50)	11/13 11/13	90/90 30/90	1/4	Normal	

Table B-2. Dive and Swim Parameters of all the Potentially Occurring Marine Mammal Species Modeled to Assess the Potential Impact of Exposure to SURTASS LFA Sonar Transmissions in 26 Representative Mission Areas.

Modeled Species	*Min/Max Surface Time (Min)*	*Surface/ Dive Angle*	*Dive Depth (m) Min/Max (Percentage)*	*Min/Max Dive Time (Min)*	*Heading Variance (Angle/Time)*	*Min/ Max Speed (kph)*	*Speed Distribution*	*Depth Limit (M)/ Reaction Angle*
Right Whale (migrating)	1/1	75	10/200 (10) 10/35 (90)	1/10 1/7	90/60 30/300	2/5	Normal	
Right Whale (breeding)	1/3	75	2/25 (50) 2/25 (50)	1/8 1/8	30/300 90/90	1/3	Normal	
Sei/Bryde's/Omura's Whales	1/1	90/75	10/40 (80) 50/267 (20)	2/11	30/300 (50%) 90/300 (50%)	1/20	5/1	50/reflect
Beaked Whales—Small (Blainville's, Cuvier's, Longman's, Sowerby's, Andrews', Hubbs', Gervais', Ginkgo-toothed, Gray's, Hector's, Deraniyagala's, Strap-toothed, True's, Perrin's, Pygmy, Spade-toothed, Stejneger's	1/7		2000/3000 (5) 1000/2000 (25) 200/500 (70)	100/140 48/74 12/30	30/300 (50) 90/300 (50)	2/7	Normal	253/ reflect
Beaked Whales—Large (Arnoux', Shepherd's, and Baird's beaked whales, northern bottlenose and southern bottlenose whales)	1/7		500/1453 (50) 50/200 (50)	48/70 12/70	30/300 (50) 90/300 (50)	3/6	Normal	253/reflect
Blackfish (False killer whale, Pygmy killer whale, Melon-headed whale)	1/1		5/50 (80) 50/300 (20)	1/3 4/8	30/300 (50) 90/90 (50)	2/22.4	Gamma	200/reflect
Bottlenose Dolphins (Coastal)	1/1		15/98	1/3	90/300 (50) 90/90 (50)	2/16	Normal	10/reflect
Bottlenose Dolphins (Pelagic)	1/1		6/50 (80) 50/100 (5) 100/250 (5) 250/500 (10)	1/2 2/3 3/4 5/6	30/300 (45) 90/90 (45) 90/90(10)	2/16	Normal	101/1226 reflect

Table B-2. Dive and Swim Parameters of all the Potentially Occurring Marine Mammal Species Modeled to Assess the Potential Impact of Exposure to SURTASS LFA Sonar Transmissions in 26 Representative Mission Areas.

Modeled Species	*Min/Max Surface Time (Min)*	*Surface/ Dive Angle*	*Dive Depth (m) Min/Max (Percentage)*	*Min/Max Dive Time (Min)*	*Heading Variance (Angle/Time)*	*Min/ Max Speed (kph)*	*Speed Distribution*	*Depth Limit (M)/ Reaction Angle*
Common Dolphins	1/1		50, /200	1/5	30	2/9	Normal	100-1000/reflect
Dall's Porpoise	1/1		5/94	1/2	30	6/16	Normal	>100 m
Fraser's Dolphin	1/1		50/700	1/6	30/300 (50) 90/300 (50)	2/15	Normal	100/reflect
Harbor Porpoise	1/1	17/31	1/10 (35) 10/40 (45) 40/100 (15) 100/230 (5)	1/4	30/150	2/8	Normal	100-1000/reflect
Killer Whale	1/1		10/180	1/10	30/300 (50)	3/12	Normal	25/ reflect
Kogia spp.	1/2		200/1000	5/12	30	1/11	Normal	117/reflect
Lagenorhynchus spp.	1/1		25/125	1/3	30/300 (50) 90/90 (50)	2/9	Normal	
Pilot Whales	1/1		5/100 (80) 50/1000 (20)	1/10 5/21	30	2/12	Normal	200/ reflect
Right Whale Dolphins	1/1			1/6	30	2/30	Gamma	
Risso's Dolphin	1/3		150/1000	2/12	30/300 (50) 90/300 (50)	2/12	Normal	150/ reflect
Rough-toothed Dolphin	1/3		50/600	1/7	30/300 (50) 90/300 (50)	5/16	Normal	194/ reflect
Sperm Whale	8/11	90/75	600/1400 (90) 200/600 (10)	40/65 18/40	20	1/10	Normal	200/reflect
Sperm Whale (Atlantic)	5/9	90/75	600/1000 (100)	35/65	30/300 (50) 90/300 (50)	1/8	Normal	200/reflect

Table B-2. Dive and Swim Parameters of all the Potentially Occurring Marine Mammal Species Modeled to Assess the Potential Impact of Exposure to SURTASS LFA Sonar Transmissions in 26 Representative Mission Areas.

Modeled Species	*Min/Max Surface Time (Min)*	*Surface/ Dive Angle*	*Dive Depth (m) Min/Max (Percentage)*	*Min/Max Dive Time (Min)*	*Heading Variance (Angle/Time)*	*Min/ Max Speed (kph)*	*Speed Distribution*	*Depth Limit (M)/ Reaction Angle*
Stenella spp.	1/1		Day: 5/25 (50) Night: 10/400 (10) Night: 10/100 (40)	1/4	30	2/15	Normal	10/ reflect
Bearded Seal	1/8	30°	5/40(80) 40/80(20)	1/4.3 5/10		2.2/5.8		
California Sea Lion	2/3		8/75 (96) 75/224 (4)	1/3 4/8		6/12	0/0	
Guadalupe Fur Seal	0.5/2 0.5/1 1/2 1/2		0/5 (73) 5/50 (22) 60/100 (2) -1/5 (3)	1/4 2.4/4.2 4.2/7.7 1/4		5/9 5/9 5/9 0/1		
Gray seal	1/2		10/200 (50%) 10/200 (50%)	4/8	90/90 30/300	1/10	Normal	
Harbor Seal	0.33/1 0.33/1 0.33/1 1/4	30/70	0/5 (40) 5/20(15) 50/150(5) -1/5(40)	0.5/2 0.5/2 4/7 1/4		1/4		
Harp Seal	1/5 1/5 2/4		5/30(17) 30/90(34) 0/5(43)	1/5 3/7 2/4		0.5/3.6 0.45/1.45 0/0.5		
Hawaiian Monk Seal	1/2		10/60 (45) 10/60 (45) 50/500 (10)	2/8 2/8 8/12	30/300 90/300 90/300	2/9	Normal	
Hooded Seal	0.5/2.7 0.5/2.7		100/600 (70) 15/52 (17) 100/1016(13)	5/25 1/5		1/4		
Northern Elephant Seal (male)	1.8/3.6	45	328/404	21.5/26.1		1/5		

Table B-2. Dive and Swim Parameters of all the Potentially Occurring Marine Mammal Species Modeled to Assess the Potential Impact of Exposure to SURTASS LFA Sonar Transmissions in 26 Representative Mission Areas.

Modeled Species	*Min/Max Surface Time (Min)*	*Surface/ Dive Angle*	*Dive Depth (m) Min/Max (Percentage)*	*Min/Max Dive Time (Min)*	*Heading Variance (Angle/Time)*	*Min/ Max Speed (kph)*	*Speed Distribution*	*Depth Limit (M)/ Reaction Angle*
Northern Elephant Seal (female)	1.5/2.7	45	437/535	22.1/26.9		1/5		
Northern Fur Seal (on shelf)	0.5/2 1/2 1/2		0/5 (57) 100/150 (26) -1/5 (17)	1/4 3/7 1/4		4.0/6.5 4.0/6.5 0/1		>200/reflect
Northern Fur Seal (off shelf)	0.5/2 1/2 1/2		0/5 (57) 30/75 (26) -1/5 (17)	1/4 1/4 1/4		4.0/6.5 4.0/6.5 0/1		<1000/reflect
Pagophilic *Phoca* spp. (spotted, ringed, and ribbon seals)	1/2 0.4/2.3		-1/5(30) 5/50(49)	1/4 1/5.4		0/1 1.1/3.6		
Steller Sea Lion (winter)	3/8		4/10 (54) 10/50 (37) 50/250 (10)	0/2 2/4 4/8		3/10		
Steller Sea Lion (summer)	3/8		4/10 (35) 10/50 (61) 50/250 (3)	0/1 1/4 4/8		3/10		

- California Sea Lion (*Zalophus californianus*)
- Harbor Seal (*Phoca vitulina*)
- Northern Elephant Seal (*Mirounga angustirostris*)
- Northern Fur Seal (*Callorhinus ursinus*)
- Steller Sea Lion (*Eumetopias jubatus*)

Updated details follow on diving for the remainder of marine mammal species that occur in the potential mission areas for SURTASS LFA sonar.

B-2.4 Marine Mammal Diving Descriptions

B-2.4.1 Blue Whale (*Balaenoptera musculus*)

Surface Time

Of four satellite-tagged blue whales, data reported for one whale's surface intervals was 7 to 90 sec, with a mean of 48 sec. No surface intervals >60 sec were reported for the other three whales, indicating that the surface time was short (Lagerquist et al., 2000). Blue whales off Sri Lanka had a mean surfacing time of 167 (+/-68) sec, with a range of 29 to 421 sec (de Vos et al., 2013). Based on these two reports, the AIM surfacing interval will range from 1 to 4 min.

Dive Depth

Croll et al. (2001) reported a mean dive depth of 140 m (± 46.01) for non-foraging animals, while foraging whales had a mean dive depth of 67.6 m (± 51.46). Satellite-tagged whales off California had a maximum dive depth of 192 m (Lagerquist et al., 2000). The distribution of dive depths was bimodal (Figure B-5) (note that this is from one animal). In a separate study (Calambokidis et al., 2008), a series of blue whales had a Crittercam attached to them off California and Mexico. The maximum dive depth reported was 293 m. Many of these animals had deep feeding dives, with lunges occurring between 200 and 260 m. Notably, as the sun set, one animal transitioned from deep feeding dives of decreasing depth, transitioning into shallow non-feeding dives, which is indicative of a possible diurnal character to some blue whale diving behavior. Separate animats for foraging and non-foraging blue whales have been created. Foraging animats have a 50/50 distribution between deep dives (200 to 300 m) and shallower dives (20 to 100 m).

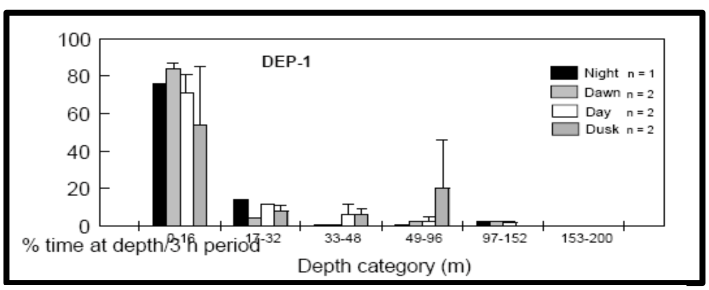


Figure B-5. Blue Whale Dive Depth Distribution (for One Whale) Showing Bimodal Distribution.

Dive Time

Mean dive times of 4.3, 7.8, 4.9 5.7, 10.0, and 7.0 min have been reported for blue whales (Laurie, 1933; Doi, 1974; Lockyer, 1976; Croll et al., 1998; Croll et al., 2001). The best estimate of the maximum dive time is 14.7 min (Croll et al., 2001), although a maximum time of 30 min was reported by Laurie (1933). The longest dive reported for satellite-tagged whales was 18 min, and the mean dive time for all whales was 5.8 (±1.5) min (Lagerquist et al., 2000).

Speed

Dive descent rates of 1.26 m/sec have been recorded (Williams et al., 2000). A mean surface speed of 1.25 m/sec with a maximum speed of 2.0 m/sec was reported from satellite tags (Mate et al., 1999), although satellite data tend to smooth the track and therefore underestimate speed. A second satellite tag study found straight-line speed (under) estimates from 1.3 to 14.2 kph.

Group Size

Blue whales in the Eastern Tropical Pacific had a modal group size of one, although pods of two were somewhat common (Reilly and Thayer, 1990). The mean group size of blue whales off Australia (*B. m. brevicauda*) was 1.55 animals (Gill, 2002).

B-2.4.2 Bowhead Whale (*Balaena mysticetus*)

Surface Time

On overage, bowhead whales spent 5.5 percent of their time at or near the surface (Krutzikowsky and Mate, 2000). Bowheads averaged 4.3 blows per surfacing with a mean blow interval of 13.5 seconds (Dorsey et al., 1989) with a mean surfacing duration of 1.10 minutes (SD = 1.137), consistent with a surface time of 1-2 minutes. Another study reported a mean of 15 seconds for the blow interval with a mean of 6.9 blows per surfacing for the western bowhead population, while the eastern (Baffin Island) population had a mean interval of 16.9 seconds with 17.3 blows/surfacing (Richardson et al., 1995).

Dive Depth

The maximum dive depth recorded for bowhead whales was 352 m (Krutzikowsky and Mate, 2000). During that study, the whales spent 60 percent of their time at depths < 16 m, 33 percent of their time between 17 and 96 meters and < 3 percent of their time at depths > 96 meters. Davis strait bowheads had a maximum dive depth of 416 m, although only 15 percent of the dives were deeper than 152 meters (Heide-Jørgensen et al., 2003).

Most of the dives of foraging bowheads were either V-shaped (presumed exploratory) or U-shaped (presumed foraging) (Heide-Jørgensen et al., 2013). Dive depth was strongly linked to prey distribution; either near the seafloor or near the surface.

Dive Time

Dorsey et al (Dorsey et al., 1989) report that during their data collection, one year (1982) was best for resolving long dive durations. The values from that year are a mean duration of 12.08 minutes (SD = 9.153). The duration of 'sounding dives', or dives >1 min, was calculated (Krutzikowsky and Mate, 2000). These values ranged from 2.6 to 30.4 minutes across all individuals. The mean sounding dive duration for the eight individuals ranges from 6.9 to 14.1 min, with an overall mean of 10.4 min. Richardson et al found that western bowheads had a mean dive time of 11.05 min (SD = 9.95) while the eastern bowheads had a longer dive time, with a mean of 15.80 min (SD = 7.09)

These data will be combined in AIM to produce three dive-behavior states (see table above for details), with a short, shallow dive, a moderate deep and moderately long dive, and a very deep and very long dive. The frequency of these dives is based on the frequency of the dive types. The underlying assumption here is that there is a correlation between dive depth and dive duration.

Heading Variance

Migrating bowheads will have a low variance of 10 degrees, while foraging bowheads will be programmed with a higher variance of 45°.

Speed

The mean speed of eight satellite tagged bowheads was 3.8 kph. The mean speeds of the eight individuals varied from 1.1 to 5.8 kph (Mate et al., 2000). Therefore, AIM modeling will use normally distributed values ranging between 1 and 8 kph. Two acoustically tracked migrating bowheads average 1.5 and 1.8 kt (Cummings and Holliday, 1985). Migrating bowheads were tracked from between 3 to 9 kph, while the typical foraging speed was ~ 4 kph (Werth, 2004). Mean swimming speeds for individual bowheads in Davis Strait ranged from 0.87 (0.5) to 4.53 (1.1) kph (SD) (Heide-Jørgensen et al., 2003).

Habitat

Bowheads are found in Arctic regions exclusively. The Alaska population migrates between summering grounds off eastern Alaska and Canada, past Pt. Barrow, to wintering grounds in the Chukchi Sea and as far south as the Bering Sea. In the Bering Sea, they appear to be found in waters shallower than 200 m, and generally in the western portion of the sea (Citta et al., 2012). Foraging in the Alaskan Beaufort has been observed in July (Christman et al., 2013).

Group Size

Migrating bowheads are typically in groups of 1 to 5 animals, with a modal size of one (Zeh et al., 1993).

B-2.4.3 Common Minke Whale (*Balaenoptera acutorostrata*)

Surface Time

A mean surface time of 1.72 min, with a range of 0.63 to 2.35 min was reported by Stern (1992).

Dive Depth

Minke whales' dive depth is inferred from other species; however, reduced in depth, since minke whales are likely to be pelagic feeders, feeding on species found near the surface (Olsen and Holst, 2001).

Dive Time

The mean dive time of 4.43 +/- 2.7 min was reported by (Stern, 1992). Dive times measured off Norway range from approximately 1 to 6 min (Joyce et al., 1989). Dive times also show small diel and seasonal variability (Stockin et al., 2001), but the variability is small enough to be considered not significant for AIM modeling. Dive times were non-normal (Figure B-6) (Øien et al., 1990). Minke whales in the St. Lawrence River performed both 'short' and 'long' dives. Short dives lasted between 2 and 3 minutes, while long dives ranged from 4-6 min (Christiansen et al., 2015).

Speed

The mean speed value for minke whales in Monterey Bay was 8.3 +/- 6.4 kph (4.5 +/- 3.45 knots) (Stern, 1992). Satellite tagging studies have shown movement of up to 79 km/day (3.3 kph). Minke whales being pursued by killer whales were able to swim at 15 to 30 kph (Ford et al., 2005). A gamma function was fit to the available speed data (Figure B-7). The modal speed of this function is 4.5 kph, matching the Stern (1992) data, and

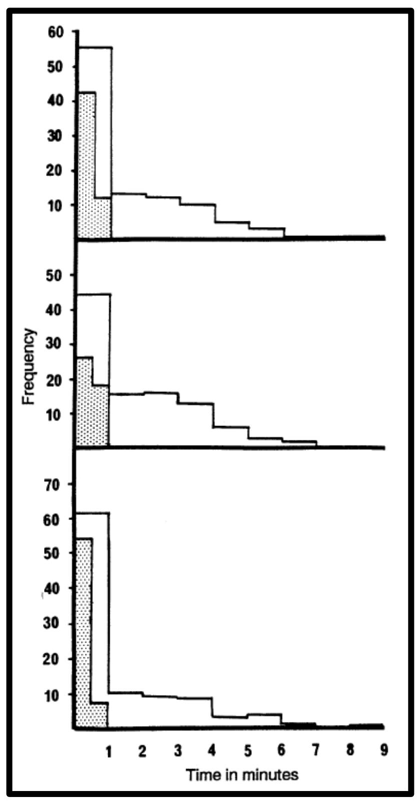


Figure B-6. Minke Whale Dive Durations (Øien et al., 1990).

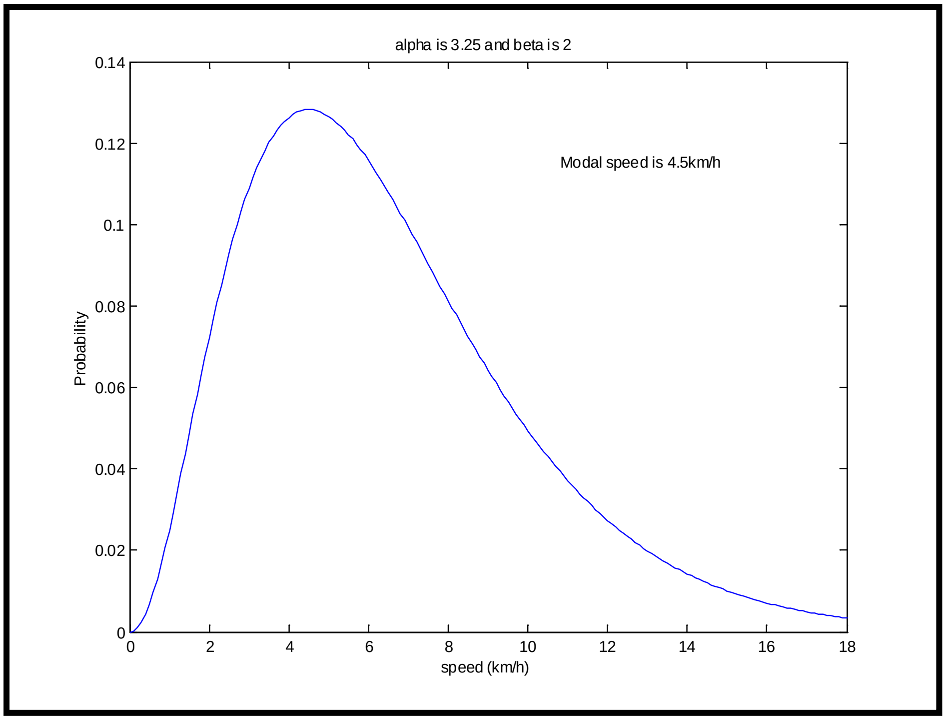


Figure B-7. Speed Distribution for the Minke Whale.

has a maximum of 18 kph, somewhat less than the maximum speed achievable (30 kph), observed during predation.

Habitat

Minke whales in Monterey Bay were reported to be at a median depth of 48.6 m (Stern, 1992). They are known to move into very shallow water as well as deep oceanic basins. The 10-m limit and reflection aversion are intended to let minke whales roam freely, but to stay off the beach.

Group Size

Minke whales in the Gulf of California were seen in group sizes of 1 to 50, with a mean group size of 5.7 (Silber et al., 1994)

Residency

Foraging minke whales have been shown to exhibit small-scale site fidelity (Morris and Tscherter, 2006). Therefore, foraging minke whales should have their course change parameters set to be variable to allow for small net movements.

B-2.4.4 Fin Whale (Balaenoptera physalus)

Surface Time

Remarkably good data for surface times exist for fin whales. A log survivorship analysis of all inter-blow intervals was used to determine an inflection point of 28 and 31 sec between surface and dive activity for feeding and non-feeding animals, respectively (Kopelman and Sadove, 1995). The mean surface duration for fin whales, without boats present, off Maine was 54.63 sec (SD = 59.61) while dive times were 200.84 sec (SD = 192.91) (Stone et al., 1992).

Dive Depth

Foraging fin whales had mean dive depths of 97.9 +/- 32.59 m, while traveling fin whales had mean dive depths of 59.3 +/- 29.67 m(Croll et al., 2001). Migrating fin whales were determined to have a maximal dive depth of 364 m (Charif et al., 2002). Fin whales in the Mediterranean Sea typically dove to about 100 m, and occasionally dove to 470 m, or more (Panigada et al., 1999), however these are unusually deep dives. The animats here model the more typical dive pattern 90 percent of the time. Foraging fin whales off California had a mean maximum dive depth of 248 m (Goldbogen et al., 2006). Based on this study, the most frequent AIM dive depth is extended to 250 m.

Dive Time

Foraging fin whales had mean dive times of 6.3 +/- 1.53 min, while traveling fin whales had a mean dive time of 4.2 +/- 1.67 min (Croll et al., 2001). The maximum dive time observed was 16.9 min. Fin whales off the east coast of the U.S. were observed to have mean dive times of 2.9 min. Ranges for the dive times of feeding animals was from 29 to 1001 sec, while non-feeding animals had longer dives between 32 and 1212 sec (Kopelman and Sadove, 1995). Panigada et al. (1999) found that shallow (<100m) dives had a mean dive time of 7.1 min, while deeper dives had dive times of 11.7 and 12.6 min. Fin whales foraging on Jeffrey's Ledge in the Gulf of Maine had mean dive times of 5.83 to 5.89 min (Ramirez et al., 2006).

Speed

Watkins (1981) reported a mean speed of 10 kph, ranging from 1 to 16 kph, with bursts of 20 kph reported. Mean descent speeds of 3.2 m/sec (SD = 1.82) and ascent speeds of 2.1 m/sec (SD=0.82) have been reported from fin whales in the Mediterranean (Panigada et al., 1999; Watkins, 1981). Acoustically tracked fin whales had mean speeds of 4.3 kph (SD = 2.1) with a range of 1-12 kph (Soule and Wilcock, 2013).

Habitat

Fin whales are found feeding on shallow banks and in bays (Woodley and Gaskin, 1996) as well as in the abyssal plains of the ocean (Watkins, 1981). Thus, fin whales are allowed to move into shallow water in AIM, with a 30-m inshore limit to keep them out of the very shallow waters.

Group Size

In the Gulf of Mexico, fin whales had a mean group size of 5.7, with a range in group sizes from 1 to 50 (Silber et al., 1994). In the Mediterranean Sea, the mean group size over a number of years was 1.75 animals (Panigada et al., 2005; Panigada et al., 1999).

B-2.4.5 Gray Whale (*Eschrichtius robustus*)

Surface Time

Most of the surface times for summering gray whales fell in the range of 0 to 2 min (Würsig et al., 1986).

Dive Depth

No dive depth data for migrating grays were available. However, the near shore habitat of migrating gray whales makes the estimated ranges of 10 to 40 m a reasonable estimate. Summering (foraging) gray whales are presumed to dive to depths between 10 m and the local bottom depth, since they are bottom feeders (Nerini, 1984).

Dive Time

Gray whales migrating past Unimak Island in Alaska were recorded to have dive times between 3 and 700 sec (Rugh, 1984). However, numerous other papers cite a minimum dive time of 3 min or longer (Wyrick, 1954; Rice and Wolman, 1971). Therefore, the values of 3 to 12 min were used to model this animat. Summering gray whales appear to have shorter dive times, ranging up to approximately 7 min, with a mean near 4 min (Würsig et al., 1986).

Heading Variance

Gray whales on feeding grounds off Russia had a very high site fidelity with relatively small home ranges (Heide-Jørgensen et al., 2012). Therefore, the variance and time settings for foraging gray whales were set to 90/90.

Speed

Tagged migrating gray whales have been documented to cover between 31.4 and 125 km/day (Mate and Harvey, 1984). Gray whales migrating northward in Canada had mean speeds of 4.7-5.9 kph (Ford et al., 2013). A maximum speed of 9 kph was calculated by Rice and Wolman (1971). Summering (foraging) gray whales were measured at 2.3 +/-2.18, 2.3 +/- 1.75 and 2.8 +/- 2.23 kph (Würsig et al., 1986). Therefore, summering gray whales are programmed to swim between 1 and 5 kph.

Habitat

Gray whales are famous for migrating very close to shore. They will occasionally cross the mouths of bays (e.g., San Diego) which may take them further offshore. Therefore, their inshore depth limit is set at 10 m, a depth from which they will 'reflect' or move seaward in the model. All gray whales are currently set to avoid waters deeper than 100 m.

Group Size

Migrating gray whales off California had slightly different pod sizes during the day and the night (mean day = 1.75 ± 0.280, mean night = 1.63 ± 0.232) (Perryman et al., 1999). Foraging western gray whales off Sakhalin Island, Russia had pod sizes ranging from 1 to 3, with a mean size of 1.2 animals (Weller et al., 2002).

B-2.4.6 Humpback Whale (*Megaptera novaeangliae*) (Migrating)

Surface Time

Approximately 65 percent of all surfacings observed in Alaska were 2 min in duration or less (Dolphin, 1987a; Dolphin, 1987c). Surface times in Hawai'i are similar, with the exception of surface-active groups (SAGs) (Bauer et al., 1995).

Dive Depth

Humpback whale dive depths have been measured on feeding grounds, with 75 percent of dives ranging to 40 m or less (Dolphin, 1988). It is likely that migrating animals would also predominantly dive to these shallow depths.

Dive Time

Surface times range between 1 and 2 min, while dive times range between 5 and 10 min (Gabriele et al., 1996). Foraging humpbacks off California had mean dive times of 7.8 +/- 2.0 minutes (Goldbogen et al., 2008).

Heading Variance

This value is set very low for migrating animals. Most non-competitive group breeding animals also have linear travel. Migrating humpbacks swam very close to magnetic north from Hawai'i with very little deviation (Mate et al., 1998).

Speed

The mean speed for humpback whales is about 4.5 kph. The measured range is 2 to 11.4 kph (excluding stationary pods) (Gabriele et al., 1996). Satellite-tracked migrating humpback whales moved at a minimum of 150 km/day (6.25 kph) for a mother and calf pod, while another two whales moved 110 km/day (4.5 kph). Humpbacks off Australia were estimated to migrate at a mean speed of 8 kph, with a range between 4.8 to 14.2 kph (Chittleborough, 1953). More recent studies of Australian humpbacks found a mean northern migration speed of 5.47 kph, while the southern migration speed had a mean of 5.02 kph for non-calf pods, while calf pods had mean speeds of 5.03 and 4.25 kph (Chaudry, 2006). Migrating humpbacks in the NW Atlantic had a mean estimated migratory speed of 4.3 (SD = 1.2) kph (Kennedy et al., 2014).

Habitat

Migrating humpbacks swim both along the coast (California population) as well as through the oceanic abyssal plains. Humpbacks that swim along coastal regions are known to swim further offshore than gray whales. Therefore, the minimum depth for this species has been set at 100 m. Non-calf pods migrating off Australia had a mean offshore distance of 3.2 km during the northern migration and 2.6 km during the southern migration. Calf pods migrated “significantly” closer inshore (Chaudry, 2006).

B-2.4.7 Humpback Whale (*Megaptera novaeangliae*) (Feeding)

Surface Time

Approximately 65 percent of all surfacings were 2 min in duration or less (Dolphin, 1987a; Dolphin, 1987b)

Dive Depth

Humpback whale dive depths have been measured on the feeding grounds, where 75 percent of their dives were to 40 m or less with a maximum depth of 150 m (Dolphin, 1988). Dive depth appears to be determined by prey distribution. Whales in this study were primarily foraging on euphausiids. There is also a strong correlation of dive depth and dive time and is described by the following equation (Dolphin, 1987a; Dolphin, 1987b):

$$\text{Time (s)} = 0.52 * \text{depth (m)} + 3.95,\ r^2 = 0.93$$

Feeding humpbacks off Kodiak Alaska had a mean maximum dive depth of 106.2 m, with 62 percent of the dives occurring between 92 and 120 m, with a maximum of about 160 m (Witteveen et al., 2008) (Figure B-8). The humpbacks appeared to be feeding largely on capelin and pollock. There are strong differences in the data between these two studies. These differences may reflect the distribution of prey rather than behavioral abilities of the whales.

Dive Time

The maximum of the continuous portion of the distribution of dive times was 15 min (Dolphin, 1987a; Dolphin, 1987b). The distribution was skewed toward shorter dives. Several dive steps can be programmed in AIM to capture this variability.

Heading Variance

Satellite tracking of feeding humpback whales in the Southern Ocean showed very erratic travel, and animals frequently remained in a specific area for up to a week at a time. There were periodic movements between feeding areas (Dalla Rosa et al., 2008). Therefore, the heading variance for feeding humpbacks will be set relatively high, for 80 percent of the time. A low heading variance will be used for the remaining 20 percent of the time, to simulate movement between feeding areas. Argos data for

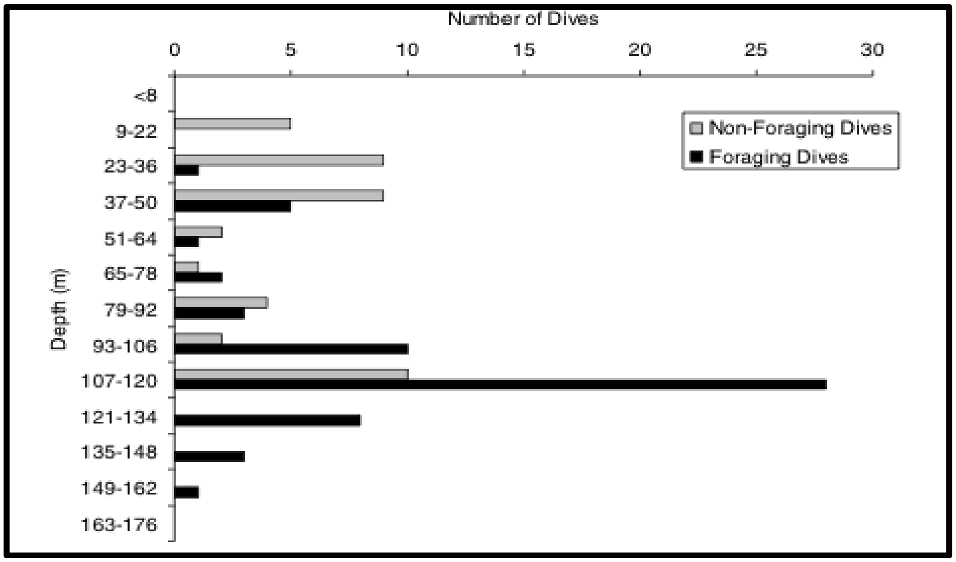


Figure B-8. Frequency Distribution of Feeding Humpback Whale Mean Maximum Dive Depths in 14 M (1 SD of Mean Maximum Dive Depth) Depth Bins for Dives Recorded from Tagged Humpback Whales (Witteveen et al., 2008).

humpbacks feeding in the Aleutian Islands found that the animals spent 13 percent of their time in travel mode, 62 percent in "area-restricted search" (presumed to be foraging) and 25 percent in 'unclassified' behavior (Kennedy et al., 2014).

Speed

Mean speeds for humpbacks are near 4.5 kph. The measured range is 2 to 11.4 kph (excluding stationary pods) (Gabriele et al., 1996). Feeding humpbacks in the Southern Ocean had mean measured speeds between 2.26 and 4.03 kph (Dalla Rosa et al., 2008). These values were derived from short segments of satellite tracking data; therefor they are likely underestimates of speed. Ascent rates during dives range from 1.5 to 2.5 m/sec, while descent rates range between 1.25 and 2 m/sec (Dolphin, 1987a). The mean speed for all pod types in Glacier Bay was 3.31 kph (Baker and Herman, 1989).

Habitat

Migrating humpbacks swim both along the coast (California population) as well as through the oceanic abyssal plains. Humpbacks that swim along coastal regions are known to swim further offshore than gray whales. Therefore, the minimum depth for this species has been set at 100 m.

Group Size

Ninety-six percent of 27,252 pods in the Gulf of Maine were composed of 1 to 3 animals, with a modal size of one adult (Clapham, 1993).

B-2.4.8 Humpback Whale (*Megaptera novaeangliae*) (Winter Ground and Migrating Adult)

Surface Time

Approximately 65 percent of all surfacings observed in Alaska were 2 minutes in duration or less (Dolphin, 1987b). Surface times in Hawaiʻi are similar, with the exception of SAGs (Bauer et al., 1995).

Dive Depth

The maximum dive depth reported for a humpback on the Hawaiian winter grounds was 176 m (Baird et al., 2000). The distribution of dive depths was strongly skewed toward shallower dives (Table B-3).

Dive Time

Surface times range between 1 and 2 min, while dive times range between 5 and 10 min (Gabriele et al., 1996).

Heading Variance

Most non-competitive group breeding animals also have largely linear travel.

Speed

The estimated speed on the breeding grounds from satellite tagged whales was 1.7 (SD = 0.8) kph (Kennedy et al., 2014). Mean speeds for humpbacks are near 4.5 kph while the measured range is 2 to 11.4 kph (excluding stationary pods) (Gabriele et al., 1996). Fitted Gamma curve parameters (Table B-4) and the humpback whale speed distribution (Figure B-9) are shown below.

Group Size

The modal group size in Hawai'i was two adults (Mobley and Herman, 1985).

Habitat

Migrating humpbacks swim both along the coast (California population) as well as through the oceanic abyssal plains. Humpbacks that swim along coastal regions are known to swim further offshore than gray whales. Therefore, the minimum depth for migrating animals has been set at 100 m.

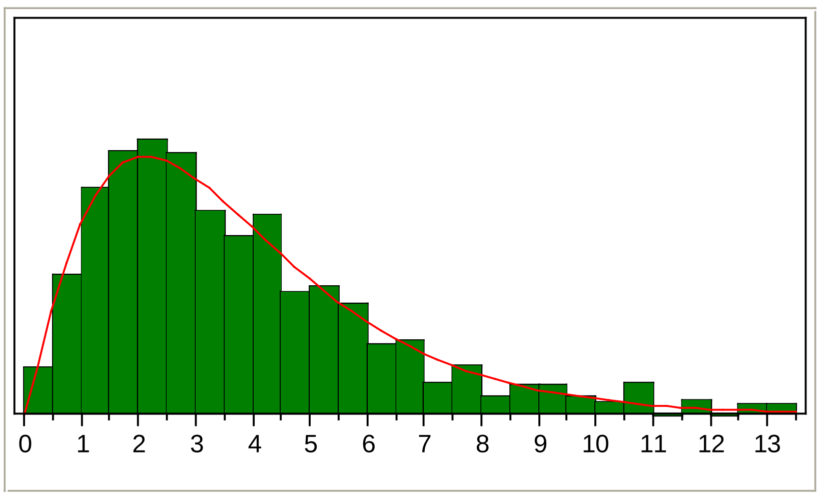


Figure B-9. Histogram of Speeds for all Humpback Whale Pods Tracked in Hawai'i.

B-2.4.9 Sei/Bryde's/Omura's Whales

(*Balaenoptera borealis, B. edeni,* and *B. omurai*)

There is a paucity of data for these species. Since they are similar in size, data for both species have been pooled to derive model parameters for these species.

Table B-3. Humpback Whale Dive Distributions.

Depth Category (m)	Mean Time In Depth Category (%)	SD	Cumulative Time (%)
1-10	39.55	20.57	39.55
11-20	26.51	13.29	66.06
21-30	11.65	11.84	77.71
31-40	4.25	2.77	81.96
41-50	3.04	2.28	85.00
51-60	2.47	2.28	87.47
61-70	2.14	1.73	89.61
71-80	1.66	1.54	91.27
81-90	1.97	1.91	93.24
91-100	1.55	2.36	94.79
101-110	1.39	2.17	96.18
111-120	1.31	2.33	97.49
121-130	0.92	1.75	98.41
131-140	0.72	1.73	99.13
141-150	0.30	0.56	99.43
151-160	0.23	0.40	99.66
161-170	0.15	0.26	99.81
171-180	0.09	0.22	99.90

Table B-4. Gamma Curve Parameters for Figure B-9.

Type	Parameter	Estimate	Lower 95%	Upper 95%
Shape	Alpha	2.326775	2.255537	2.398012
Scale	Sigma	1.617174	1.561936	1.672412
Threshold	Theta	0.000000	1.570127	

Surface Time

No direct data were available so fin whale values were used.

Dive Depth

A limited number of Bryde's whales have been tagged with TDRs (Alves et al., 2010). Shallow dives, less than 40 m were recorded 85 percent of the time, while deep dives occurred 15 percent of the time. The maximum dive depth reported was 267 m.

Two distinct dive types were noted for Bryde's whales. Both performed a long series of shallow dives of less than 40 m until 1.5 hours before sunset. The animals then made the deepest dives. During the night, sequential deep dives took place. Foraging lunges were recorded during about half of these nighttime dives. Vocalizing sei whales were most often acoustically located at depths of 15 to 40 m, with occasional calls at 70 m (Newhall et al., 2012).

Dive Time

Dive times ranged between 0.75 and 11 min, with a mean duration of 1.5 min (Schilling et al., 1992). Most of the dives were short in duration, presumably because they were associated with surface or near-surface foraging. The same paper reported surface times that ranged between 2 sec and 15 min. The maximum dive time reported for two Bryde's whales was 9.4 minutes (Alves et al., 2010), with mean durations of 0.4-6 minutes.

Heading Variance

Observations of foraging sei whales found that they had a very high reorientation rate, frequently resulting in minimal net movement (Schilling et al., 1992).

Speed

Brown (1977) reported an overall speed of advance from tagged sei whales as 4.6 kph. The highest speed reported for a Bryde's whale was 20 kph (Cummings, 1985). A Bryde's whale being attacked by killer whales traveled approximately 9 km in 94 min, with most of the travel occurring in the first 50 min, producing an estimated speed of 10.8 kph (Silber et al., 1990). The maximum speed of sei whales reported from a satellite tracking study was 7.6 m/sec, although the distribution of speeds was highly skewed toward lower values (Olsen et al., 2009). The speed parameters used in AIM are 0 to 20 kph, using a gamma distribution with alpha and beta parameters of 5 and 1 (Figure B-10), which covers the

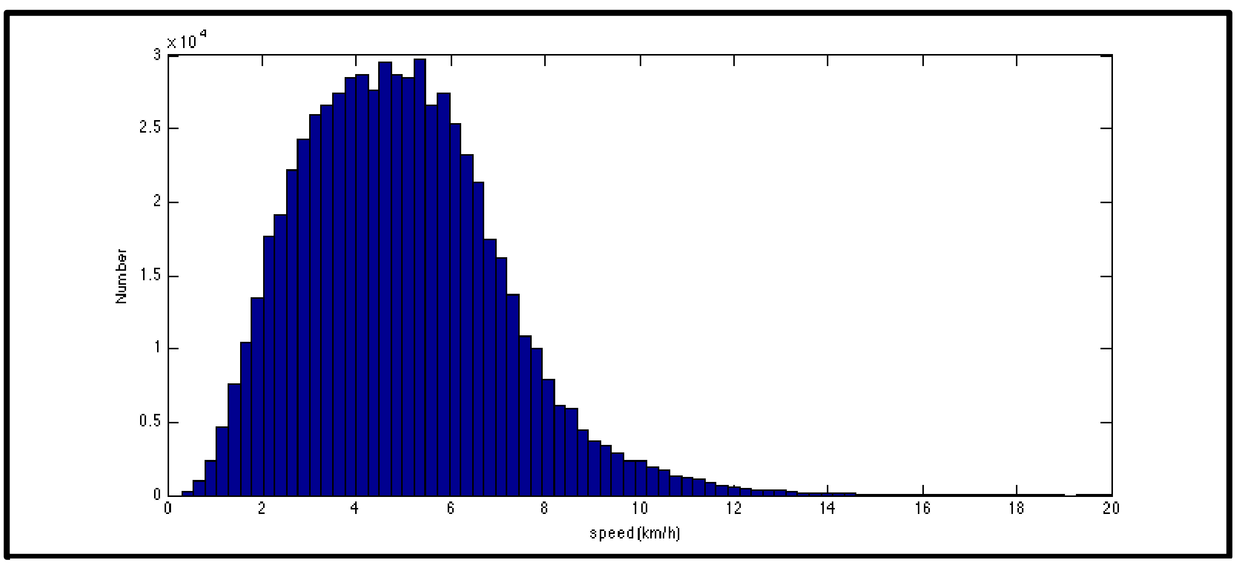


Figure B-10. Bryde's Whale Speed Distribution.

reported range of speed reported by (Olsen et al., 2009) and approximated the mean value reported by (Brown, 1977).

Habitat

Sei whales are known to feed on shallow banks, such as Stellwagen Bank (Kenney and Winn, 1986). Therefore, sei and Bryde's whales are allowed to move into shallow water.

Group Size

Sei whales in the Gulf of Maine were seen in groups of 1 to 6 animals with a mean group size of 1.8 whales (Schilling et al., 1992). Bryde's whales in the Gulf of California were seen in groups of 1 to 2 animals, with a mean size of 1.2 whales (Silber et al., 1994).

B-2.4.10 Beaked Whales

Data on the behavior of beaked whales is sparse. Therefore, all beaked whale species have been pooled into two animats, large and small beaked whales. A taxonomic approach (Dalebout et al., 2004) would suggest divisions into the genus *Berardius*, *Hyperoodon*/*Tasmacetus*, and *Mesoplodon*. *Ziphius*, a genus with a single species, seems to be behaviorally related most closely to *Mesoplodon*. At this point, however, available behavioral data are sufficient to support splitting beaked whales into large (*Berardius, Hyperoodon, Tasmacetus*) and smaller whales (*Mesoplodon, Ziphius, Indopacetus*) (Table B-5). *Indopacetus* has been grouped with *Mesoplodon* because it was initially classified as a *Mesoplodon*.

Small Beaked Whales (*Mesoplodon, Ziphius, Indopacetus*)

Surface Time

Sowerby's beaked whales had surface times of 1-2 minutes, during which they would blow 6 to 8 times (Hooker and Baird, 1999b). Cuvier's beaked whales have surfacing bouts of 23 to 26 intervals that are 3-15 sec apart, with a mean of 7 sec (SD = 2.1) (Baird et al., 2006). Blainville's beaked whale surfacings are composed of an average of 18 (SD = 11.3) surfacing intervals, each with a mean duration of 10.9 (SD = 5.51) sec. Thus a mean three-minute total surfacing time is predicted for both *Ziphius* and *Mesoplodon*.

Dive Depth

Ziphius tagged off the Canary Islands had foraging dives between 824 m and 1267 m while Blainville's beaked whales dove to depths between 655 and 975 m (Johnson et al., 2004). Blainville's beaked whales in Hawaiʻi performed dives to mid-water depth (100 to 600 m) approximately 6 times more frequently than at night. Dives deeper than 800 m had no diurnal difference (Baird et al., 2008). Cuvier's beaked whales tagged off southern California had mean deep dive depths of 1401 (SD = 137.8) m and a duration of 67.4 (SD = 6.9) min (Schorr et al., 2014). This study also reported a maximum dive depth of 2,992 m that lasted 137.5 min.

Dive Time

The minimum and maximum dive time measured was 16 and 70.5 min respectively (Hooker and Baird, 1999a). Sowerby's beaked whales had dives between 12 and (at least) 28 min in the Gully in Canada (Hooker and Baird, 1999b). Arnoux's beaked whale had modal dive times between 35 to 65 min (mean = 46.4 min, SD = 13.1), with a maximum dive-time of at least 70 min (Hobson and Martin, 1996). Tagging results with *Ziphius* had one animal diving for 50 min (Johnson et al., 2004). *Mesoplodon stejnegeri* were observed to dive for "10-15 min" in Alaska (Loughlin, 1982).

Cuvier's beaked whales in Hawaii performed a regular pattern of one very long (>59 min) and deep dive (>1000 m), followed by 1-4 shallow (~ 292-568 m) and shorter (~ 20 min) dives (Baird et al., 2006). This pattern has been seen in many other studies as well.

Table B-5. Model Groupings of the Beaked Whale Species Encountered in Mission Areas for SURTASS LFA Sonar.

Common Name	*AIM Grouping*
Arnoux' beaked whale	Large
Baird's beaked whale	Large
Northern bottlenose whale	Large
Shepherd's beaked whale	Large
Southern bottlenose whale	Large
Andrews' beaked whale	Small
Blainville's beaked whale	Small
Cuvier's beaked whale	Small
Deraniyagala's beaked whale	Small
Gervais' beaked whale	Small
Ginkgo-toothed beaked whale	Small
Gray's beaked whale	Small
Hector's beaked whale	Small
Hubbs' beaked whale	Small
Longman's beaked whale	Small
Perrin's beaked whale	Small
Pygmy beaked whale	Small
Sowerby's beaked whale	Small
Spade-toothed whale	Small
Stejneger's beaked whale	Small
Strap-toothed beaked whale	Small
True's beaked whale	Small

Blainville's beaked whales in Hawaii appeared to have two general dive types. The first are shallow dives that range from < 50 m to a bit deeper. Deep dives (> 800 m) were reported to occur once every 2 hrs with a maximum depth of 1408 m (Baird et al., 2006).

Heading Variance

Sowerby's beaked whales surfacing in the Gully were reported to have no apparent orientation, and would change orientation up to 180 ° between surfacings (Hooker and Baird, 1999b). The opposite pattern was seen in open-ocean Blainville's beaked whales, which showed very directed travel for long distances before beginning a different pattern with more turns (Baird, 2011).

The distributions of changes in headings were presented for a Blainville's beaked whale before and after presentation of a killer whale playback (Figure B-11) (Allen et al., 2014). The pre-test data are taken as a good estimate of the normal variance in heading data for this species.

Speed

Dive rates averaged 1 m/sec or 3.6 kph (Hooker and Baird, 1999a). A mean surface speed of 5 kph was reported by (Kastelein and Gerrits, 1991).

Habitat

The minimum sea depth in which beaked whales were found in the Gulf of Mexico was 253 m (Davis et al., 1998). In the Gully in Canada, Sowerby's beaked whales were found in water ranging from 550 to 1500 m in depth (Hooker and Baird, 1999b). Blainville's beaked whales (*M. densirostris*) were found in water depths of 136 to 1319 m in the Bahamas, and were found most often in areas with a high bathymetric slope (MacLeod and Zuur, 2005). *Mesoplodon* whales were found in waters from 700 m to >1800 m off Scotland and the Faroe Islands (Weir, 2000) and between 680 and 1933 m in the Gulf of Mexico (Davis et al., 1998).

Baird et al. (Baird et al., 2006) reported that Blainville's beaked whales off Hawaii were found in waters from 633 to 2050 m deep (mean = 1119) while Cuvier's beaked whales were found in waters from 1381 to 3655 m deep (mean = 2131).

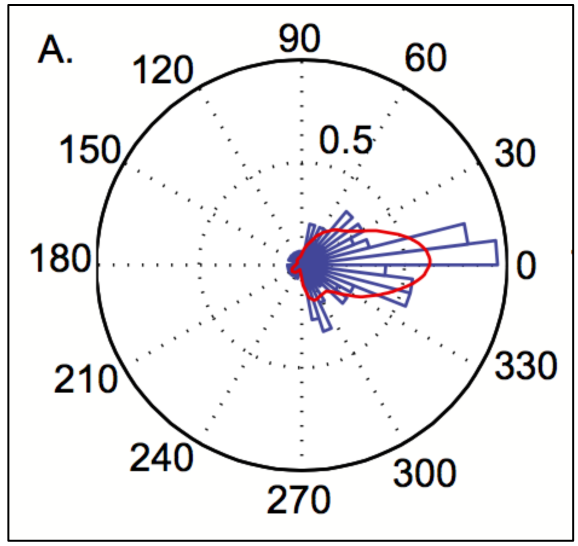


Figure B-11. Distributions of Changes in Course Direction are Shown for Blainville's Beaked Whale Before the Presentation of Killer Whale Recordings (Allen et al., 2014).

Group Size

Mesoplodon stejnegeri in Alaska had pod sizes between 5 and 15 animals (Loughlin, 1982). Sowerby's beaked whale in the Gully in Canada had group sizes between 3 and 10 (Hooker and Baird, 1999b). Dense-beaked whales off the Canary Islands had group sizes ranging between 2 and 9 with a mean size of 3.44 whales (Ritter and Brederlau, 1999). Sightings of Longman's beaked whale in the western Indian ocean found group sizes between 1 and 40, with a mean size of 7.2 whales (Anderson et al., 2006). Blainville's beaked whales off Hawai'i had a mean group size of 2.6 (SD=3.0) with a range of 1-9, while Cuvier's beaked whales groups were smaller, with a mean size of 2.6 (SD = 1.3) and a range of 1-5 animals (Baird et al., 2006).

Large Beaked Whales

Surface Time

Surface times in Arnoux's beaked whales ranged from 1.2 to 6.8 min (Hobson and Martin, 1996).

Dive Depth

The minimum and maximum dive depth measured for a northern bottlenose whale was 120 and 1453 m respectively (Hooker and Baird, 1999a). Northern bottlenose whales performed shallow dives with a range of 41 to 332 m (n=33), while deep dives ranged from 493 to 1453 m (n=23). Dive depth and dive duration were strongly correlated (Hooker and Baird, 1999a). Based on the depth distribution of the most commonly consumed prey, Baird's beaked whales off Honshu, Japan probably feed at depths of 800-1,200 m (Walker et al., 2002).

Dive Time

The minimum and maximum dive time measured was 16 and 70.5 min respectively (Hooker and Baird, 1999a). Arnoux's beaked whale had modal dive times between 35-65 min (mean = 46.4 min, SD = 13.1), with a maximum dive time of at least 70 minutes (Hobson and Martin, 1996). Tagging results with *Ziphius* had one animal diving for 50 min (Johnson et al., 2004).

Heading Variance

Sowerby's beaked whales surfacing in the Gully were reported to have no apparent orientation, and would change orientation up to 180° between surfacings (Hooker and Baird, 1999b).

Speed

Northern bottlenose whale dive rates averaged 1 m/s or 3.6 kph (Hooker and Baird, 1999a). A mean surface speed of 5 kph was reported by (Kastelein and Gerrits, 1991) for Northern Bottlenose whales.

Habitat

The minimum sea depth in which beaked whales were found in the Gulf of Mexico was 253 m (Davis et al., 1998). The distribution of Baird's beaked whale is restricted to the cool, deep waters of the northern North Pacific Ocean and contiguous seas (Reeves and Mitchell, 1993). Northern bottlenose whales are known for inhabiting deep-water nearshore canyons (Wimmer and Whitehead, 2004).

Group Size

Baird's beaked whales have been seen in groups of up to 30, but groups of four to ten whales are more common (Reeves and Mitchell, 1993).

B-2.4.11 Blackfish: False Killer Whale, Pygmy Killer Whale, and Melon-Headed Whale (*Feresa, Pseudorca*, and *Peponocephala* spp.)

Studies describing the movements and diving patterns of these animals are rare and sparse. Therefore, they have been combined into a single "blackfish" category. As more data become available, these species will be split into separate animats.

Surface Time

No direct measurements of surface time are available, so the default value of one minute was used.

Dive Depth

The maximum dive depth of a single false killer whale off the Madeira Islands was 72 m. Most of the time was spent at depths deeper than 20 m, and the dives were V-shaped (Alves et al., 2006). Three false killer whales in Hawai'i had shallow dives as well, with maximum depths of 22, 52 and 53 m (Ligon and Baird, 2001). It should be noted that these animals were feeding on fish. False killer whales offshore of Japan had mean dive depths of 56 ft (17 m) (SD = 5) for shallow dives and 423 ft (129 m) (SD = 185) for deep dives; the deepest dive was to 2,133 ft (650 m) (Minamikawa et al., 2013). Shallow dives were approximately five times more common than deep dives and dives were deeper during the day.

Mooney et al. (2012) reported in preliminary research findings that a tagged melon-headed whale in Hawaiian waters dove deeply to near the seafloor, >984 ft (300 m), at night but stayed near the sea surface during the day, with no dives >67 ft (20 m).

Dive Time

In the western North Pacific Ocean, shallow dives of false killer whales were reported with a mean duration of 103 sec, while deep dives had a mean duration of 269 sec (SD = 189) (Minamikawa et al., 2013).

Speed

Maximum speed recorded for false killer whales was 8.0 m/sec (28.8 kph) (Rohr et al., 2002), although the typical cruising speed is 20 to 24 percent less than the maximum speed (Fish and Rohr, 1999). This "typical" maximum of 6.24 m/sec (22 kph) was used as the maximum speed for AIM. Off the Madeira Islands false killer whales were found in water depths from 900 to 2000 m (Alves et al., 2006).

Group Size

False killer whales in the Gulf of Mexico had group sizes between 20 and 35 (mean = 27.5, SE = 7.5, n=2) (Mullin et al., 2004). False killer whales off of Costa Rica had a mean group size of 36.16 (+/- 52.38 (May-Collado et al., 2005).

B-2.4.12 Bottlenose dolphins (*Tursiops truncatus* and *T. aduncus*)

In many environments there can be coastal and pelagic stocks of bottlenose dolphins. This is certainly the case off the east coast of the United States. However, defining the range of offshore form is difficult (Wells et al., 1999). Regardless of the genetic differences that may exist between these two forms, they frequently occur in different densities, and so they are split into two animat categories.

Dive Depth

The maximum recorded dive depth for wild bottlenose dolphins is 200 m (Kooyman and Andersen, 1969). More recently, offshore bottlenose dolphins were reported to dive to depths greater than 450 meters (Klatsky et al., 2007). A satellite-tagged dolphin in Tampa Bay had a maximum dive depth of 98 m (Mate et al., 1995). This value was used as the maximum dive depth for the coastal form of bottlenose.

Dive Time

Measured surface times ranged from 38 sec to 1.2 min (Mate et al., 1995; Lockyer and Morris, 1987; Lockyer and Morris, 1986). Dive times for a juvenile bottlenose had a mean value of 55.3 sec, although the distribution was skewed toward shorter dives (Lockyer and Morris, 1987) (Figure B-12). However, pelagic bottlenose dolphins were observed to dive for periods longer than five minutes (Klatsky et al., 2007).

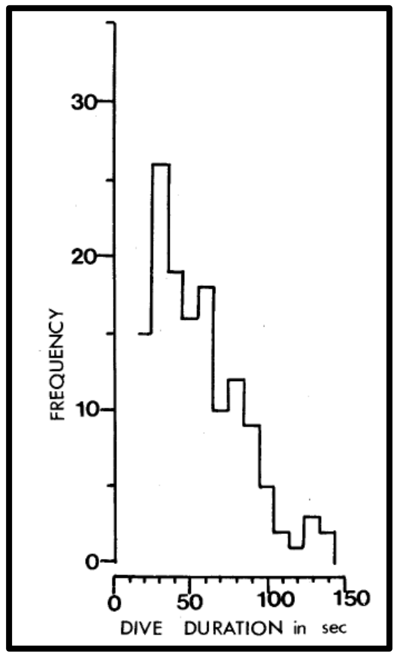


Figure B-12. Duration of Bottlenose Dolphin Dives (Lockyer and Morris, 1987).

Speed

Bottlenose dolphins were observed to swim, for extended periods, at speeds of 2.2 to 11 kt (4 to 20 kph), although they could burst (for about 20 sec) at up to 54 kph (Lockyer and Morris, 1987). Dolphins in the Sado Estuary, Portugal had a mean speed of 2.3 kt (4.3 kph) and maximum speed of 6.2 kt (11.2 kph) (Harzen, 2002). A more recent analysis found that the maximum speed of wild dolphins was 11.0 kt (20.5 kph), although trained animals could double this speed when preparing to leap (Rohr et al., 2002). Maximum speeds of wild dolphins in France was 4.8 m/sec, with an average speed (relative to water) of 4.3 kt (7.9 kph) (Ridoux et al., 1997). Bottlenose dolphins off Argentina swam much faster (7.6 kt [14 kph]) when in water >10 m than while in shallow water (3 kt [5.8 kph]) (Würsig and Würsig, 1979).

Habitat

In the Gulf of Mexico, bottlenose where observed in water depths between 101 and 1226 m (Davis et al., 1998). However, tagged animals have been observed to swim into water 5000 m deep (Wells et al., 1999).

Group Size

Bottlenose dolphins in the Gulf of California were seen in groups of 1 to 60 dolphins with a mean group size of 10.1 (Silber et al., 1994). In the Gulf of Mexico, they were seen in groups of 1 to 68 individuals (mean = 14.5, SE = 1.5, n=83) (Mullin et al., 2004). Off the Pacific coast of Costa Rica, the mean group size was 21.5 (SD=33.73, n=176) (May-Collado et al., 2005).

B-2.4.13 Harbor Porpoise (*Phocena phocena*)

Surface Time

Mean surface time was reported as 3.9 sec (Otani, 2000).

Dive Depth

Maximum observed dive depth for a free-ranging harbor porpoise was 64.7 m (Otani, 2000). However, the same study reported that >90 percent of dives were less than 10 m. Another TDR study with seven animals tagged had dive depths that ranged from a mean of 14 +/- 16 m to 41 +/- 32 m, while the mean for all animals tagged was 25 +/- 30 m (Westgate et al., 1995). One large female made a very deep dive to 226 m, although dives this deep were infrequent.

Dive Time

Maximum observed dive time for a free-ranging harbor porpoise was 193 sec (Otani, 2000), although most dives were less than one minute in length. The mean dive duration of seven animals in the Bay of Fundy was 65 +/-33 sec (Westgate et al., 1995). Maximum dive time of harbor porpoise in Denmark was 213 seconds (Linnenschmidt et al., 2013).

Speed

Mean descent speed was 0.8 m/sec (2.9 kph) with a maximum descent speed of 4.3 m/sec (15.5 kph). Ascent speeds were similar, with a mean of 0.9 m/sec (3.24 kph) and a maximum of 4.1 m/sec (14.5 kph) (Otani, 2000). TDR-tagged animals moved at least 51 km in a 24 hr period (2.125 kph) (Westgate et al., 1995). A captive harbor porpoise swam between 1 and 2 m/sec (3.6 to 7.2 kph) (Curren et al., 1994). Harbor porpoises tagged in Denmark had a minimum average speed of 2.6 to 8.0 kph (Linnenschmidt et al., 2013). A speed range of 2 to 7 kph is used in AIM to represent harbor porpoise speed.

Group Size

Off California, the mean group size of harbor porpoise was 5.0 (n=31) (Barlow, 1995).

B-2.4.14 Pilot Whales: Short-finned and Long-finned Pilot Whales (*Globicephala* spp.)

There are insufficient data available to have separate animats for the two pilot whale species. Therefore, they are combined into a single pilot whale animat.

Surface Time

A rehabilitated long-finned pilot whale in the North Atlantic was equipped with a satellite tag and a time-depth recorder (TDR). The log survivorship plot of dive time from this animal had an inflection point at about 40 sec (Mate et al., 2005). The authors did not feel that this qualified as a breakpoint to separate surface and dive behavior. However, it does suggest that most surface intervals are less than one minute.

Dive Depth

Long-finned pilot whales in the Mediterranean were observed to display considerable diurnal variation in their dive depths. During the day they never dove to more than 16 m. However, at night, they dove to maximum depths of 360 and 648 m with mean depth of 308 and 416 m (Baird et al., 2002). Rehabilitated long-finned pilot whales dove to 312 m on Georges Bank, which has a depth of 360 m; these values should therefore not be taken as the maximum. The distribution of dive depths was also skewed toward lower values (Nawojchik et al., 2003).

Short-finned pilot whales off Madeira Island in the Atlantic Ocean spent most (~ 75 percent) of their time in the top 10 m of the water column during the day, with a very few deep dives, including one to a maximum depth of 130-988 m (Alves et al., 2013). Short-finned pilot whales off the Canary Islands had maximum depth of 1019 m (Aguilar Soto et al., 2008). The majority of these were to depths of less than 100 m, while the remainders of depths were approximately evenly distributed between 100 and 1000 m (Figure B-13).

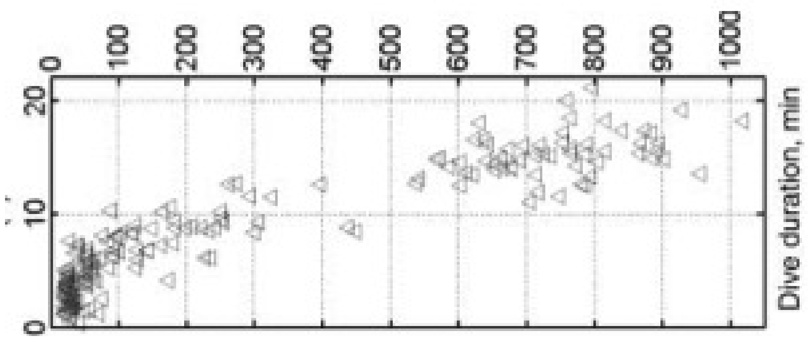


Figure B-13. Relationship of Dive Depth and Dive Time for Short-Finned Pilot Whales of the Canary Islands (Aguilar Soto et al., 2008).

Dive Time

Baird et al. (2002) reported on dives of two individual long-finned pilot whales, which varied between 2.14 and 12.7 min during the night. Animals spent all of their time in the top 16 m during the day. A rehabilitated long-finned pilot whale in the North Atlantic had dive times between 1 and 6 min (Mate et al., 2005). Other rehabilitated long-finned pilot whales were reported to dive for at least 25 min, although the distribution is skewed toward shorter dives, with most lasting about 2 min (Figure B-14; (Nawojchik et al., 2003). Long-finned pilot whales off the Faroe Islands never dove longer than 18 min (Heide-Jørgensen et al., 2002).

Speed

Shane (1995) reported a minimum speed of 2 kph and a maximum of 12 kph for pilot whales. During the day in the Mediterranean, animals slowly swam, with mean values for two animals of 0.762 and 0.885 m/sec (2.85 and 3.18 kph), while at night, they swam faster at 1.898 m/sec (6.83 kph) and 1.523 m/sec (5.48 kph) (Baird et al., 2002). A single satellite-tracked long-finned pilot whale had a minimum speed of 1.4 kph (Mate et al., 2005). The speeds of traveling pilot whales (*G. scammoni*) was estimated at 4 to 5 kts (7.4 to 9.3 kph) (Norris and Prescott, 1961 cited in Mate et al., 2005). Vertical dive

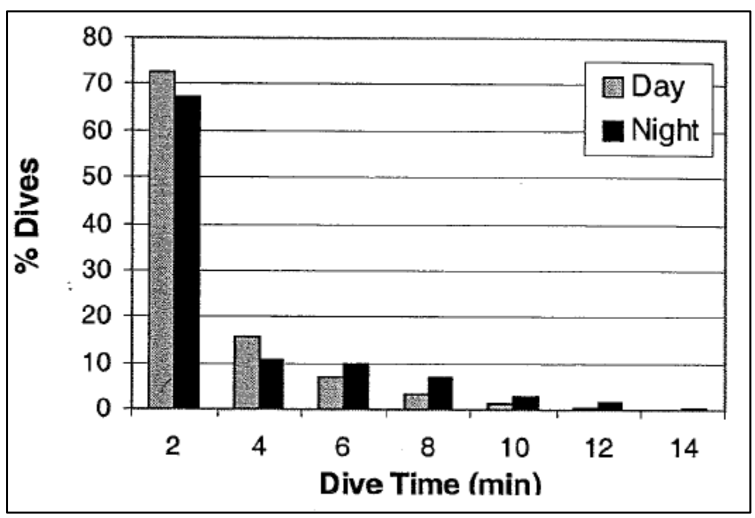


Figure B-14. Dive Times for Long-Finned Pilot Whales (Nawojchik et al., 2003).

speeds of three TDR-tagged long-finned pilot whales ranged from 0.79 to 3.38 m/sec, with a mean of 1.99 m/sec (Heide-Jørgensen et al., 2002). A long-finned pilot whale had speeds of ~ 0.8 to 2.2 m/s before playback of acoustic stimuli (Miller et al., 2012).

Habitat

The minimum water depth that pilot whales were seen in the Gulf of Mexico was 246 m (Davis et al., 1998), while off of Spain, they preferred water over 600 m deep (Cañadas et al., 2002).

Group Size

Short-finned pilot whales in the Gulf of Mexico ranged in group size between 5 and 50 (mean = 20.4, SE=3.6, n=11) (Mullin et al., 2004). Off the Pacific coast of Costa Rica, the mean group size of pilot whales was 14.22 (SD=12.06) (May-Collado et al., 2005).

B-2.4.15 Sperm Whale (*Physeter macrocephalus*)

Surface Time

Male sperm whales in New Zealand had a mean duration on the surface of 9.1 min, with a range of 2 to 19 min (Jaquet et al., 2000). The distribution of surface times was non-normal, with 68 percent of the surface times falling in between 8 and 11 min. These values were used for AIM modeling.

Surfacing and Dive Angles

Surfacing angles of 90° and diving angles between 60° and 90° have been reported (Miller et al., 2004).

Dive Depth

The maximum, accurately measured, sperm whale dive depth was 1,330 m (Watkins et al., 2002). Foraging dives typically begin at depths of 300 m (Papastavrou et al., 1989). Sperm whale diving is not uniform. As an example of this, data from a paper on sperm whale diving reported different dive types for the sperm whales in their study (Amano and Yoshioka, 2003). AIM can now accommodate these different dive types, at different frequencies of use (Table B-6). Dive depths have also been shown to have diel variation in some areas, while others do not show this variation (Aoki et al., 2007). These differences have been attributed to the behavior of the prey species. Off California, tagged whales changed their dive patterns in response to changes in the depth of tagged squid (Davis et al., 2007). Male sperm whales foraging in high-latitude waters dove to a maximum depth of 1,860 m, but the median dive depth was only 175 m (Teloni et al., 2008). In the Atlantic, maximum dive depths ranged from 639 to 934 m (Table B-7) (Palka and Johnson, 2007).

In Japan, sperm whales showed diel variability off Ogasawara. Whales dove deeper during the day (mean = 853 +/- 130 m) than at night (mean = 469 +/- 122 m) (Aoki et al., 2007). However, off of Kumano Coast, there was not a strong difference in depths (561 m vice 646 m).

Heading Variance

Whales in the Gulf of Mexico tend to follow bathymetric contours (Jochens et al., 2008).

Dive Time

Sperm whale dive times average 44.4 min in duration and range from 18.2 to 65.3 min (Watkins et al., 2002). In the Gulf of Mexico, the modal dive time is about 55 minutes (Jochens et al., 2008). Dive times in the Atlantic averaged 40 to 45 minutes (Palka and Johnson, 2007), while dive times of sperm whales off Ogasawara, Japan averaged 40.1 min (SD = 4.5) during the day and with a mean time at night of 32.3 min (SD = 5.3) (Aoki et al., 2007). Off the Kumano Coast of Japan, sperm whale dives had intermediate times of 36.1 min (SD = 3.7) during the day and 34.1 (SD=7) min at night.

Table B-6. Sperm Whale Dive Parameters (Amano and Yoshioka, 2003).

Type of Dive	*N*	*Depth (m)*		*Time (min)*	
		Min	*Max*	*Min*	*Max*
Dives w/ active bottom period	65	606	1082	33.17	41.63
Dives w/o active bottom period	4	417	567	31.29	33.71
V shaped dives	3	213	353	12.77	20.83
Total	74				

Note: The dive data in this table represent only the sperm whales in the Amano and Yoshioka study. These data do not equate to the values used in AIM. For example, the table shows minimum and maximum dive times as 12.77 and 41.63 min respectively, while the values used in AIM runs are 18.2 and 65.3 min respectively, as stated below under dive time.

Table B-7. Dive Depths for Sperm Whales in the Atlantic Ocean (Palka and Johnson, 2007).

Area	Average Duration (min)				
	Foraging Dive			Inter-Dive Interval	Surface Interval
	Total	Descent	Ascent		
North Atlantic	44.6	24.4	20.2	7.1	70.0
Gulf of Mexico	44.7	22.2	22.4	8.2	63.7
Mediterranean	40.3	24.4	19.3	9.7	57.5

Area	Average Depth (m)		
	Maximum Depth of Foraging Dives	Inter-Dive Interval	Surface Interval
North Atlantic	933.9	1.15	5.6
Gulf of Mexico	638.7	0.45	4.6
Mediterranean	797.3	0.34	4.9

Speed

Sperm whales are typically slow or motionless on the surface. Mean surface speeds of 1.25 kph were reported by (Jaquet et al., 2000) and 3.42 kph (Whitehead et al., 1989). Their mean dive rate ranges from 5.22 kph to 10.08 kph with a mean of 7.32 kph (Lockyer, 1997). In Norway, horizontal swimming speeds varied between 0.2 and 2.6 m/sec (0.72 and 9.36 kph) (Wahlberg, 2002). Sperm whales in the Atlantic Ocean swam at speeds between 2.6 and 3.5 kph (Watkins et al., 1999; Jaquet and Whitehead, 1999). Mean speeds in the Gulf of Mexico were 3.3 kph (Jochens et al., 2008). Based on these data, a minimum speed of 1 kph, and a maximum speed of 8 kph was set for sperm whales, specified with a normal distribution, so that mean speeds will be about 4 kph.

Habitat

Sperm whales are found almost everywhere, but they are usually in water deeper than 480 m (Davis et al., 1998). However, there have been sightings of animals in shallow water (40 to 100 m) (Scott and Sadove, 1997; Whitehead et al., 1992). In the Gulf of California, there was no relationship between depth or bathymetric slope and abundance, and animals were seen in water as shallow as 100 m (Jaquet and Gendron, 2002). Based on these reports, a compromise value of 200 m is used as the shallow water limit for sperm whales.

Group Size

Social, female-centered groups of sperm whales in the Pacific have 'typical' group sizes of 25 to 30 animals, based on the more precise measurements in Coakes and Whitehead (2004); although less precise estimates are as high as 53 whales in a group.

B-2.4.16 Bearded Seal (*Erignathus barbatus*)

Surface Time

Reproductively displaying males exhibit stereotypical diving pattern that includes a mean surface time between dives of 20 ± 16 sec (mean ± SD) (Van Parijs et al., 2003). Four lactating bearded seal mothers were tagged; exhibited mean ± SD surface times between dives of 1.9 ± 6.0 min (Krafft et al., 2000).

Dive Depth

Four lactating bearded seal mothers were tagged; exhibited mean ± SD dive depths of 17.2 ± 22.5 m (Krafft et al., 2000). Of combined dives of tagged pups, approximately 80 percent were less than 40 m, with approximately 90 percent less than 60 m (Gjertz et al., 2000b). Of three tagged adult females, 35-80 percent of their dives were between 20 and 80 m, with a maximum mean dive depth of 290 m (Gjertz et al., 2000b). Another tagging study of pups reported a mean dive depth of 10 ± 10 m (Lydersen et al., 1994).

Dive Time

Reproductively displaying males: 113.0 ± 65.2 sec dive times (Van Parijs et al., 2003). Four lactating bearded seal mothers were tagged; exhibited mean ± SD dive times of 2.0 ± 2.3 min (Krafft et al., 2000). Of mother-pup pairs tagged, 50 percent of their dives were less than 5 min long and 50 percent were between 5 and 10 min long (Gjertz et al., 2000b). Another tagging study of pups reported a mean dive time of 62 ± 46 sec (Lydersen et al., 1994).

Speed

Four lactating bearded seal mothers were tagged; exhibited 3 distinct dive types, U_1, U_2, and V (Krafft et al., 2000). Average of the mean descent velocities was 1.1 ± 0.4 m/s. Average of the mean bottom velocity was 1.1 ± 0.5 m/s. Average of the mean ascent velocities was 1.2 ± 0.5 m/s. Average of the mean post-dive surface velocities was 0.6 ± 0.3 m/s. Average of the mean angle of descent was 30 ± 18 deg. Average of the mean angle of ascent was 27 ± 17 deg.

Habitat

Bearded seals are pagophilic phocid seals that prefer open drift ice and feed predominantly on benthic prey (Gjertz et al., 2000b). Their distribution is generally restricted to shallow-water areas. Feeding depths up to 200 m have been reported, but depth in the range of 25-50 m seem to be preferred (Gjertz et al., 2000b). Reproductively displaying males remain in small areas, patrolling the ice edge or the surrounding water from April – July (Van Parijs et al., 2003). Four lactating bearded seal mothers were tagged; exhibited 3 distinct dive types, U_1, U_2, and V (Krafft et al., 2000). U_1 dives were deep, relatively long dives with long bottom times and steep and rapid ascent and descent rates. U_2 dives were shallower, shorter dives that probably represent feeding in shallower areas.

B-2.4.17 Guadalupe Fur Seal (*Arctocephalus galapagoensis*)

Surface Time

The activity budget of lactating females foraging at sea consisted of 73.2 percent of the time swimming at the surface, 24 percent of the time diving, and 2.8 percent of the time resting at the surface.

Dive Depth

Average dive depth of lactating females foraging at sea was 26 ± 14.3 m; median dive depth was 24.5 m; and max dive depth was 115 m, with an average max dive depth of 82 ± 23.7 m (Kooyman and Trillmich, 1986). The frequency distribution of dive depths was about 42 percent less than 20 m depth (minimum of 5 m depth to be considered a dive), about 50 percent between 21 and 50 m depth, and about 8 percent greater than 51 m depth (Kooyman and Trillmich, 1986). Fur seals off Fernandina Island foraged between 0 and 80 meters, primarily between the hours of 1900 and 2200 (Villegas-Amtmann et al., 2013). They spent 24 percent of their time at sea diving.

Dive Time

Maximum average duration of dives of lactating females foraging at sea was 4.2 min, maximum dive time ranging from 2.4 to 7.7 min (Kooyman and Trillmich, 1986).

Speed

Estimated velocity based on body size is about 2 m/s (Gentry et al., 1986).

Habitat

Guadalupe fur seals are the only *Arctocephalus* sp. in the northern hemisphere. They are non-migratory, existing near the equator where tropical conditions are moderated by cool water currents, creating upwelling conditions, most pronounced from June to December (Trillmich, 1986). Throughout the year, however, they are forced to deal with rock surface temperatures that may reach 60°C and sea surface temperatures that never drop below 15°C. Because of the harsh energetic demands, pups suckle until 2 years of age or older (Trillmich, 1986). Lactating females were studied to determine their foraging behavior (Kooyman and Trillmich, 1986). The average distance traveled to feeding areas was 19 km and the average duration of feeding trips was 16.4 hr (ranging from 0.5-1.3 days).

B-2.4.18 Harp Seal (*Pagophilis groenlandicus*)

Surface Time

20.6 ± 3.8 percent of time hauled out, 34.2 ± 2.5 percent of time in water at surface, 45.2 ± 5.9 percent of time diving (Lydersen and Kovacs, 1993). Average of mean surface intervals was 2.53 ± 5.00 min, with average maximum surface interval of 67.1 min (Lydersen and Kovacs, 1993).

Dive Depth

The average dive depth of all dive types reported by Lydersen and Kovacs (1993) was 49 ± 25 m (Schreer et al., 2001). Average of mean dive depths was 30.4 ± 23.2 m, with average maximum dive depth of 71.5 m (Lydersen and Kovacs, 1993). Dives were typically either shallow (0 to 30 m) and short or deep (30 to 90 m) and long.

Harp seals during breeding and molting (April and May) stayed near the pack-ice edge typically dove to depths <100 m. Harp seals migrated into the Barents Sea (July to August) and dove to <400 m. In September to December, they moved into the Denmark Strait and dove to depths between 100 to 400 m. Overall, dives were significantly deeper during the day and in winter than at night and in summer (Folkow et al., 2004). Harp seals in the White and Barents seas worked the water column between 20-300 m, presumably foraging on capelin (Nordøy et al., 2008).

Dive Time

The average dive duration of all dive types reported by Lydersen and Kovacs (1993) was 5.6 ± 2.0 min (Schreer et al., 2001). Mean dive durations of 3.2 ± 2.4 min, maximum duration of 13 min (Lydersen and Kovacs, 1993). Dive durations for ten seals were longer in a more recent study. The mean was 8.3 (SD=4.6) minutes with maximum durations in excess of 20 minutes (Folkow et al., 2004).

Speed

Shallow dives: average of mean descent rates was 0.7 ± 0.5 kt, mean ascent rates was 0.67 kt ± 0.41 kt; deep dives: average of mean descent rates was 1.8 ± 1.0 kt, mean ascent rates was 1.4 ± 0.8 kt (Lydersen and Kovacs, 1993).

Habitat

Harp seals gather in large and dense breeding aggregations on the pack ice, give birth between mid-March and early April. Approximately 12-day lactation period, occurs, and then mating takes place. After mating, forage along the pack ice edge. In April/May, aggregate in large molting lairs on the pack ice and complete molting within a month. Then disperse to exploit food resources along the pack ice edge, perhaps in large aggregations (Lydersen and Kovacs, 1993).

Group Size

Large groups may also feed and travel together during migration (Reeves et al., 2002).

B-2.4.19 Hawaiian Monk Seal (*Monachus schauinslandi*)

Surface Time

The mean surface time for monk seals was 0.8 sec (Kiraç et al., 2002).

Dive Depth

Monk seals were observed to dive between 50 and 500 m (Parrish et al., 2000). The overwhelming majority of the foraging dives recorded with an animal-mounted video recorder were to 50 to 60 m in depth (Parrish et al., 2000).

Dive Time

Maximum dive times of 12 min were observed (Neves, 1998). Mean dive times of 6.4 minutes have been observed (Kiraç et al., 2002). The mean proportion of time ashore ranges from 0.13 to 0.43, with a mean of 0.27 (DeLong et al., 1984).

Speed

No swim speeds have been reported for Hawaiian monk seals. Therefore, the 4.6 kt (9 kph) value for harbor seals was used (Lesage et al., 1999).

Habitat

Hawaiian monk seals are found primarily on the Hawaiian leeward islands north of Kaua'i, although they are occasionally seen on the main islands. They haul out on the shores and return to the water to feed. Their atoll habitat makes deep water available close to shore, and they are known to dive to the bottom in at least 500 m of water.

Group Size

Hawaiian monk seals are solitary, except for mothers and calves (Reeves et al., 2002).

B-2.4.20 Hooded Seal (*Cystophora cristata*)

Surface Time

Hooded seals dive continuously while at sea, being submerged for 90.7 ±. 0.8 percent of the time (Folkow and Blix, 1999).

Dive Depth

Hooded seal dives to depths of 100 to 600 m accounted for >70 percent of dives whereas dives to less than 52 m accounted for about 17 percent of dives (Folkow and Blix, 1999). The maximum recorded dive depth was 1,016 m, the limit of the recording equipment (Folkow and Blix, 1999). The average dive depth of all dive types reported by Kovacs et al. (1996) was 39 ± 17 m (Schreer et al., 2001). These two reports disagree strongly suggesting a seasonal difference in behavior between the two populations. Andersen et al. (2013) observed that hooded seals had a mean dive depth of 837 ft (255 m) and a maximum depth of 5,420 ft (1,652 m).

Dive Time

Dives of 5 to 15 min durations accounted for 47.1 percent of dives and dives of 15 to 25 min durations accounted for 30.6 percent of dives, for an average duration ± SE of 14.3 ± 0.1 min (Folkow and Blix, 1999). The average (± SD) dive duration of all dive types reported by Kovacs et al. (1996) was 5.5 ± 3.9 m (Schreer et al., 2001). Andersen et al. (2013) reported the mean dive duration for hooded seals as 13.9 min with a maximum dive duration of 57.3 min.

Habitat

Pupping season is March/April, molting season is July. After pupping or molting on the sea ice near Jan Mayen, seals disperse to distant waters off the Faroe Islands, south of Bear Island, or the Irminger Sea (Folkow and Blix, 1999).

Group Size

Hooded seals are solitary (Reeves et al., 2002).

B-2.4.21 Pagophilic *Phoca* spp. Seals (Ringed, Spotted, and Ribbon Seals)

Surface Time

Ringed seal studies: Submerged 69.7 percent of time at sea, at surface 30.3 percent (Lydersen, 1991).

Dive Depth

Ringed seal studies: Max depth of 43.87 m (14, 81 interquartile range) (Simpkins et al., 2001). Mean depth of 10.6 ± 9.0 m, max 40 m (Lydersen, 1991). Max daily dive depth 156-360 m, adults spent 66 percent of time at depths between 0 and 50 m (Born et al., 2004).

Ringed seals near Svalbard had a bimodal distribution of depths, with a peaks occurring between 1 and 4, as well as between 40 and 50 m (each peak accounts for ~25 percent of all dives). Very few dives were deeper than 150 m (Gjertz et al., 2000a).

Boveng et al. (2013) noted that ribbon seal diving patterns are tied to season, with a tendency for the dive depths to increase as the ice edge expands south, nearer to the continental shelf break. When ribbon seals on are on the sea ice in shallow water, they dive to the sea floor, typically to depths of 233 to 328 ft (71 to 100 m), but when not tied to sea ice, ribbon seals dive deeper, up to 1,640 ft (500 m) and rarely to 1,969 ft (600 m) (Boveng et al., 2013).

Dive Time

Ringed seal studies: Mean duration 2.7 ± 2.7 min, max 17 min (Lydersen, 1991).

Speed

Ringed seal swim speeds: 1-3 m/s (Simpkins et al., 2001). Mean swim speed during spring and summer 1.6 ± 0.5 km/h (Born et al., 2004). Swim speed of 0.92 ± 0.702 km/h and 1.56 ± 0.959 km/h (Teilmann et al., 1999).

Satellite-linked tags were attached to 12 spotted seals, range of speeds reported as 0.4-5.2 km/h, with an average of the mean speeds calculated as 2.2 ± 0.8 km/h (Lowry et al., 1998).

Habitat

Ribbon and ringed seals are not benthic predators (Simpkins et al., 2003). No data available on ribbon seals. Only habitat and swim speed data available on spotted seals. During the open-water season (summer and fall), spotted seals use nearshore habitats and coastal haulouts unlike other ice-breeding seals (Lowry et al., 1998). From November to May/Jun, spotted seals are associated with sea ice, with the highest concentration of animals occurring near the southern edge of the ice, in waters less than 200 m deep, approximately at the edge of the continental shelf (Lowry et al., 2000). Spotted seals were considered a subspecies of the Pacific harbor seal at one point (Lowry et al., 1998).

Group Size

Ringed seals are solitary (Reeves et al., 2002). Ribbon seals are typically solitary but aggregate at breeding and pupping sites or at favored haulouts (Fedoseev, 2002).

B-3 RESULTS OF AIM MODELING

B-3.1 Animat Exposure Histories

AIM simulates realistic animal movement through the defined acoustic field during which the received level is recorded at each time step, which is call an exposure history. Thus, the output of AIM is the exposure history for each animat. The sound energy received over the 24-hr modeled period was calculated as SEL and the potential for PTS and then TTS was considered for each individual animat using the NOAA (2016) guidance, as described in Chapter 4 and summarized below. The sound energy received over the 24-hr modeled period was also calculated as dB SPE and used as input to the risk continuum function (described below) in order to assess the potential risk of biologically significant behavioral reaction.

Because AIM records the exposure history for each individual animat, the potential impact is determined on an individual animal basis using the methods described below. The potential for PTS is considered first. If an individual does not exceed the PTS threshold, then the potential for TTS is considered. If an animal does not exceed the TTS threshold, then the potential for a behavioral response is considered. Thus, individuals are not considered for more than one acoustic impact during a 24-hr exposure scenario.

B-3.2 Behavioral Risk Function for SURTASS LFA Sonar

The potential for a biologically significant behavioral response is estimated using the SURTASS LFA risk continuum function. This function has been described in detail in the Navy's 2001, 2007, and 2012 SEISs for SURTASS LFA sonar (DoN, 2001, 2007, 2012, and 2015), which as previously noted are incorporated by reference. The risk continuum is based on the premise that a smooth, continuous function that maps RL to risk is most appropriate for defining the potential or risk for a biologically significant behavioral response (Figure B-15).

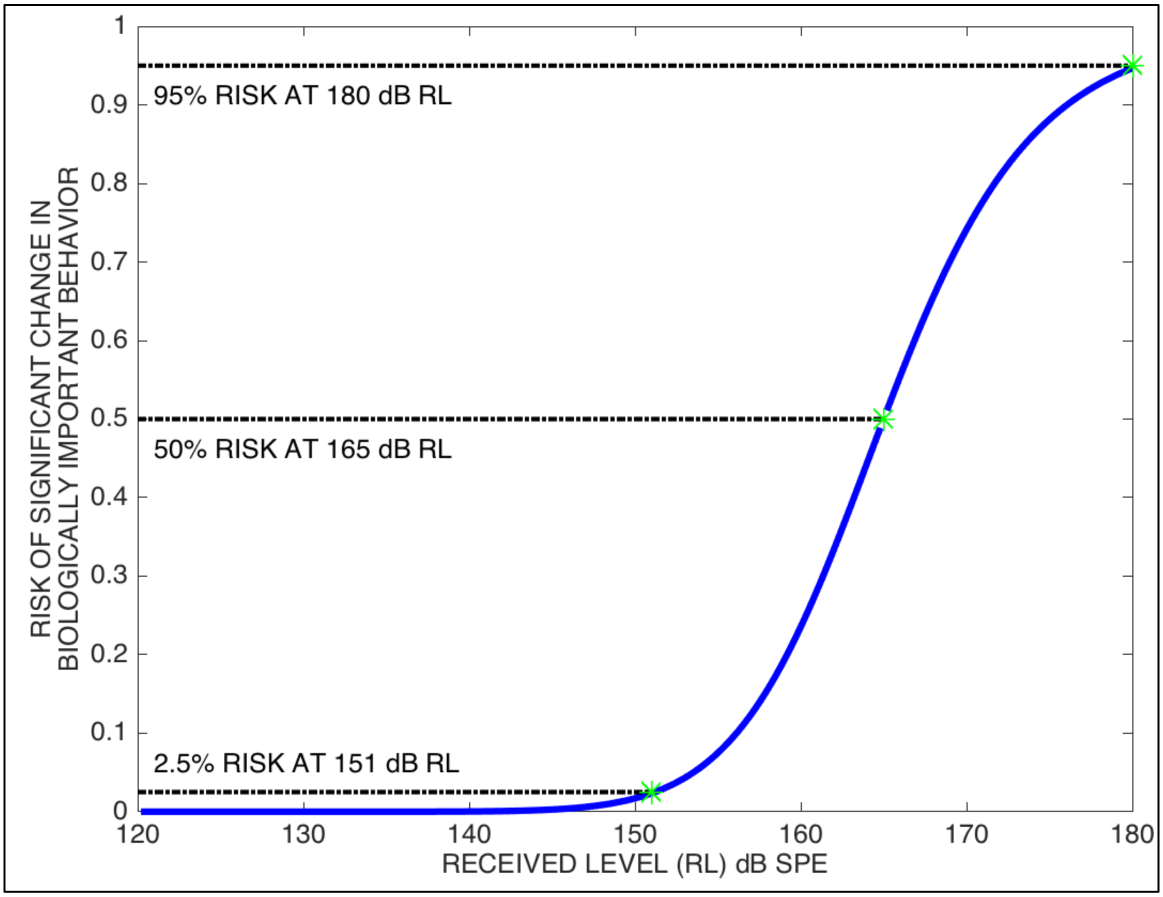


Figure B-15. Risk Continuum Function for SURTASS LFA Sonar Analysis that Relates the Risk of Significant Change in Biologically Important Behavior to Received Levels in Decibels Single Ping Equivalent (SPE).

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

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

The function used here is adapted from the solution in Feller (1968) and the parameter values are provided as determined through the Low Frequency Sound Scientific Research Program (LFS SRP):

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

Where:

- R = risk (values=0-1.0)
- L = RL in dB
- B = basement RL in dB, below which risk is negligible (value=120 dB)
- K = RL increment above basement at which there is 50 percent risk (value=45 dB)
- A = risk transition sharpness parameter (value=10).

To determine the parameters to bound the behavioral risk function, the Navy undertook the LFS SRP in which a SURTASS LFA sonar vessel, the R/V *Cory Chouest*, was made available for scientific studies. The scientific objective of the LFS SRP was to conduct independent field research in the form of controlled experimental tests, consisting of three phases, of how baleen whales responded to SURTASS LFA sonar signals.

These experiments, which exposed baleen whales to RLs ranging from 120 to about 155 dB re 1 µPa (rms) (SPL), detected only minor, short-term behavioral responses. Short-term behavioral responses do not necessarily constitute significant changes in biologically important behaviors. The fact that none of the LFS SRP observations revealed a significant change in a biologically important behavior helped determine an upper bound for risk. However, the LFS SRP results cannot be used to prove that there is zero risk at these levels. Accordingly, the risk continuum assumes that risk is small, but not zero, at the RLs achieved during the LFS SRP.

The risk continuum modeled a smooth increase in risk that culminates in a 95 percent level of risk of significant change in a biologically important behavior at 180 dB SPE. In this region, the risk continuum is unsupported by observations. However, the AIM simulation results indicate that a small fraction of any marine mammal stock would be exposed to sound levels exceeding 155 dB re 1 µPa (rms) (SPL). Since the risk continuum function was derived from the behavioral response data of baleen whales collected with an actual SURTASS LFA sonar source, these data are realistic contextually and remain the best available for the response of LF-sensitive marine mammals to the SURTASS LFA sonar source.

B-3.3 Current TTS and PTS Thresholds

According to the NOAA acoustic guidance (NOAA, 2016), quantitative assessment of TTS and PTS consists of two parts: 1) an acoustic threshold level and 2) an associated auditory weighting function. To account for the fact that different species groups use and hear sound differently, acoustic thresholds and auditory weighting functions were defined for five broad functional hearing groups: low-, mid-, and high-frequency cetaceans as well as phocid and otariid pinnipeds in water. NOAA (2016) defined these functional hearing groups by combining behavioral and electrophysiological audiograms with comparative anatomy, modeling, and response measured in ear tissues:

- Low-frequency Cetaceans—this group consists of the mysticetes (baleen whales) with a collective a generalized hearing range of 7 Hz to 35 kHz.
- Mid-frequency Cetaceans—this group includes most of the dolphins, all the toothed whales except for the Family Kogidae, and all the beaked and bottlenose whales with a generalized hearing range of approximately 150 Hz to 160 kHz.
- High-frequency Cetaceans—this group incorporates all the true porpoises, the river dolphins, plus the franciscana, *Kogia* spp., all of the genus *Cephalorhynchus*, and two species of *Lagenorhynchus* (Peale's and hourglass dolphins) with a generalized hearing range estimated from 275 Hz to 160 kHz.

- Phocids in Water—this group consists of 23 species and subspecies of true seals with a generalized underwater hearing range from 50 Hz to 86 kHz.
- Otariids in Water—this group includes 16 species and subspecies of sea lions and fur seals with a generalized underwater hearing range from 60 Hz to 39 kHz.

The NOAA guidance (NOAA, 2016) details the science underlying the development of the acoustic threshold levels and the associated auditory weighting functions. Quantitative assessment of the received levels, or acoustic thresholds, above which individuals are predicted to experience changes in their hearing sensitivity for acute, incidental exposure to underwater sound is based upon marine mammal composite audiograms, equal latency, and data on susceptibility to noise-induced hearing loss. Acoustic thresholds and auditory weighting functions are defined for each functional hearing group.

The overall shape of the weighting functions is based on a generic band-pass filter described as:

$$W(f) = C + 10log_{10}\left(\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right)$$

where W(f) is the weighting function amplitude in dB at a particular frequency (f) in kHz. The function shape is determined by the following weighting function parameters (Figures B-16 and B-17, Table B-8).

Table B-8. Parameters of the Weighting Functions Utilized in AIM Modeling of PTS and TTS Potential Impacts Associated with Exposure to SURTASS LFA Sonar Transmissions.

Functional Hearing Group	*a*	*b*	*f_1 (kHz)*	*f_2 (kHz)*	*C (dB)*
Low-frequency (LF) cetaceans	1.0	2	0.2	19	0.13
Mid-frequency (MF) cetaceans	1.6	2	8.8	110	1.20
High-frequency (HF) cetaceans	1.8	2	12	140	1.36
Phocid pinnipeds (underwater)	1.0	2	1.9	30	0.75
Otariid pinnipeds (underwater)	2.0	2	0.94	25	0.64

The weighting function is based on parameters that define a generic band-pass filter:

- Low-frequency exponent (a): This parameter determines the rate at which the weighting function amplitude declines with frequency at the lower frequencies. As the frequency decreases, the change in amplitude becomes linear with the logarithm of frequency, with a slope of “a” times 20 dB/decade (e.g., if “a” equals 1, the slope is 20 dB/decade).
- High-frequency exponent (b*):* Rate at which the weighting function amplitude declines with frequency at the upper frequencies. As the frequency increases, the change in amplitude becomes linear with the logarithm of frequency, with a slope of “b” times 20 dB/decade.
- Low-frequency cutoff (f_1): This parameter defines the lower limit of the band-pass filter (i.e., the lower frequency where weighting function amplitude begins to roll off or decline from the flat, central portion of the function). This parameter is directly dependent on the value of the low-frequency exponent (a).

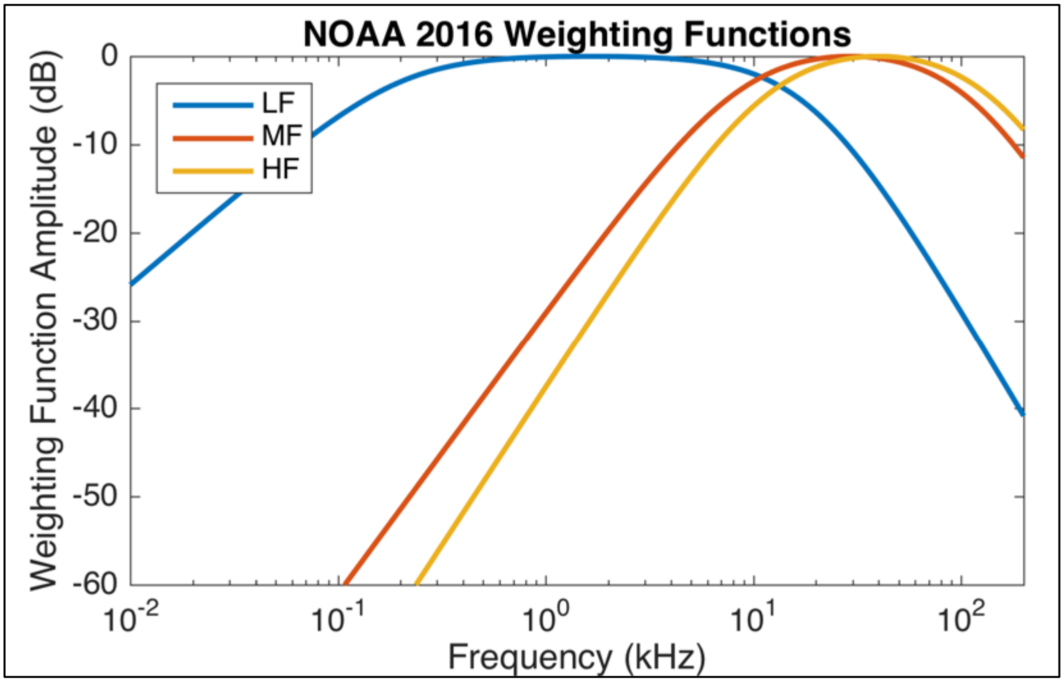


Figure B-16. NOAA (2016) Auditory Hearing Weighting Functions for Cetaceans, Where LF = Low-Frequency Cetacean, MF = Mid-Frequency Cetacean, and HF = High Frequency Cetacean.

1

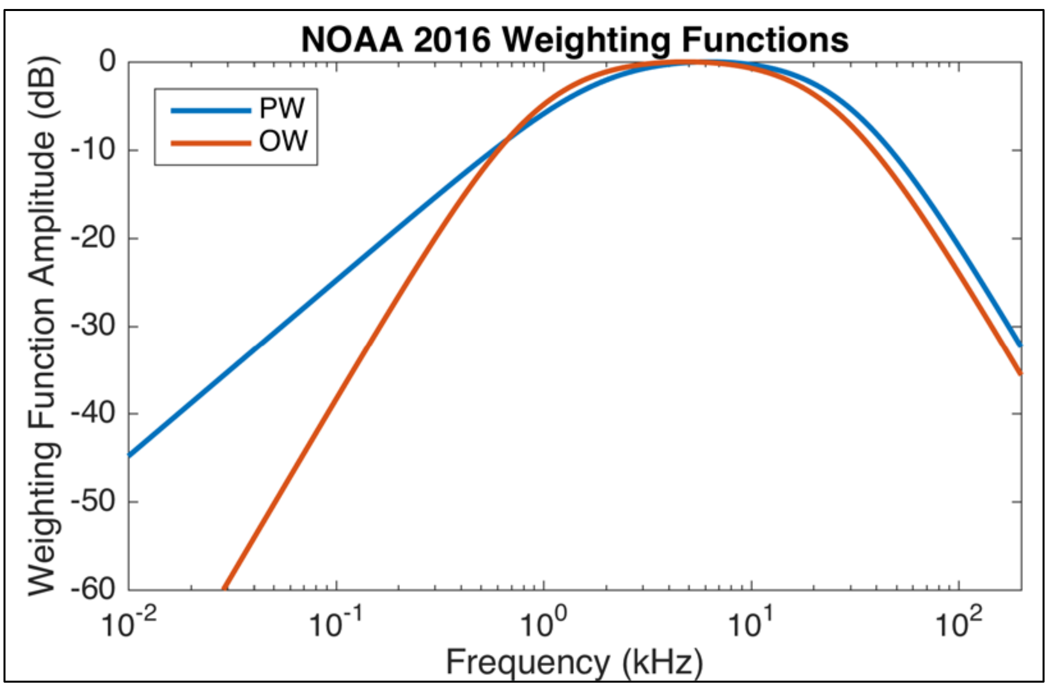


Figure B-17. NOAA (2016) Auditory Hearing Weighting Functions for Pinnipeds, Where PW = Phocid in Water, OW = Otariid in Water.

- High-frequency cutoff (f_2): This parameter defines the upper limit of the band-pass filter (i.e., the upper frequency where weighting function amplitude begins to roll off or decline from the flat, central portion of the function). This parameter is directly dependent on the value of the high-frequency exponent (b).
- Weighting function gain (C*):* This parameter determines the vertical position of the function and is adjusted to set the maximum amplitude of the weighting function to 0 dB.

These weighting function parameters have been used in AIM modeling of potential noise-induced hearing loss to marine mammals (Table B-8). The calculated SEL exposure for each individual animat is weighted by the appropriate auditory weighting function, which is then compared to the acoustic thresholds described in the next section.

B-3.4 Application of PTS and TTS Acoustic Thresholds

In the assessment of the potential for noise-induced hearing loss to marine mammals from exposure to SURTASS LFA sonar transmissions, the final step is to compare the weighted SEL values to the appropriate weighted SEL_{cum}[1] threshold to determine if the threshold is exceeded and noise-induced hearing loss is predicted to occur (Table B-9). Since TTS is recoverable and is considered to result from the temporary, non-injurious fatigue of hearing-related tissues, it represents the upper bound of the potential for MMPA Level B impacts. PTS, however, is non-recoverable and results from irreversible impacts on auditory sensory cells, supporting tissues, or neural structures within the auditory system. PTS is thus considered within the potential for MMPA Level A impacts.

Table B-9. Acoustic Criteria and Thresholds Used to Predict Physiological Impacts on Marine Mammals Associated with Exposure to SURTASS LFA Sonar Transmissions (NOAA, 2016).

Functional Hearing Group	*Weighted TTS onset acoustic threshold level (SEL_{cum}) (dB)*	*Weighted PTS onset acoustic threshold level (SEL_{cum}) (dB)*
Low-frequency (LF) Cetaceans	179	199
Mid-frequency (MF) Cetaceans	178	198
High-frequency (HF) Cetaceans	153	173
Phocid Pinnipeds (PW underwater)	181	201
Otariid Pinnipeds (OW underwater)	199	219
Note: LF cetaceans include all mysticetes (baleen whales) while MF cetaceans include dolphins, beaked whales, and medium to large toothed whales		

B-3.5 Conclusion

The acoustic impact analysis integrates Navy mission planning needs (routine training, testing, and military operations) with the best available data on marine mammal populations to estimate the potential impacts from incidental exposure to SURTASS LFA sonar. In this supplemental analysis, marine mammal takes incidental to the employment of SURTASS LFA sonar at 26 representative mission areas have been estimated, with the results presented in Chapter 4.

1 Cumulative sound exposure level

B-4 Literature Cited

Aguilar Soto, N., M. P. Johnson, P. T. Madsen, F. Diaz, I. Domínguez, A. Brito, and P. L. Tyack. (2008). Cheetahs of the deep sea: deep foraging sprints in short-finned pilot whales off Tenerife (Canary Islands). *Journal of Animal Ecology,* 77(5), 936 - 947.

Allen, A. N., J. J. Schanze, A. R. Solow, and P. L. Tyack. (2014). Analysis of a Blainville's beaked whale's movement response to playback of killer whale vocalizations. *Marine Mammal Science,* 30(1), 154-168. doi:10.1111/mms.12028

Alves, F., A. Dinis, I. Cascão, and L. Freitas. (2010). Bryde's whale (*Balaenoptera brydei*) stable associations and dive profiles: New insights into foraging behavior. *Marine Mammal Science,* 26(1), 202-212.

Alves, F., A. Dinis, C. Ribeiro, C. Nicolau, M. Kaufmann, C. M. Fortuna, and L. Freitas. (2013). Daytime dive characteristics from six short-finned pilot whales Globicephala macrorhynchus off Madeira Island. Arquipelago - Life and Marine Sciences.

Alves, F., L. Freitas, and A. Dinis. (2006). *Occurrence and diving behaviour of false killer whale off Madeira archipelago (NE Atlantic).* Paper presented at the ECS 2006, Gydnia, Poland.

Amano, M., and M. Yoshioka. (2003). Sperm whale diving behavior monitored using a suction-cup-attached TDR tag. *Marine Ecology Progress Series,* 258, 291-295.

Anderson, R. C., R. Clark, P. T. Madsen, C. Johnson, J. Kiszka, and O. Breysse. (2006). Observations of Longman's Beaked Whale (*Indopacetus pacificus*) in the Western Indian Ocean. *Aquatic Mammals,* 32(2), 223-231.

ANSI, A. N. S. I. (2006). *ANSI reference quantities for acoustical levels*. New York, New York: Acoustic Society of America.

Aoki, K., M. Amano, M. Yoshioka, K. Mori, D. Tokuda, and N. Miyazaki. (2007). Diel diving behavior of sperm whales off Japan. *Marine Ecology Progress Series,* 349, 277-287.

Baird, R. (2011). Short Note: Open-Ocean Movements of a Satellite-Tagged Blainville's Beaked Whale (*Mesoplodon densirostris*): Evidence for an Offshore Population in Hawai'i? *Aquatic Mammals,* 37(4), 506-511. doi:10.1578/am.37.4.2011.506

Baird, R. W., J. F. Borsani, M. B. Hanson, and P. L. Tyack. (2002). Diving and night-time behavior of long-finned pilot whales in the Ligurian Sea. *Marine Ecology Progress Series,* 237, 301-305.

Baird, R. W., A. D. Ligon, and S. K. Hooker. (2000). Sub-surface and night-time behavior of humpback whales off Maui, Hawaii: a preliminary report

Baird, R. W., D. L. Webster, D. J. McSweeney, A. D. Ligon, G. S. Schorr, and J. Barlow. (2006). Diving behaviour of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawai'i. *Canadian Journal of Zoology,* 84, 1120-1128.

Baird, R. W., D. L. Webster, G. S. Schorr, D. J. McSweeney, and J. Barlow. (2008). Diel variation in beaked whale diving behavior. *Marine Mammal Science,* 24(3), 630-642. doi:10.1111/j.1748-7692.2008.00211.x

Baker, C. S., and L. M. Herman. (1989). The behavioral responses of summering humpback whales to vessel traffic: Experimental and opportunistic observations. Honolulu

Barlow, J. (1995). The abundance of cetaceans in California waters: Part I. Ship surveys in summer and fall of 1991. U S Natl Mar Fish Serv Fisheries Bulletin*,* 93(1), 1-14.

Bauer, G. B., J. R. Mobley, A. S. Frankel, D. A. Helweg, and L. M. Herman. (1995). *Behavior characteristics of humpback whales in Hawaii.* Paper presented at the Eleventh Biennial conference on the Biology of Marine Mammals, Orlando, FL.

Born, E. W., J. Teilmann, M. Acquarone, and F. F. Riget. (2004). Habitat use of ringed seals, Phoca hispida, in the North Water area (north Baffin Bay). *Arctic,* 57(2), 129-142.

Boveng, P. L., Bengtson, J. L., Cameron, M. F., Dahle, S. P., Logerwell, E. A., London, J. M., Overland, J. E., Sterling, J. T., Stevenson, D. E., Taylor, B. L., & Ziel, H. L. (2013). *Status review of the ribbon seal.* (NOAA Technical Memorandum NMFS-AFSC-255). Seattle, WA: Alaska Fisheries Science Center, National Marine Fisheries Service.

Brown, S. G. (1977). Some results of sei whale marking in the southern hemisphere. *Report of the International Whaling Commission,* Si1, 39-43.

Calambokidis, J., G. S. Schorr, G. H. Steiger, J. Francis, M. Bakhtiari, G. Marshall, E. M. Oleson, D. Gendron, and K. Robertson. (2008). Insights into the underwater diving, feeding, and calling Bbehavior of blue whales from a suction-cup-attached video-imaging tag (CRITTERCAM). *Marine Technology Society Journal,* 41(1), 19-29.

Cañadas, A., R. Sagarminaga, and T. S. Garcia. (2002). Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain. *Deep Sea Research Part I Oceanographic Research Papers,* 49(11), 2053-2073.

Carnes, M. R. (2009). *Description and Evaluation of GDEM-V 3.0*. Naval Research Laboratory Report NRL/MR/7330-09-9165.

Charif, R. A., D. K. Mellinger, K. J. Dunsmore, and C. W. Clark. (2002). Estimated source levels of fin whale *(Balaenoptera physalus)* vocalizations: Adjustments for surface interference. *Marine Mammal Science,* 18(1), 81-98.

Chaudry, F. A. (2006). *A comparison of east Australian humpback whale migratory behaviour between the northern and southern migrations.* Paper presented at the ECS 2006, Gydnia, Poland.

Chittleborough, R. G. (1953). Aerial observations of the humpback whale (*Megaptera nodosa*). *Australian Journal of Marine and Freshwater Research,* 4, 219-226.

Christiansen, F., N. M. Lynas, D. Lusseau, and U. Tscherter. (2015). Structure and dynamics of minke whale surfacing patterns in the gulf of st. Lawrence, Canada. *PLoS One,* 10(5), e0126396. doi:10.1371/journal.pone.0126396

Christman, C. L., J. J. Citta, L. T. Quakenbush, J. T. Clarke, B. K. Rone, R. A. Shea, M. C. Ferguson, and M. P. Heide-Jørgensen. (2013). Presence and behavior of bowhead whales (Balaena mysticetus) in the Alaskan Beaufort Sea in July 2011. *Polar Biology,* 36(12), 1851-1856. doi:10.1007/s00300-013-1395-4

Citta, J. J., L. T. Quakenbush, J. C. George, R. J. Small, M. P. Heide-Jørgensen, H. Brower, B. Adams, and L. Brower. (2012). Winter movements of bowhead whales (*Balaena mysticetus*) in the Bering Sea. *Arctic,* 65(1), 13-34.

Clapham, P. J. (1993). Social organization of humpback whales on a North Atlantic feeding ground. *Symp. Zool. Soc. Lond.,* 66, 131-145.

Coakes, A. K., and H. Whitehead. (2004). Social structure and mating system of sperm whales off northern Chile. *Canadian Journal of Zoology,* 82(8), 1360-1369.

Croll, D. A., A. Acevedo-Gutierrez, B. R. Tershy, and J. Urban-Ramirez. (2001). The diving behavior of blue and fin whales: is dive duration shorter than expected based on oxygen stores? *Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology,* 129(4), 797-809.

Croll, D. A., B. R. Tershy, R. P. Hewitt, D. A. Demer, P. C. Fiedler, S. E. Smith, W. Armstrong, J. M. Popp, T. Kiekhefer, V. R. Lopez, J. Urban, and D. Gendron. (1998). An integrated approach to the foraging ecology of marine birds and mammals. *Deep Sea Research II,* 45, 1353-1371.

Cummings, W. C. (1985). Bryde's whale *Balaenoptera edeni* Anderson, 1878. In S. H. Ridgway and R. Harrison (Eds.), *Handbook of marine mammals, Vol. 3: The sirenians and baleen whales* (pp. 137-154). London: Academic Press.

Cummings, W. C., & D. V. Holliday. (1985). Passive acoustic location of bowhead whales in a population census off Point Barrow, Alaska. *Journal of the Acoustical Society of America,* 78(4), 1163-1169.

Curren, K., N. Bose, and J. Lien. (1994). Swimming kinematics of a harbor porpoise (*Phocoena phocoena*) and an Atlantic white-sided dolphin (*Lagenorhynchus acutus*). *Marine Mammal Science,* 10(4), 485-492.

Dalebout, M., C. Baker, J. Mead, V. Cockcroft, and T. Yamada. (2004). A comprehensive and validated molecular taxonomy of beaked whales, family Ziphiidae. *Journal of Heredity,* 95(6), 459-476.

Dalla Rosa, L., E. R. Secchi, Y. G. Maia, A. N. Zerbini, and M. P. Heide-Jørgensen. (2008). Movements of satellite-monitored humpback whales on their feeding ground along the Antarctic Peninsula. *Polar Biology*. doi:10.1007/s00300-008-0415-2.

Davis, R. W., G. S. Fargion, N. May, T. D. Leming, M. Baumgartner, W. Evans, E, L. J. Hansen, and K. Mullin. (1998). Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. *Marine Mammal Science,* 14(3), 490-507.

Davis, R. W., N. Jaquet, D. Gendron, U. Markaida, G. Bazzino, and W. Gilly. (2007). Diving behavior of sperm whales in relation to behavior of a major prey species, the jumbo squid, in the Gulf of California, Mexico. *Marine Ecology Progress Series,* 333, 291-302.

de Vos, A., F. Christiansen, R. G. Harcourt, and C. B. Pattiaratchi. (2013). Surfacing characteristics and diving behaviour of blue whales in Sri Lankan waters. *Journal of Experimental Marine Biology and Ecology,* 449, 149-153. doi:10.1016/j.jembe.2013.09.010

DeLong, R. L., G. L. Kooyman, W. G. Gilmartin, and T. R. Loughlin. (1984). Hawaiian monk seal diving behavior. *Acta Zool. Fennica,* 172, 129-131.

Department of the Navy (DoN). (2001). *Final overseas environmental impact statement and environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar*. Washington, D.C.

DoN. (2007). *Final supplemental environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar*. Washington, D.C.

DoN. (2012). *Final supplemental environmental impact statement/supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar*. Washington, D.C.

DoN. (2015). *Final supplemental environmental impact statement/supplemental overseas environmental impact statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) sonar*. Washington, D.C.

Doi, T. (1974). Further development of whale sighting theory. In W. E. Schevill (Ed.), *The Whale Problem: A status report* (pp. 359-368). Cambridge, MA: Harvard University Press.

Dolphin, W. F. (1987a). Dive behavior and estimated energy expenditure of foraging humpback whales in southeast Alaska. *Canadian Journal of Zoology,* 65(2), 354-362.

Dolphin, W. F. (1987b). Ventilation and dive patterns of humpback whales, *Megaptera novaeangliae*, on their Alaskan feeding grounds. *Canadian Journal of Zoology,* 65(1), 83-90.

Dolphin, W. F. (1987c). Ventilation and dive patterns of humpback whales, *Megaptera novaeangliae*, on their Alaskan feeding grounds. *Canadian Journal of Zoology,* 65(1), 83-90.

Dolphin, W. F. (1988). Foraging dive patterns of humpback whales *Megaptera novaeangliae* in Southeast Alaska USA: A cost-benefit analysis. *Canadian Journal of Zoology,* 66(11), 2432-2441.

Dorsey, E. M., W. J. Richardson, and B. Würsig. (1989). Factors affecting surfacing respiration and dive behavior of bowhead whales *Balaena mysticetus* summering in the Beaufort Sea, Canada. *Canadian Journal of Zoology,* 67(7), 1801-1815.

Fedoseev, G. (2002). Ribbon seal, *Histriophoca fasciata*. Pages 1027-1030 in Perrin, W.F., B. Würsig and J.G.M. Thewissen, editors. *Encyclopedia of Marine Mammals*. San Diego, California: Academic Press.

Feller, W. (1968). *Introduction to probability theory and its application*. Volume 1. 3rd ed. New York, NY: John Wiley & Sons.

Fish, F. E., & J. J. Rohr. (1999). Review of Dolphin Hydrodynamics and Swimming Performance (TR 1801)

Folkow, L. P., & A. S. Blix. (1999). Diving behaviour of hooded seals (*Cystophora cristata*) in the Greenland and Norwegian Seas. *Polar Biology,* 22(1), 61-74.

Folkow, L. P., E. S. Nordøy, and A. S. Blix. (2004). Distribution and diving behaviour of harp seals (*Pagophilus groenlandicus*) from the Greenland Sea stock. *Polar Biology,* 27(5), 281-298.

Ford, J. K. B., J. W. Durban, G. M. Ellis, J. R. Towers, J. F. Pilkington, L. G. Barrett-Lennard, and R. D. Andrews. (2013). New insights into the northward migration route of gray whales between Vancouver Island, British Columbia, and southeastern Alaska. *Marine Mammal Science,* 29(2), 325-337. doi:10.1111/j.1748-7692.2012.00572.x

Ford, J. K. B., G. A. Ellis, D. R. Matkin, K. C. Balcomb, D. Briggs, and A. B. Morton. (2005). Killer whale attacks on minke whales: Prey capture and antipredator tactics. *Marine Mammal Science,* 21(4), 603-618.

Gabriele, C. M., J. M. Straley, L. M. Herman, and R. J. Coleman. (1996). Fastest documented migration of a North Pacific humpback whale. *Marine Mammal Science,* 12(3), 457-464.

Gentry, R. L., G. L. Kooyman, and M. E. Goebel. (1986). Feeding and Diving Behavior of Northern fur seals. In R. L. Gentry and G. L. Kooyman (Eds.), *Fur seals: maternal strategies on land and at sea* (pp. 61-78). Princeton: Princeton University Press.

Gill, P. C. (2002). A blue whale (*Balaenoptera musculus*) feeding ground in a southern Australian coastal upwelling zone. *Journal of Cetacean Research and Management,* 4(2), 179-184.

Gjertz, I., K. M. Kovacs, C. Lydersen, and O. Wiig. (2000a). Movements and diving of adult ringed seals (*Phoca hispida*) in Svalbard. *Polar Biology,* 23(9), 651-656.

Gjertz, I., K. M. Kovacs, C. Lydersen, and O. Wiig. (2000b). Movements and diving of bearded seal (*Erignathus barbatus*) mothers and pups during lactation and post-weaning. *Polar Biology,* 23(8), 559-566.

Goldbogen, J., J. Calambokidis, R. E. Shadwick, E. M. Oleson, M. A. McDonald, and J. A. Hildebrand. (2006). Kinematics of foraging dives and lunge-feeding in fin whales. *Journal of Experimental Biology,* 209(7), 1231-1244.

Goldbogen, J. A., J. Calambokidis, D. A. Croll, J. T. Harvey, K. M. Newton, E. M. Oleson, G. Schorr, and R. E. Shadwick. (2008). Foraging behavior of humpback whales: kinematic and respiratory patterns suggest a high cost for a lunge. *Journal of Experimental Biology,* 211(23), 3712-3719.

Harzen, S. E. (2002). Use of an electronic theodolite in the study of movements of the bottlenose dolphin (*Tursiops truncatus*) in the Sado Estuary, Portugal. *Aquatic Mammals,* 28(3), 251-260.

Heide-Jørgensen, M. P., D. Bloch, E. Stefansson, B. Mikkelsen, L. H. Ofstad, and R. Dietz. (2002). Diving behaviour of long-finned pilot whales *Globicephala melas* around the Faroe Islands. *Wildlife Biology,* 8(4), 307-313.

Heide-Jørgensen, M. P., K. L. Laidre, D. Litovka, M. Villum Jensen, J. M. Grebmeier, and B. I. Sirenko. (2012). Identifying gray whale (Eschrichtius robustus) foraging grounds along the Chukotka Peninsula, Russia, using satellite telemetry. Polar Biology, 35(7), 1035-1045. doi:10.1007/s00300-011-1151-6

Heide-Jørgensen, M. P., K. L. Laidre, N. H. Nielsen, R. G. Hansen, and A. Røstad. (2013). Winter and spring diving behavior of bowhead whales relative to prey. *Animal Biotelemetry,* 1, 15.

Heide-Jørgensen, M. P., K. L. Laidre, Ø. Wiig, M. V. Jensen, L. Dueck, L. Maiers, H. Schmidt, and R. Hobbs. (2003). From Greenland to Canada in Ten Days: Tracks of Bowhead Whales, *Balaena mysticetus*, across Baffin Bay. *Arctic,* 56(1), 21-31.

Hobson, R. P., & A. R. Martin. (1996). Behaviour and dive times of Arnoux's beaked whales, *Berardius arnuxii*, at narrow leads in fast ice. *Canadian Journal of Zoology,* 74(2), 388-393.

Hooker, S. K., & R. W. Baird. (1999a). Deep-diving behaviour of the northern bottlenose whale, *Hyperoodon ampullatus* (Cetacea: Ziphiidae). *Proceedings of the Royal Society of Biological Sciences: Series B,* 266(1420), 671-676.

Hooker, S. K., & R. W. Baird. (1999b). Observations of Sowerby's beaked whales, *Mesoplodon bidens*, in the Gully, Nova Scotia. *Canadian Field-Naturalist,* 113(2), 273-277.

Jaquet, N., S. Dawson, and E. Slooten. (2000). Seasonal distribution and diving behaviour of male sperm whales off Kaikoura: Foraging implications. *Canadian Journal of Zoology,* 78(3), 407-419.

Jaquet, N., & D. Gendron. (2002). Distribution and relative abundance of sperm whales in relation to key environmental features, squid landings and the distribution of other cetacean species in the Gulf of California, Mexico. *Marine Biology,* 141(3), 591-601.

Jaquet, N., & H. Whitehead. (1999). Movements, distribution and feeding success of sperm whales in the Pacific Ocean, over scales of days and tens of kilometers. *Aquatic Mammals,* 25(1), 1-13.

Jochens, A., D. Biggs, K. Benoit-Bird, D. Engelhaupt, J. Gordon, C. Hu, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, and B. Würsig. (2008). Sperm whale seismic study in the Gulf of Mexico, Synthesis Report (OCS Study MMS 2008-006)

Johnson, M., P. T. Madsen, W. M. X. Zimmer, N. Aguilar de Soto, and P. L. Tyack. (2004). Beaked whales echolocate on prey. *Proceedings of the Royal Society of London Series B-Biological Sciences,* 271, S383-S386.

Joyce, G., N. Øien, J. Calmabokidis, and J. C. Cubbage. (1989). Surfacing rates of minke whales in Norwegian waters. *Report of the International Whaling Commision,* 39, 431-434.

Kastelein, R. A., & N. M. Gerrits. (1991). Swimming, diving, and respiration patterns of a Northern bottlenose whale (*Hyperoodon ampullatus*, Forster, 1770). *Aquatic Mammals,* 17(1), 20-30.

Kennedy, A. S., A. N. Zerbini, O. V. Vásquez, N. Gandilhon, P. J. Clapham, and O. Adam. (2014). Local and migratory movements of humpback whales (Megaptera novaeangliae) satellite-tracked in the North Atlantic Ocean. *Canadian Journal of Zoology,* 92(1), 9-18. doi:10.1139/cjz-2013-0161

Kenney, R. D., & H. E. Winn. (1986). Cetacean high-use habitats of the northeast United States continental shelf. *Fishery Bulletin,* 84(2), 345- 357.

Kiraç, C. O., Y. Savas, H. Güçlüsoy, and N. O. Veryeri. (2002). Observations on diving behaviour of free ranging Mediterranean monk seals Monachus monachus on Turkish coasts. *Monachus Guardian* 5(1):1-8.*,* 5(1), 1-8.

Klatsky, L. J., R. S. Wells, and J. C. Sweeney. (2007). Offshore bottlenose dolphins (*Tursiops truncatus*): movement and dive behavior near the Bermuda pedestal. *Journal of Mammalogy,* 88(1), 59-66.

Kooyman, G. L., & H. T. Andersen. (1969). Deep diving. In H. T. Andersen (Ed.), *Biology of marine mammals* (pp. 65-94): Academic Press.

Kooyman, G. L., & F. Trillmich. (1986). Diving behavior of Galapagos fur seals. In R. L. Gentry and G. L. Kooyman (Eds.), *Fur Seals: Maternal Strategies on Land and at Sea* (pp. 186-195). Princeton, NJ: Princeton University Press.

Kopelman, A. H., & S. S. Sadove. (1995). Ventilatory rate differences between surface-feeding and non-surface-feeding fin whales (*Balaenoptera physalus*) in the waters off eastern Long Island, New York, U.S.A., 1981-1987. *Marine Mammal Science,* 11(2), 200-208.

Kovacs, K. M., C. Lydersen, M. O. Hammill, and D. M. Lavigne. (1996). Reproductive effort of male hooded seals (*Cystophora cristata*): estimates from mass loss. *Canadian Journal of Zoology,* 74, 1521-1530.

Krafft, B. A., C. Lydersen, K. M. Kovacs, I. Gjertz, and T. Haug. (2000). Diving behaviour of lactating bearded seals (*Erignathus barbatus*) in the Svalbard area. *Canadian Journal of Zoology,* 778(8), 1408-1418.

Krutzikowsky, G. K., & B. R. Mate. (2000). Dive and surfacing characteristics of bowhead whales (*Balaena mysticetus*) in the Beaufort and Chukchi seas. *Canadian Journal of Zoology,* 78(7), 1182-1198.

Kryter, K. D. (1985). *The effects of noise on man*, 2nd edition. Orlando, FL: Academy Press. 688 pages.

Lagerquist, B. A., K. M. Stafford, and B. R. Mate. (2000). Dive characteristics of satellite-monitored blue whales (*Balaenoptera musculus*) off the central California coast. *Marine Mammal Science,* 16(2), 375-391.

Laurie, A. H. (1933). Some aspects of respiration in fin and blue whales. *Discovery Reports,* 7, 365-406.

Leibier, G. A. (1978). The acoustic propagation model RAYMODE: Theory and numerical treatment. U.S. Naval Underwater Systems Center (NUSC), New London, CT.

Lesage, V., M. O. Hammill, and K. M. Kovacs. (1999). Functional classification of harbor seal (*Phoca vitulina*) dives using depth profiles, swimming velocity, and an index of foraging success. *Canadian Journal of Zoology,* 77(1), 74-87.

Ligon, A. D., and R. W. Baird. (2001). *Diving behaviour of false killer whales off Maui and Lana'i, Hawai'i.* Paper presented at the 14th Biennial Conference on the Biology of Marine Mammals, Vancouver.

Linnenschmidt, M., J. Teilmann, T. Akamatsu, R. Dietz, and L. A. Miller. (2013). Biosonar, dive, and foraging activity of satellite tracked harbor porpoises (*Phocoena phocoena*). *Marine Mammal Science,* 29(2), E77-E97. doi:10.1111/j.1748-7692.2012.00592.x

Lockyer, C. (1976). Body Weights of Some Species of Large Whales. J. Cons. int. Explor. Mer*.,* 36(3), 259-273.

Lockyer, C. (1997). Diving behaviour of the sperm whale in relation to feeding. Bulletin de l'Institut Royal des Sciences Naturelles de Belgique Biologie*,* 67(SUPPL), 47-52.

Lockyer, C., & R. Morris. (1987). Observations on diving behavior and swimming speeds in a wild juvenile *Tursiops truncatus*. Aquatic Mammals*,* 13(1), 31-35.

Lockyer, C., & R. J. Morris. (1986). The history and behavior of a wild, sociable bottlenose dolphin (*Tursiops truncatus*) off the north coast of Cornwall (England, UK). *Aquatic Mammals,* 12(1), 3-16.

Loughlin, T. R. (1982). Observations of *Mesoplodon stejnegeri* in the central Aleutian Islands, Alaska. *Journal of Mammalogy,* 63(3), 697-700.

Lowry, L. F., V. N. Burkanov, K. J. Frost, M. A. Simpkins, R. Davis, D. P. DeMaster, R. Suydam, and A. Springer. (2000). Habitat use and habitat selection by spotted seals (*Phoca largha*) in the Bering Sea. *Canadian Journal of Zoology,* 78(11), 1959-1971.

Lowry, L. F., K. J. Frost, R. Davis, D. P. DeMaster, and R. S. Suydam. (1998). Movements and behavior of satellite-tagged spotted seals (*Phoca largha*) in the Bering and Chukchi Seas. *Polar Biology,* 19(4), 221-230.

Lydersen, C. (1991). Monitoring ringed seal (*Phoca hispida*) activity by means of acoustic telemetry. *Canadian Journal of Zoology,* 69(5), 1178-1182.

Lydersen, C., M. O. Hammill, and K. M. Kovacs. (1994). Diving activity in nursing bearded seal (*Erignathus barbatus*) pups. *Canadian Journal of Zoology,* 72, 96-103.

Lydersen, C., & K. M. Kovacs. (1993). Diving behaviour of lactating harp seal, *Phoca groenlandica*, females from the Gulf of St. Lawrence, Canada. *Animal Behavior,* 46, 1213-1221.

MacLeod, C. D., and A. F. Zuur. (2005). Habitat utilization by Blainville's beaked whales off Great Abaco, northern Bahamas, in relation to seabed topography. *Marine Biology,* 147(1), 1-11.

Mate, B. R., R. Gisiner, and J. Mobley. (1998). Local and migratory movements of Hawaiian humpback whales tracked by satellite telemetry. *Canadian Journal of Zoology,* 76, 863-868.

Mate, B. R., & J. T. Harvey. (1984). Ocean Movements of Radio-Tagged Gray Whales *The Gray Whale* (pp. 577-589). London: Academic Press.

Mate, B. R., G. K. Krutzikowsky, and M. H. Winsor. (2000). Satellite-monitored movements of radio-tagged bowhead whales in the Beaufort and Chukchi seas during the late-summer feeding season and fall migration. *Canadian Journal of Zoology,* 78(7), 1168-1181.

Mate, B. R., B. A. Lagerquist, and J. Calambokidis. (1999). Movements of North Pacific blue whales during the feeding season off southern California and their southern fall migration. *Marine Mammal Science,* 15(4), 1246-1257.

Mate, B. R., B. A. Lagerquist, M. Winsor, J. Geraci, and J. H. Prescott. (2005). Movements and dive habits of a satellite-monitored longfinned pilot whale (*Globicephala melas*) in the northwest Atlantic. Marine Mammal Science*,* 21(1), 136-144.

Mate, B. R., K. A. Rossbach, S. L. Nieukirk, R. S. Wells, A. B. Irvine, M. D. Scott, and A. J. Read. (1995). Satellite-monitored movements and dive behaviour of a bottlenose dolphin (*Tursiops truncatus*) in Tampa Bay, Florida. *Marine Mammal Science,* 11(4), 452-463.

May-Collado, L., T. Gerrodette, J. Calambokidis, K. Rasmussen, and I. Sereg. (2005). Patterns of cetacean sighting distribution in the Pacific Exclusive Economic Zone of Costa Rica based on data collected from 1979-2001. *Revista De Biologia Tropical,* 53(1-2), 249-263.

Miller, P. J. O., M. P. Johnson, P. L. Tyack, and E. A. Terray. (2004). Swimming gaits, passive drag and buoyancy of diving sperm whales Physeter macrocephalus. *Journal of Experimental Biology,* 207(11), 1953-1967.

Miller, P. J. O., P. H. Kvadsheim, F. P. Lam, P. J. Wensveen, R. Antunes, A. C. Alves, F. Visser, L. Kleivane, P. L. Tyack, and L. D. Sivle. (2012). The severity of behavioral changes observed during experimental exposures of killer (*Orcinus orca*), long-finned pilot (*Globicephala melas*), and sperm (*Physeter macrocephalus*) whales to naval sonar. *Aquatic Mammals,* 38(4), 362-401. doi:10.1578/am.38.4.2012.362

Minamikawa, S., H. Watanabe, & T. Iwasaki. (2013). Diving behavior of a false killer whale, *Pseudorca crassidens*, in the Kuroshio-Oyashio transition region and the Kuroshio front region of the western North Pacific. *Marine Mammal Science, 29*(1), 177-185. doi:10.1111/j.1748-7692.2011.00532.x.

Mobley, J. R., Jr, & L. M. Herman. (1985). Transience of social affiliations among humpback whales (*Megaptera novaeangliae*) on the Hawaiian wintering grounds. *Canadian Journal of Zoology, 63*, 762-772.

Mooney, T. A., Tyack, P., Baird, R. W., and Nachtigall, P. E. (2012*). Acoustic behavior, baseline ecology and habitat use of pelagic odontocete species of concern.* Annual progress report to the Office of Naval Research, FY 2013. Award Number: N000141110612. Arlington, VA: Office of Naval Research. Retrieved from http://www.onr.navy.mil/reports/FY13/mbmoone1.pdf.

Morris, C., & U. Tscherter. (2006). *Site fidelity of individual minke whales (Balaenoptera acutorostrata) in the St. Lawrence estuary.* Paper presented at the ECS 2006, Gydnia, Poland.

Mullin, K. D., W. Hoggard, and L. J. Hansen. (2004). Abundance and seasonal occurence of cetaceans in outer continental shelf and slope waters of the North-central and Northwestern Gulf of Mexico. *Gulf of Mexico Science, 1*, 62-73.

National Oceanic and Atmospheric Administration (NOAA). (2016). *Guidance for assessing the effect of anthropogenic sound on marine mammal hearing: Underwater acoustic threshold levels for onset of permanent and temporary threshold shifts*. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Nawojchik, R., D. J. St Aubin, and A. Johnson. (2003). Movements and dive behavior of two stranded, rehabilitated long-finned pilot whales (*Globicephala melas*) in the northwest Atlantic. *Marine Mammal Science, 19*(1), 232-239.

Nerini, M. (1984). A review of gray whale feeding ecology. In M. Jones, Swartz, S., and Leatherwood, S. (Ed.), *The gray qhale* (pp. 423-448). Orlando, FL: Academic Press, Inc.

Neves, H. C. (1998). Preliminary findings on the feeding behaviour and general ecology strategy of the Mediterranean monk seal *Monachus monachus* (Pinnipedia: Monachinae) on the Desertas islands. *Boletim do Museu Municipal do Funchal, 5*(SUPPL. 5 PART A), 263-271.

Newhall, A. E., Y. T. Lin, J. F. Lynch, M. F. Baumgartner, and G. G. Gawarkiewicz. (2012). Long distance passive localization of vocalizing sei whales using an acoustic normal mode approach. *Journal of the Acoustical Society of America,* 131(2), 1814-1825. doi:10.1121/1.3666015.

NGDC (National Geophysical Data Center). (2006). 2-minute gridded global relief data (ETOPO2v2). National Oceanic and Atmospheric Administration. Retrieved from <http://www.ngdc.noaa.gov/mgg/fliers/06mgg01.html>.

Nordøy, E. S., L. P. Folkow, V. A. Potelov, V. Prischemikhin, and A. Schytte Blix. (2008). Seasonal distribution and dive behaviour of harp seals (*Pagophilus groenlandicus*) of the White Sea-Barents Sea stock. *Polar Biology, 31*(9), 1119-1135.

Norris, K. S., & J. H. Prescott. (1961). Observations on Pacific cetaceans of Californian and Mexican waters. *University of California Publications in Zoology, 63*, 291-402.

Øien, N., L. Folkow, and C. Lydersen. (1990). Dive Time Experiments On Minke Whales in Norwegian Waters During the 1988 Season. *RIWC, 40*, 337-341.

Olsen, E., W. P. Budgell, E. Head, L. Kleivane, L. Nottestad, R. Prieto, M. A. Silva, H. Skov, G. A. Vikingsson, G. Waring, and N. Oien. (2009). First Satellite-Tracked Long-Distance Movement of a Sei Whale (*Balaenoptera borealis*) in the North Atlantic. *Aquatic Mammals,* 35(3), 313-318.

Olsen, E., & J. C. Holst. (2001). A note on common minke whale (*Balaenoptera acutorostrata*) diets in the Norwegian Sea and the North Sea. *Journal of Cetacean Research and Management, 3*(2), 179-183.

Otani, S. (2000). Diving behavior and swimming speed of a free-ranging harbor porpoise, *Phocoena phocoena*. *Marine Mammal Science, 16*(4), 811-814.

Palka, D., & M. Johnson. (2007). Cooperative research to study dive patterns of sperm whales in the Atlantic Ocean (OCS Study MMS 2007-033). New Orleans, LA: Minerals Management Service.

Panigada, S., G. Nortarbartolo di Sciara, M. Panigada, S. Airoldi, J. Borsani, and M. Jahoda. (2005). Fin whales (*Balaenoptera physalus*) summering in the Ligurian Sea: distribution, encounter rate, mean group size and relation to physiographic variables. *Journal of Cetacean Research and Management, 7*(2), 137-145.

Panigada, S., M. Zanardelli, S. Canese, and M. Jahoda. (1999). How Deep Can Baleen Whales Dive? *Marine Ecology Progress Series, 187*, 309-311.

Papastavrou, V., S. C. Smith, and H. Whitehead. (1989). Diving behavior of the sperm whale *Physeter macrocephalus* off the Galapagos Islands, Ecuador. C*anadian Journal of Zoology, 67*(4), 839-846.

Parrish, F. A., M. P. Craig, T. J. Ragen, G. J. Marshall, and B. M. Buhleier. (2000). Identifying diurnal foraging habitat of endangered Hawaiian monk seals using a seal-mounted video camera. *Marine Mammal Science, 16*(2), 392-412.

Perryman, W. L., M. A. Donahue, J. L. Laake, and T. E. Martin. (1999). Diel variation in migration rates of eastern Pacific gray whales measured with thermal imaging sensors. *Marine Mammal Science, 15*(2), 426-445.

Ramirez, N., D. Schulte, and J. Kennedy. (2006). *Finback whale (Balaenoptera physalus) behavior on Jeffreys Ledge in the Gulf Of Maine.* Paper presented at the ECS 2006, Gydnia, Poland.

Rasmussen, M. H., Akamatsu, T., Teilmann, J., Vikingsson, G., and Miller, L. A. (2013). Biosonar, diving and movements of two tagged white-beaked dolphin in Icelandic waters. *Deep Sea Research II, 88-89*, 97-105. doi.org/10.1016/j.dsr2.2012.07.011.

Reeves, R. R., & E. Mitchell. (1993). Status of Baird beaked whale, *Berardius bairdii*. *Canadian Field Naturalist, 107*(4), 509-523.

Reeves, R. R., B. S. Stewart, J. Clapham Phillip, and J. A. Powell. (2002). *Guide to marine mammals of the world*. New York: Knopf.

Reilly, S. B., & V. G. Thayer. (1990). Blue whale *Balaenoptera musculus* distribution in the Eastern Tropical Pacific. *Marine Mammal Science, 6*(4), 265-277.

Renner, W. W., & C. W. Spofford. (1985). *Consolidated BLUG Classe*s. SAIC-85/1591.

Rice, D. W., & A. A. Wolman. (1971). The life history and ecology of the gray whale (*Eschrichtius robustus*). *American Society of Mammalogy Special Publications, 3.*

Richardson, J. W., K. J. Finley, G. W. Miller, R. A. Davis, and W. R. Koski. (1995). Feeding, social, and migration behavior of bowhead whales, *Balaena mysticetus*, in Baffin Bay vs. Beaufort Sea--regions with different amounts of human activity. *Marine Mammal Science, 11(*1), 1-45.

Ridoux, V., C. Guinet, C. Liret, P. Creton, R. Steenstrup, and G. Beauplet. (1997). A video sonar as a new tool to study marine mammals in the wild: measurements of dolphin swimming speed. *Marine Mammal Science, 13*(2), 196-206.

Ritter, F., & B. Brederlau. (1999). Behavioural observations of dense beaked whales (*Mesoplodon densirostris*) off La Gomera, Canary Islands (1995-1997). *Aquatic Mammals, 25*(2), 55-61.

Rohr, J. J., F. E. Fish, and J. W. Gilpatrick. (2002). Maximum swim speeds of captive and free-ranging delphinids: Critical analysis of extraordinary performance. *Marine Mammal Science, 18*(1), 1-19.

Rugh, D. J. (1984). Census of gray whales at Unimak Pass, Alaska: November-December 1977-1979. In M. L. Jones, S. L. Swartz, and S. Leatherwood (Eds.), *The gray whale, Eschrichtius robustus* (pp. 225-248): Academic Press.

Schilling, M. R., I. Seipt, M. T. Weinrich, A. E. Kuhlberg, and P. J. Clapham. (1992). Behavior of individually-identified sei whales *Balaenoptera borealis* during an episodic influx into the southern gulf of maine in 1986. *Fishery Bulletin, 9*0(4), 749-755.

Schorr, G. S., E. A. Falcone, D. J. Moretti, and R. D. Andrews. (2014). First Long-Term Behavioral Records from Cuvier's Beaked Whales (*Ziphius cavirostris*) Reveal Record- Breaking Dives. *PLoS One, 9*(3), 1-10. doi:10.1371/journal.pone.0092633.g001

Schreer, J. F., K. M. Kovacs, & R. J. O'Hara Hines. (2001). Comparative diving patterns of pinnipeds and seabirds. *Ecological Monographs, 71*(1), 137-162.

Scott, T. M., & S. S. Sadove. (1997). Sperm Whale, *Physeter macrocephalus*, sightings in the shallow shelf waters off Long Island, New York. *Marine Mammal Science, 13*(2), 317-320.

Shane, S. H. (1995). Behavior patterns of pilot whales and Risso's dolphins off Santa Catalina Island, California. *Aquatic Mammals, 21*(3), 195-197.

Silber, G. K., M. W. Newcomer, & H. M. Pérez-Cortés. (1990). Killer Whales (*Ornicus orca*) attack and kill a Bryde's whale (*Balaenoptera edeni*). *Canadian Journal of Zoology, 68,* 1603-1606.

Silber, G. K., M. W. Newcomer, P. C. Silber, H. Pérez-Cortés M, & G. M. Ellis. (1994). Cetaceans of the northern Gulf of California: distribution, occurrence, and relative abundance. *Marine Mammal Science, 10*(3), 283-298.

Simpkins, M. A., L. M. Hiruki-Raring, G. Sheffield, J. M. Grebmeier, & J. L. Bengtson. (2003). Habitat selection by ice-associated pinnipeds near St. Lawrence Island, Alaska in March 2001. *Polar Biology, 26*, 577-586.

Simpkins, M. A., B. P. Kelly, & D. Wartzok. (2001). Three-dimensional diving behaviors of ringed seals (*Phoca hispida*). *Marine Mammal Science, 17*(4), 909-925.

Soule, D. C., & W. S. Wilcock. (2013). Fin whale tracks recorded by a seismic network on the Juan de Fuca Ridge, Northeast Pacific Ocean. *Journal of the Acoustical Society of America, 133*(3), 1751-1761. doi:10.1121/1.4774275

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene, Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, and P. L. Tyack. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals*, 33(4), 411-522.

Stern, S. J. (1992). Surfacing rates and surfacing patterns of minke whales (*Balaenoptera acutorostrata*) off central California, and the probability of a whale surfacing within visual range. *Report of the International Whaling Commission, 42,* 379-385.

Stockin, K. A., R. S. Fairbairns, E. C. M. Parsons, & D. W. Sims. (2001). Effects of diel and seasonal cycles on the dive duration of the minke whale (*Balaenoptera acutorostrata*). *Journal of the Marine Biological Association of the United Kingdom, 8*1(1), 189-190.

Stone, G. S., S. K. Katona, M. Mainwaring, J. M. Allen, & H. D. Corbett. (1992). Respiration and surfacing rates of fin whales (*Balaenoptera physalus*) observed from a lighthouse tower. *International Whaling Commission, 42*, 739-745.

Teilmann, J., E. W. Born, & M. Acquarone. (1999). Behaviour of ringed seals tagged with satellite transmitters in the North Water polynya during fast-ice formation. *Canadian Journal of Zoology, 77*, 1934-1946.

Teloni, V., J. P. Mark, M. J. O. Patrick, & M. T. Peter. (2008). Shallow food for deep divers: Dynamic foraging behavior of male sperm whales in a high latitude habitat. J*ournal of Experimental Marine Biology and Ecology, 354*(1), 119-131.

Trillmich, F. (1986). Attendance behavior of Galapagos fur seals. In R. L. Gentry and G. L. Kooyman (Eds.), *Fur Seals: Maternal strategies on land and at sea* (pp. 168-185). Princeton, NJ: Princeton University Press.

Urick, R. J. (1983). *Principles of underwater sound* (3rd ed.). New York: McGraw-Hill Book Company.

Van Parijs, S. M., C. Lydersen, & K. M. Kovacs. (2003). Vocalizations and movements suggest alternative mating tactics in male bearded seals. *Animal Behaviour, 65*(2), 273-283.

Villegas-Amtmann, S., J. W. Jeglinski, D. P. Costa, P. W. Robinson, & F. Trillmich. (2013). Individual Foraging Strategies Reveal Niche Overlap between Endangered Galapagos Pinnipeds. *PLoS ONE, 8(*8), e70748. doi:10.1371/journal.pone.0070748

Wahlberg, M. (2002). The acoustic behaviour of diving sperm whales observed with a hydrophone array. Journal of Experimental *Marine Biology and Ecology, 28*1(1-2), 53-62.

Walker, W. A., J. G. Mead, & R. L. Brownell, Jr. (2002). Diets of Baird's beaked whales, *Berardius bairdii*, in the southern sea of Okhotsk and off the Pacific coast of Honshu, Japan. *Marine Mammal Science, 18*(4), 902-919.

Ward, W. D. (ed.). (1968). Proposed damage-risk criterion for impulsed noise (gunfire). Committee on Hearing, Bioacoustics and Biomechanics. National Research Council, National Academy of Sciences, Washington, D.C.

Watkins, W. A. (1981). Activities and Underwater Sounds of Fin Whales. *The Scientific Reports of the Whales Research Institute, 33*, 83-117.

Watkins, W. A., M. A. Daher, N. A. DiMarzio, A. Samuels, D. Wartzok, K. M. Fristrup, D. P. Gannon, P. W. Howey, R. R. Maiefski, and T. R. Spradlin. (1999). Sperm whale surface activity from tracking by radio and satellite tags. *Marine Mammal Science, 15*(4), 1158-1180.

Watkins, W. A., M. A. Daher, N. A. DiMarzio, A. Samuels, D. Wartzok, K. M. Fristrup, P. W. Howey, & R. R. Maiefski. (2002). Sperm whale dives tracked by radio tag telemetry. *Marine Mammal Science, 18*(1), 55-68.

Weir, C. R. (2000). Sightings of beaked whales species (Cetacea: Ziphiidae) in the waters to the north and west of Scotland and the Faroe Islands. *European Research on Cetaceans, 14*, 239-243.

Weller, D. W., S. H. Reeve, A. M. Burdin, B. Würsig, & R. L. Brownell, Jr. (2002). A note on the spatial distribution of western gray whales (*Eschrichtius robustus*) off Sakhalin Island, Russia in 1998. *Journal of Cetacean Research and Management, 4*(1), 13-17.

Wells, R. S., H. L. Rhinehart, P. Cunningham, J. Whaley, M. Baran, C. Koberna, & C. D. P. (1999). Long distance offshore movements of bottlenose dolphins. *Marine Mammal Science, 15*(4), 1098-1114.

Werth, A. J. (2004). Models of hydrodynamic flow in the bowhead whale filter feeding apparatus. *Journal of Experimental Biology, 207*(20), 3569-3580. f

Westgate, A. J., A. J. Read, P. Berggren, H. N. Koopman, & D. E. Gaskin. (1995). Diving behaviour of harbour porpoises, *Phocoena phocoena*. *Canadian Journal of Fisheries and Aquatic Sciences, 52(*5), 1064-1073.

Whitehead, H., S. Brennan, & D. Grover. (1992). Distribution and Behavior of Male Sperm Whales on the Scotian Shelf, Canada. *Canadian Journal of Zoology, 70*(5), 912-918.

Whitehead, H., S. C. Smith, & V. Papastavrou. (1989). Diving behavior of the sperm whales, (*Physeter macrocephalus*), off the Galapagos Islands. *Canadian Journal of Zoology,* 67(4), 839-846.

Williams, T. M., R. W. Davis, L. A. Fuiman, J. Francis, B. B. J. Le, M. Horning, J. Calambokidis, & D. A. Croll. (2000). Sink or swim: Strategies for cost-efficient diving by marine mammals. *Science Washington D C, 288*(5463), 133-136.

Wimmer, T., & H. Whitehead. (2004). Movements and distribution of northern bottlenose whales, *Hyperoodon ampullatus*, on the Scotian Slope and in adjacent waters. *Canadian Journal of Zoology, 82*(11), 1782-1794.

Witteveen, B. H., R. J. Foy, K. M. Wynne, & Y. Tremblay. (2008). Investigation of foraging habits and prey selection by humpback whales (*Megaptera novaeangliae*) using acoustic tags and concurrent fish surveys. *Marine Mammal Science, 24*(3), 516-534.

Woodley, T. H., &D. E. Gaskin. (1996). Environmental characteristics of North Atlantic right and fin whale habitat in the lower Bay of Fundy, Canada. *Canadian Journal of Zoology, 74*(1), 75-84.

Würsig, B., R. Wells, & D. Croll. (1986). Behavior of gray whales summering near St. Lawrence Island, Bering Sea. *Canadian Journal of Zoology, 64*(3), 611-621.

Würsig, B., and M. Würsig. (1979). Behavior and Ecology of the bottlenose dolphin, (*Tursiops truncatus*) in the South Atlantic. *Fishery Bulletin, 77*(2), 399-412.

Wyrick, R. (1954). Observations on the movements of the Pacific gray whale *Eschrichtius glaucus*. *Journal of Mammalogy, 35*(4).

Zeh, J. E., C. W. Clark, J. C. George, D. Withrow, G. M. Carroll, & W. R. Koski. (1993). Current Population Size and Dynamics. In J. J. Burns, J. J. Montague, and C. J. Cowles (Eds.), *The bowhead whale* (pp. 409-489). Lawrence, KS: The Society for Marine Mammalogy.

APPENDIX C: MARINE MAMMAL OFFSHORE BIOLOGICALLY IMPORTANT AREAS (OBIAS) FOR SURTASS LFA SONAR

As part of the analysis conducted during the preparation of this SEIS/SOEIS for SURTASS LFA sonar, more than 100 global marine areas were reviewed and considered as OBIAs. Included in this appendix is a listing of those areas considered as marine mammal OBIAs for SURTASS LFA sonar (Table C-1). Information on the selection criteria for OBIAs for SURTASS LFA sonar may be found in Chapter 3 (Section 3.3.5.5) of this SEIS/SOEIS while information on the analysis and designation process resulting in the 11 potential OBIAs designated or expanded for this SEIS/SOEIS may be found in Chapter 4.

Eleven marine areas met the OBIA selection criteria as well as Navy operational practicability review and are being presented as potential OBIAs for SURTASS LFA sonar. However, five of these areas are expansions of existing OBIAs, while six of the areas are new OBIAs. In total, with the six new OBIAs and expansions of five existing OBIAs, 28 OBIAs have now been designated as marine mammal OBIAs for SURTASS LFA sonar. These OBIAs pertain only to the operation of SURTASS LFA sonar and are intended for no other purpose.

Descriptions of each potential OBIA, with a list of the supporting scientific data and information on the area's biological significance to the relevant LF sensitive hearing species, are included in this appendix along with map figures showing each area and its proximity to the 12-nmi (22-km) limit.

Table C-1. Marine Areas Assessed as Candidate OBIAs for SURTASS LFA Sonar for this SEIS/SOEIS.

Name of Area	*Source for Area as Potential OBIA*
South Georgia and the South Sandwich Islands MPA	Cetaceanhabitat.org
Network of marine protected areas and no-take marine reserves proposed by Antarctic Ocean Alliance	Cetaceanhabitat.org
Southeast Kamchatka Ecologically or Biologically Significant Area	Cetaceanhabitat.org
Alaska Peninsula National Wildlife Refuge	Cetaceanhabitat.org
Walrus Islands State Game Sanctuary	Cetaceanhabitat.org
Qaqulluit National Wildlife Reserve	Cetaceanhabitat.org
Nearshore Bristol Bay Trawl Closure	Cetaceanhabitat.org
Pribilof Island Area Habitat Conservation Zone	Cetaceanhabitat.org
Saros Körfezi Special Environmental Protection Area	Cetaceanhabitat.org
Assateague Island National Seashore	Cetaceanhabitat.org
Fisherman Island National Wildlife Refuge	Cetaceanhabitat.org
Skerries and Causeway SAC	Cetaceanhabitat.org
Rathlin Island SAC	Cetaceanhabitat.org
Josephine Seamount OSPAR Marine Protected Area	Cetaceanhabitat.org
Milne Seamount OSPAR Marine Protected Area	Cetaceanhabitat.org
Mid-Atlantic Ridge North of the Azores OSPAR Marine Protected Area	Cetaceanhabitat.org
Tyrella & Minerstown ASSI	Cetaceanhabitat.org
Lundy Marine Conservation Zone	Cetaceanhabitat.org
Strangford Lough Marine Conservation Zone	Cetaceanhabitat.org
Pembrokeshire Marine SAC	Cetaceanhabitat.org
Berwickshire and North Northumberland Coast SAC	Cetaceanhabitat.org
The Wash and North Norfolk Coast SAC	Cetaceanhabitat.org
Galway Bay Complex SAC	Cetaceanhabitat.org
Ballysadare Bay SAC	Cetaceanhabitat.org
Rutland Island and Sound SAC	Cetaceanhabitat.org
Everglades National Park	Cetaceanhabitat.org
Biscayne National Park	Cetaceanhabitat.org
Gulf Islands National Seashore	Cetaceanhabitat.org
Canaveral National Seashore	Cetaceanhabitat.org
Caloosahatchee National Wildlife Refuge	Cetaceanhabitat.org
Merritt Island National Wildlife Refuge	Cetaceanhabitat.org
Banco Volcan MPA	Cetaceanhabitat.org
Ascension Island Marine Reserve	Cetaceanhabitat.org
Uruguay Whale and Dolphin Sanctuary	Cetaceanhabitat.org
Makenke Coastal Marine Park	Cetaceanhabitat.org
Maldives Marine Reserve	Cetaceanhabitat.org
Swatch of No Ground Marine Protected Area	Cetaceanhabitat.org

Table C-1. Marine Areas Assessed as Candidate OBIAs for SURTASS LFA Sonar for this SEIS/SOEIS.

Name of Area	*Source for Area as Potential OBIA*
Soariake Marine Park	Cetaceanhabitat.org
Ankivonjy and Ankarea Marine Parks	Cetaceanhabitat.org
East Buleleng MPA (Tejakula)	Cetaceanhabitat.org
Badung MPA	Cetaceanhabitat.org
Central Buleleng MPA (Lovina)	Cetaceanhabitat.org
Raja Ampat Shark and Manta Ray Sanctuary	Cetaceanhabitat.org
Cook Islands Marine Park	Cetaceanhabitat.org
Natural Park of the Coral Sea	Cetaceanhabitat.org
Pitcairn Islands Marine Reserve	Cetaceanhabitat.org
Austral Islands Marine Protected Area	Cetaceanhabitat.org
East Buleleng MPA (Tejakula)	Cetaceanhabitat.org
Badung MPA	Cetaceanhabitat.org
Central Buleleng MPA (Lovina)	Cetaceanhabitat.org
Raja Ampat Shark and Manta Ray Sanctuary	Cetaceanhabitat.org
Cook Islands Marine Park	Cetaceanhabitat.org
Natural Park of the Coral Sea	Cetaceanhabitat.org
Pitcairn Islands Marine Reserve	Cetaceanhabitat.org
Austral Islands Marine Protected Area	Cetaceanhabitat.org
Nazca-Desventuradas Marine Park	Cetaceanhabitat.org
Easter Island Marine Park	Cetaceanhabitat.org
Palau National Marine Sanctuary	Cetaceanhabitat.org
Los Cóbanos Reef National Protected Area	Cetaceanhabitat.org
Seamounts Marine Management Area (Las Gemelas)	Cetaceanhabitat.org
Cordillera de Coiba MPA	Cetaceanhabitat.org
South-East Commonwealth Marine Reserves Network	Cetaceanhabitat.org
North Commonwealth Marine Reserves Network	Cetaceanhabitat.org
Temperate East Commonwealth Marine Reserves Network	Cetaceanhabitat.org
South-West Commonwealth Marine Reserves Network	Cetaceanhabitat.org
North-West Commonwealth Marine Reserves Network	Cetaceanhabitat.org
Southern Kangaroo Island Commonwealth Marine Reserve	Cetaceanhabitat.org
Western Kangaroo Island Commonwealth Marine Reserve	Cetaceanhabitat.org
Western Eyre Commonwealth Marine Reserve	Cetaceanhabitat.org
Great Australian Bight Commonwealth Marine Reserve	Cetaceanhabitat.org
Twilight Commonwealth Marine Reserve	Cetaceanhabitat.org
Eastern Recherche Commonwealth Marine Reserve	Cetaceanhabitat.org
Bremer Commonwealth Marine Reserve	Cetaceanhabitat.org
South-west Corner Commonwealth Marine Reserve	Cetaceanhabitat.org
Geographe Commonwealth Marine Reserve	Cetaceanhabitat.org
Perth Canyon Commonwealth Marine Reserve	Cetaceanhabitat.org

Table C-1. Marine Areas Assessed as Candidate OBIAs for SURTASS LFA Sonar for this SEIS/SOEIS.

Name of Area	***Source for Area as Potential OBIA***
Two Rocks Commonwealth Marine Reserve	Cetaceanhabitat.org
Jurien Commonwealth Marine Reserve	Cetaceanhabitat.org
Abrolhos Commonwealth Marine Reserve	Cetaceanhabitat.org
Shark Bay Commonwealth Marine Reserve	Cetaceanhabitat.org
Gascoyne Commonwealth Marine Reserve	Cetaceanhabitat.org
Montebello Commonwealth Marine Reserve	Cetaceanhabitat.org
Dampier Commonwealth Marine Reserve	Cetaceanhabitat.org
Eighty Mile Beach Commonwealth Marine Reserve	Cetaceanhabitat.org
Roebuck Commonwealth Marine Reserve	Cetaceanhabitat.org
Argo-Rowley Terrace Commonwealth Marine Reserve	Cetaceanhabitat.org
Kimberley Commonwealth Marine Reserve	Cetaceanhabitat.org
Ningaloo Commonwealth Marine	Cetaceanhabitat.org
Joseph Bonaparte Gulf Commonwealth Marine Reserve	Cetaceanhabitat.org
Arnhem Commonwealth Marine Reserve	Cetaceanhabitat.org
Limmen Commonwealth Marine Reserve	Cetaceanhabitat.org
Gifford Commonwealth Marine Reserve	Cetaceanhabitat.org
Norfolk Commonwealth Marine Reserve	Cetaceanhabitat.org
Lord Howe Commonwealth Marine	Cetaceanhabitat.org
Central Eastern Commonwealth Marine Reserve	Cetaceanhabitat.org
Solitary Islands Commonwealth Marine	Cetaceanhabitat.org
Cod Grounds Commonwealth Marine Reserve	Cetaceanhabitat.org
Hunter Commonwealth Marine Reserve	Cetaceanhabitat.org
Jervis Commonwealth Marine Reserve	Cetaceanhabitat.org
Camden Sound Marine Park	Cetaceanhabitat.org
Eighty Mile Beach Marine Park	Cetaceanhabitat.org
Roebuck Bay Marine Park	Cetaceanhabitat.org
Great Kimberley Marine Park	Cetaceanhabitat.org
Challenger Bank	SURTASS LFA Sonar OBIA Watchlist
Southeast Shoal	SURTASS LFA Sonar OBIA Watchlist
Hellenic Trench	SURTASS LFA Sonar OBIA Watchlist
Tanner/Cortez Banks	SURTASS LFA Sonar OBIA Watchlist

Table C-2. Potential Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar in this SEIS/SOEIS.

Potential OBIA Number	*Potential OBIA Name*	*Water Body/Location*	*Relevant Low Frequency Sensitive Marine Mammal Species*	*Effective Seasonal Period*	*Notes*
1	Grand Manan North Atlantic Right Whale Critical Habitat	Bay of Fundy, Canada	North Atlantic right whale	June through December, annually	
2	Great South Channel, Gulf of Maine, and Stellwagen Bank National Marine Sanctuary (OBIA 3) Expansion	Northeast U.S. Atlantic waters; off MA	North Atlantic right whale	January 1 to November 14, annually	Expansion of northeastern U.S. critical habitat for the North Atlantic right whale
3	Southeastern U.S. Critical Habitat for the North Atlantic Right Whale (OBIA 4) Expansion	Southeast U.S. Atlantic waters; off NC, SC, GA, and FL	North Atlantic right whale	January 15 to April 15, annually	Expansion of OBIA 4—Southeastern U.S. critical habitat for the North Atlantic right whale
4	Northeastern Gulf of Mexico	Northeastern Gulf of Mexico; off FL and AL	Bryde's whale	Year-round	
5	Central California	Southwest U.S. Pacific waters	Blue and Humpback whales	June through November, annually	Expansion of OBIA 10—Central California National Marine Sanctuaries
6	Southern Chile	Gulf of Corcovado, Southeast Pacific Ocean; southwestern Chile	Blue whale	February to April, annually	
7	Offshore Sri Lanka	North-central Indian Ocean	Blue whale	December through April, annually	
8	Great Barrier Reef	Coral Sea, Southwestern Pacific Ocean; northeastern Australia	Humpback whale	May through September, annually	Expansion of OBIA 18—Great Barrier Reef Between 16° and 21° S
9	Camden Sound/Kimberly Region	Southeastern Indian Ocean; northwestern Australia	Humpback whale	June through September, annually	
10	Perth Canyon	Southeastern Indian Ocean; southwestern Australia	Pygmy blue whale/Blue whale	January through May, annually	

Table C-2. Potential Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar in this SEIS/SOEIS.

Potential OBIA Number	*Potential OBIA Name*	*Water Body/Location*	*Relevant Low Frequency Sensitive Marine Mammal Species*	*Effective Seasonal Period*	*Notes*
11	Gulf of Alaska	Northwestern Gulf of Alaska; off Kodiak Island, AK	North Pacific right whale	March through August, annually	Expansion of OBIA 5—North Pacific Right Whale Critical Habitat

Table C-3. Comprehensive List of Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar

OBIA Number	*OBIA Name*	*Water Body/Location*	*Relevant Low-Frequency Marine Mammal Species*	*Effective Seasonal Period*	*OBIA Boundary Change*[1]	*Notes*
1	Georges Bank	Northwest Atlantic Ocean	North Atlantic right whale	Year-round	R	
2	Roseway Basin Right Whale Conservation Area	Northwest Atlantic Ocean	North Atlantic right whale	June through December, annually		
3	Great South Channel, U.S. Gulf of Maine, and Stellwagen Bank NMS	Northwest Atlantic Ocean/ Gulf of Maine	North Atlantic right whale	January 1 to November 14, annually	E-CH	OBIA 3 boundary revised to encompass expansion of northeastern U.S. critical habitat for the North Atlantic right whale (Potential OBIA 2)
4	Southeastern U.S. Right Whale Critical Habitat	Northwest Atlantic Ocean	North Atlantic right whale	November 15 to April 15, annually	E-CH	OBIA 4 boundary revised to encompass expansion of southeastern U.S. critical habitat for the North Atlantic right whale (Potential OBIA 3)
5	Gulf of Alaska[2]	Gulf of Alaska	North Pacific right whale	March through August, annually	E, R	OBIA 5 boundary revised to encompass additional foraging area for the North Pacific right whale (Potential OBIA 11)
6	Navidad Bank[3]	Caribbean Sea/Northwest	Humpback whale	December through April, annually	R	Silver Bank no longer encompassed within OBIA

1 E=OBIA boundary expanded per data justification; E-CH=OBIA boundary expanded to encompass designated critical habitat; R=OBIA landward boundary revised per higher resolution 12-nmi data.

2 OBIA name changed to indicate expansion of OBIA beyond extent of North Pacific right whale critical habitat.

3 OBIA name changed to indicate that Silver Bank is no longer encompassed within OBIA boundary but is instead encompassed in and afforded the protections of the coastal standoff range for SURTASS LFA sonar.

Table C-3. Comprehensive List of Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar

OBIA Number	*OBIA Name*	*Water Body/Location*	*Relevant Low-Frequency Marine Mammal Species*	*Effective Seasonal Period*	*OBIA Boundary Change*[1]	*Notes*
		Atlantic Ocean				boundary
7	Coastal Waters of Gabon, Congo and Equatorial Guinea	Southeastern Atlantic Ocean	Humpback whale and Blue whale	June through October, annually	R	
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, annually	R	
10	Central California[4]	Northeastern Pacific Ocean	Blue whale and Humpback whale	June through November, annually	E, R	OBIA 10 boundary revised to encompass additional foraging area for the blue and humpback whales (Potential OBIA 5)
11	Antarctic Convergence Zone	Southern Ocean	Blue whale, Fin whale, Sei whale, Minke whale, Humpback whale, and Southern right whale	October through March, annually	R	
12	Piltun and Chayvo Offshore Feeding Grounds	Sea of Okhotsk	Western Pacific gray whale	June through November, annually	R	
13	Coastal Waters off Madagascar	Western Indian Ocean	Humpback whale and Blue whale	July through September, annually for humpback whale breeding; November through December for migrating blue	R	

4 OBIA name changed to indicate that expanded OBIA boundary is not coterminous with sanctuaries' boundaries.

Table C-3. Comprehensive List of Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar

OBIA Number	OBIA Name	Water Body/Location	Relevant Low-Frequency Marine Mammal Species	Effective Seasonal Period	OBIA Boundary Change[1]	Notes
				whales		
14	Madagascar Plateau, Madagascar Ridge, and Walters Shoal	Western Indian Ocean	Pygmy blue whale, Humpback whale, and Bryde's whale	November through December, annually		
15	Ligurian-Corsican- Provençal Basin and Western Pelagos Sanctuary	Northern Mediterranean Sea	Fin whale	July to August, annually	R	
16	Penguin Bank, Hawaiian Islands Humpback Whale National Marine Sanctuary	North-Central Pacific Ocean	Humpback whale	November through April, annually	R	
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/South-western Pacific Ocean	Humpback whale and Dwarf minke whale	May through September, annually	E, R	OBIA 18 boundary revised to encompass additional breeding/calving area for the humpback whale (Potential OBIA 8)
19	Bonney Upwelling	Southern Ocean	Blue whale, Pygmy blue whale, and Southern right whale	December through May, annually	R	
20	Northern Bay of Bengal and Head of Swatch-of-No-Ground (SoNG)	Bay of Bengal/Northern Indian Ocean	Bryde's whale	Year-round	R	
21	Olympic Coast National Marine Sanctuary and The Prairie, Barkley Canyon, and Nitnat Canyon	Northeastern Pacific Ocean	Humpback whale	Olympic National Marine Sanctuary: December, January, March, and May, annually;		

Table C-3. Comprehensive List of Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar

OBIA Number	*OBIA Name*	*Water Body/Location*	*Relevant Low-Frequency Marine Mammal Species*	*Effective Seasonal Period*	*OBIA Boundary Change*[1]	*Notes*
				The Prairie, Barkley Canyon, and Nitnat Canyon: June through September, annually		
22	Abrolhos Bank	Southwest Atlantic Ocean	Humpback whale	August through November, annually		
23	Grand Manan North Atlantic Right Whale Critical Habitat	Bay of Fundy, Canada	North Atlantic right whale	June through December, annually		Potential OBIA 1; Canadian critical habitat for the North Atlantic right whale
24	Eastern Gulf of Mexico	Eastern Gulf of Mexico	Bryde's whale	Year-round		Potential OBIA 4
25	Southern Chile Coastal Waters	Gulf of Corcovado, Southeast Pacific Ocean; southwestern Chile	Blue whale	February to April, annually		Potential OBIA 6
26	Offshore Sri Lanka	North-Central Indian Ocean	Blue whale	December through April, annually		Potential OBIA 7
27	Camden Sound/Kimberly Region	Southeast Indian Ocean; northwestern Australia	Humpback whale	June through September, annually		Potential OBIA 9
28	Perth Canyon	Southeast Indian Ocean; southwestern Australia	Pygmy blue whale/Blue whale	January through May, annually		Potential OBIA 10

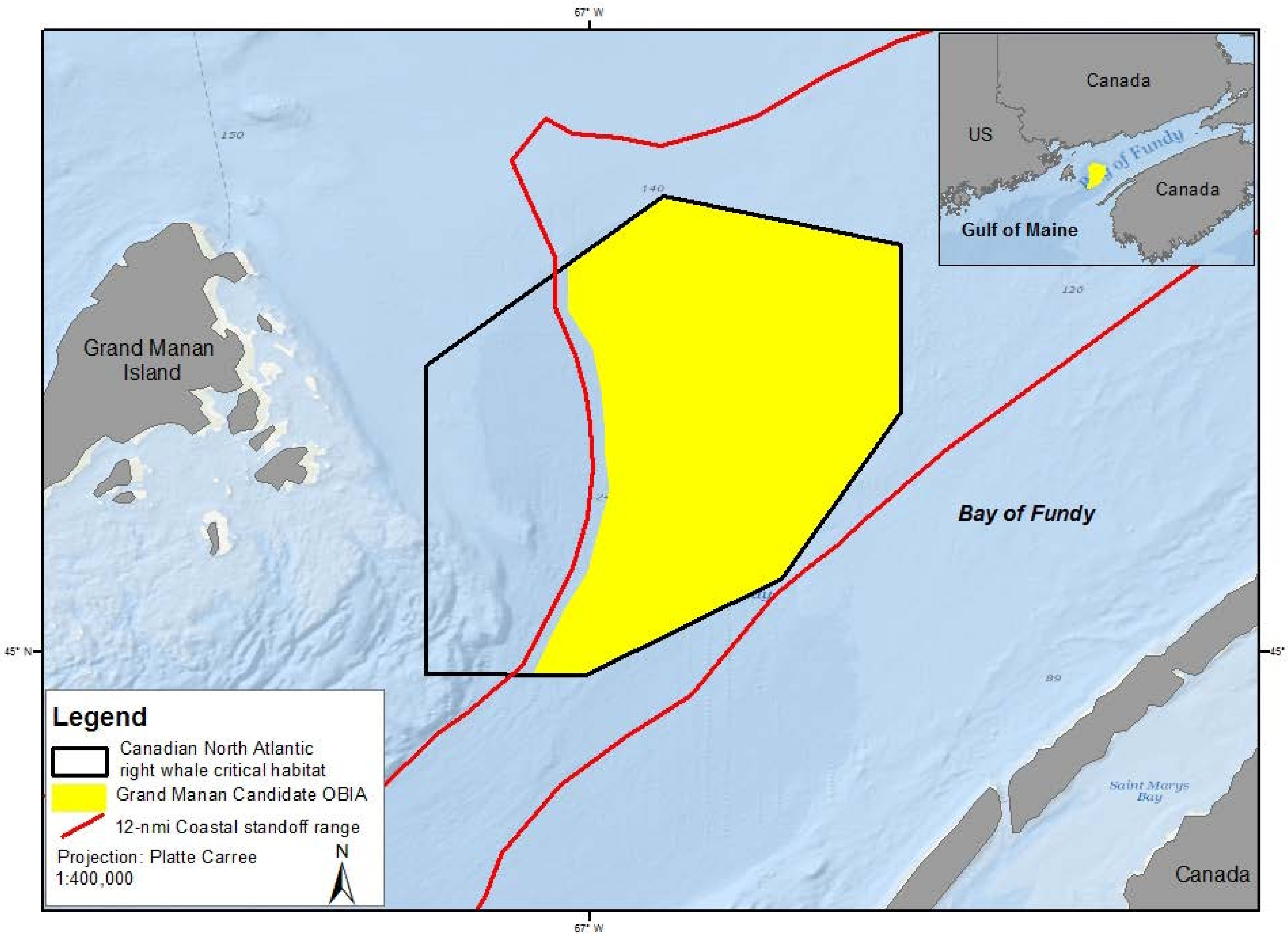


Figure C-1. Grand Manan North Atlantic Right Whale Critical Habitat potential OBIA 1.

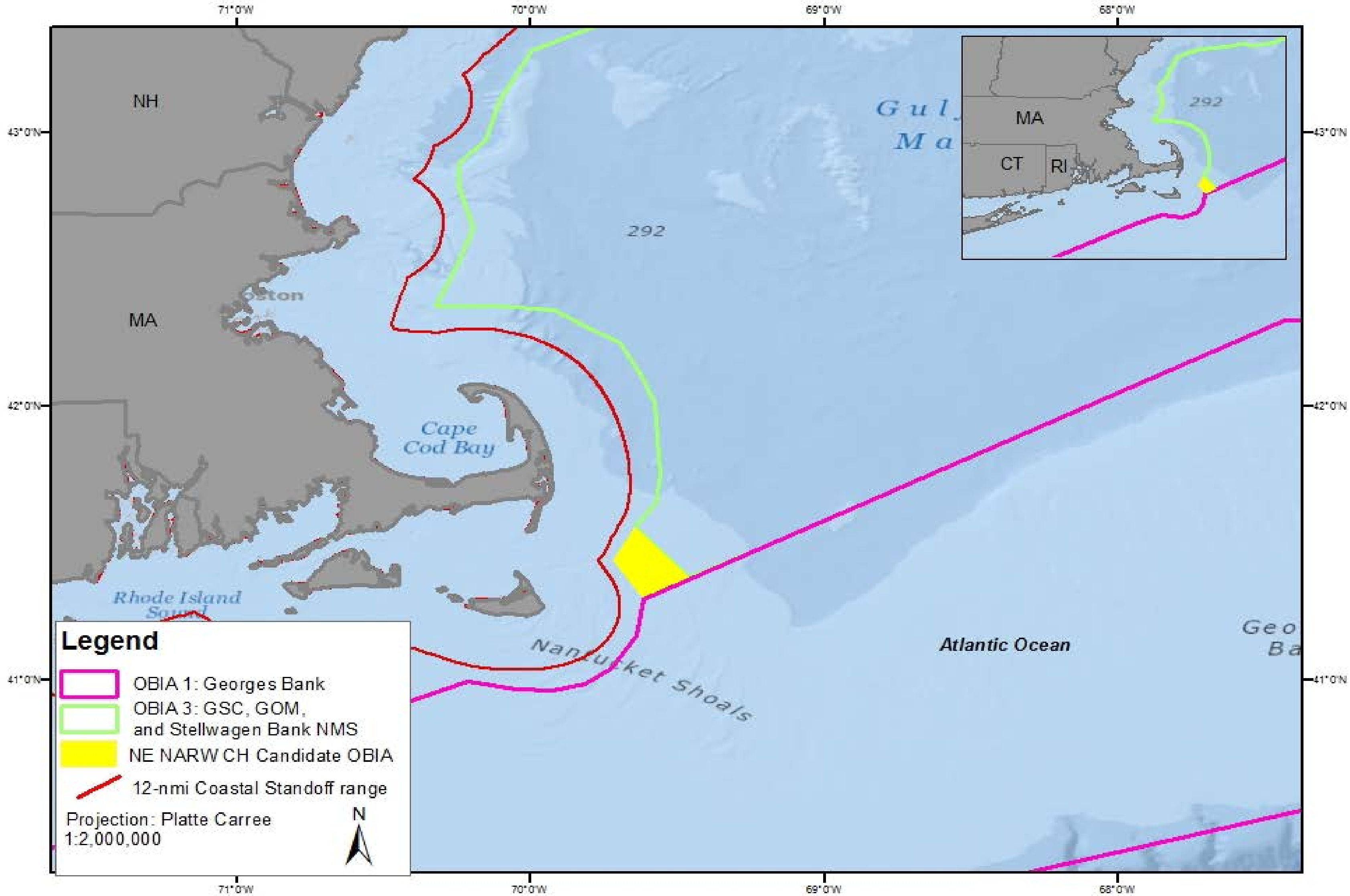


Figure C-2. Northeast North Atlantic Right Whale Critical Habitat Expansion, potential OBIA 2; expansion of existing OBIA 3.

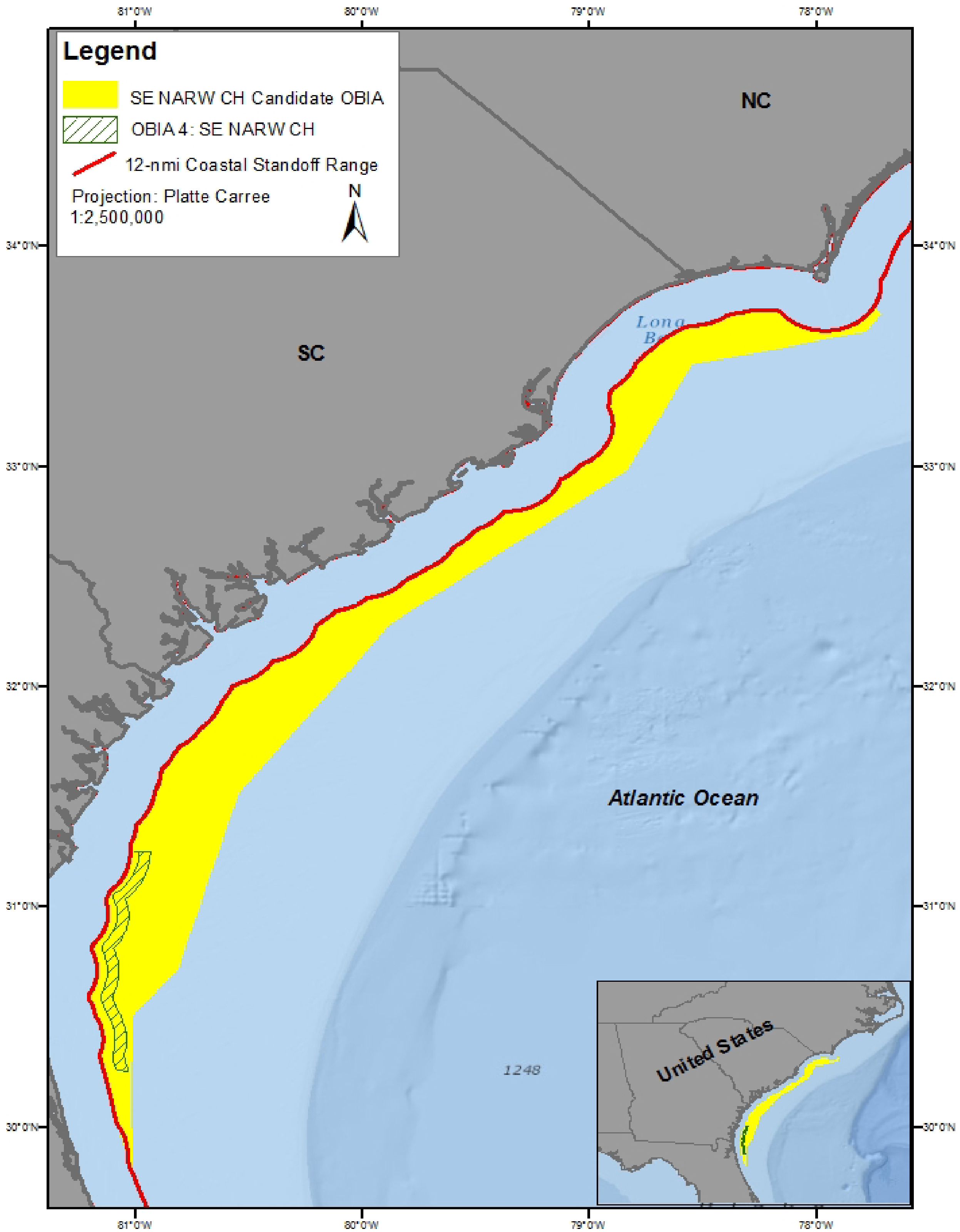


Figure C-3. Southeast North Atlantic Right Whale Critical Habitat Expansion, potential OBIA 3; expansion of OBIA 4.

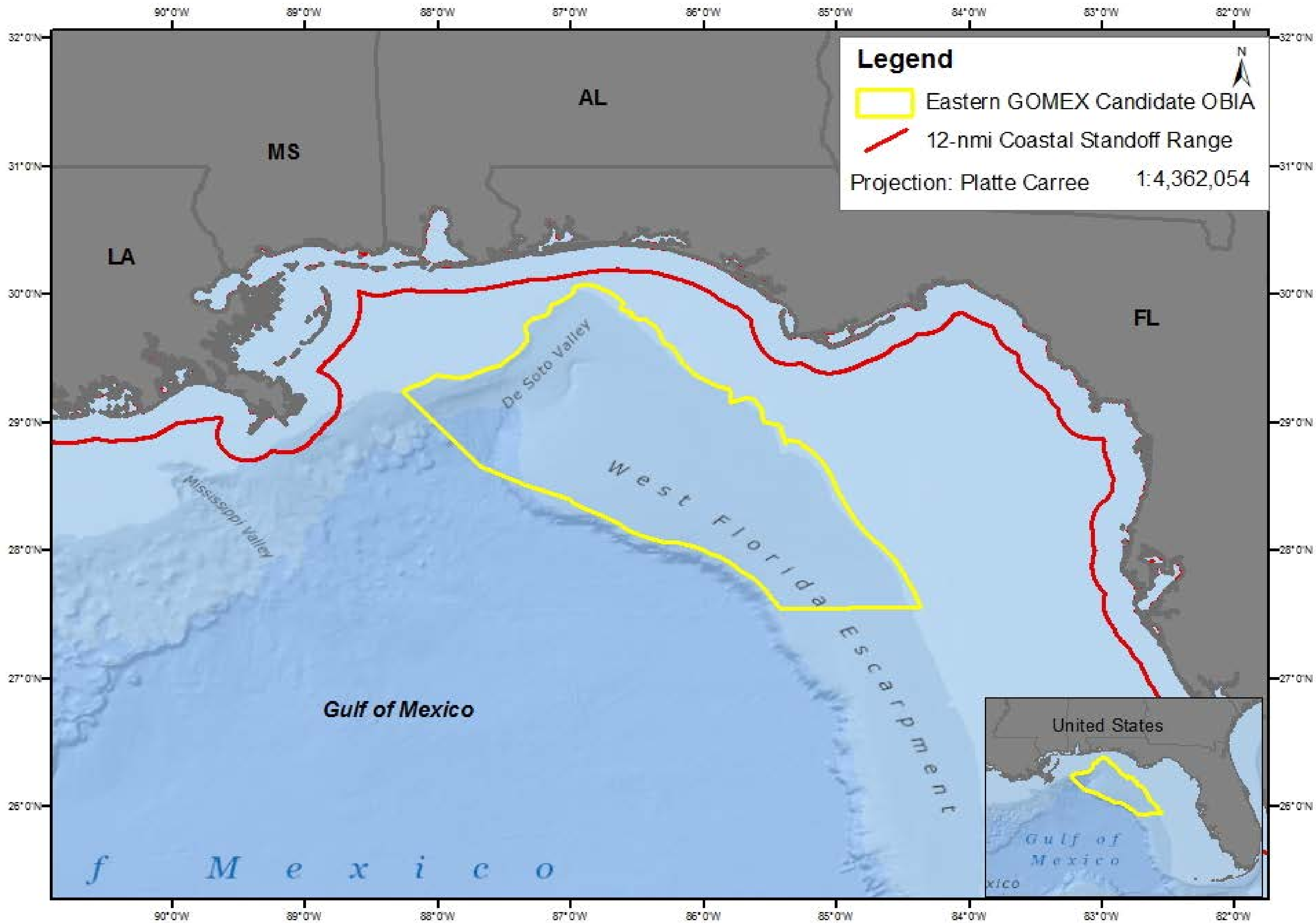


Figure C-4. Northeastern Gulf of Mexico potential OBIA 4.

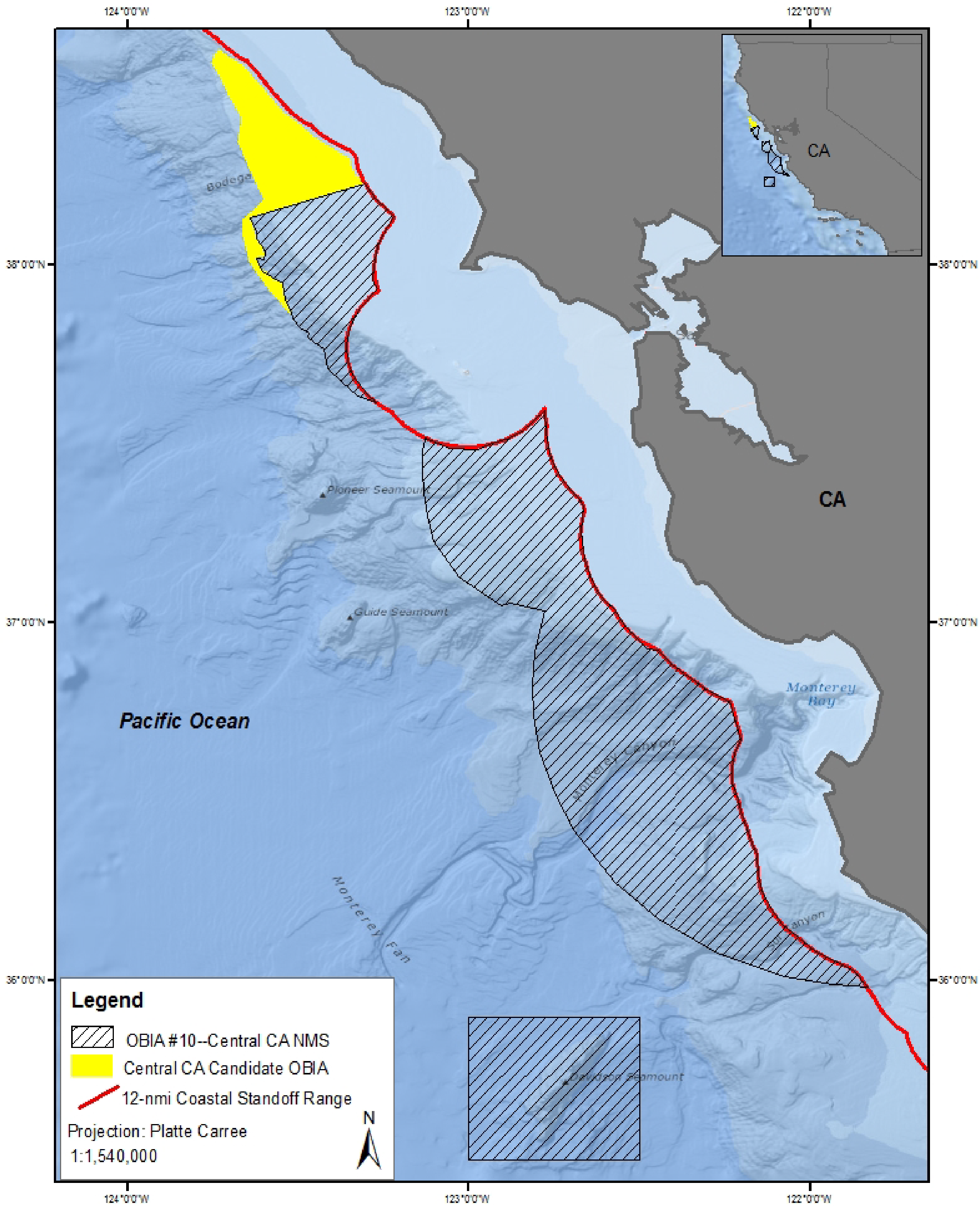


Figure C-5. Central California, potential OBIA 5; expansion of OBIA 10.

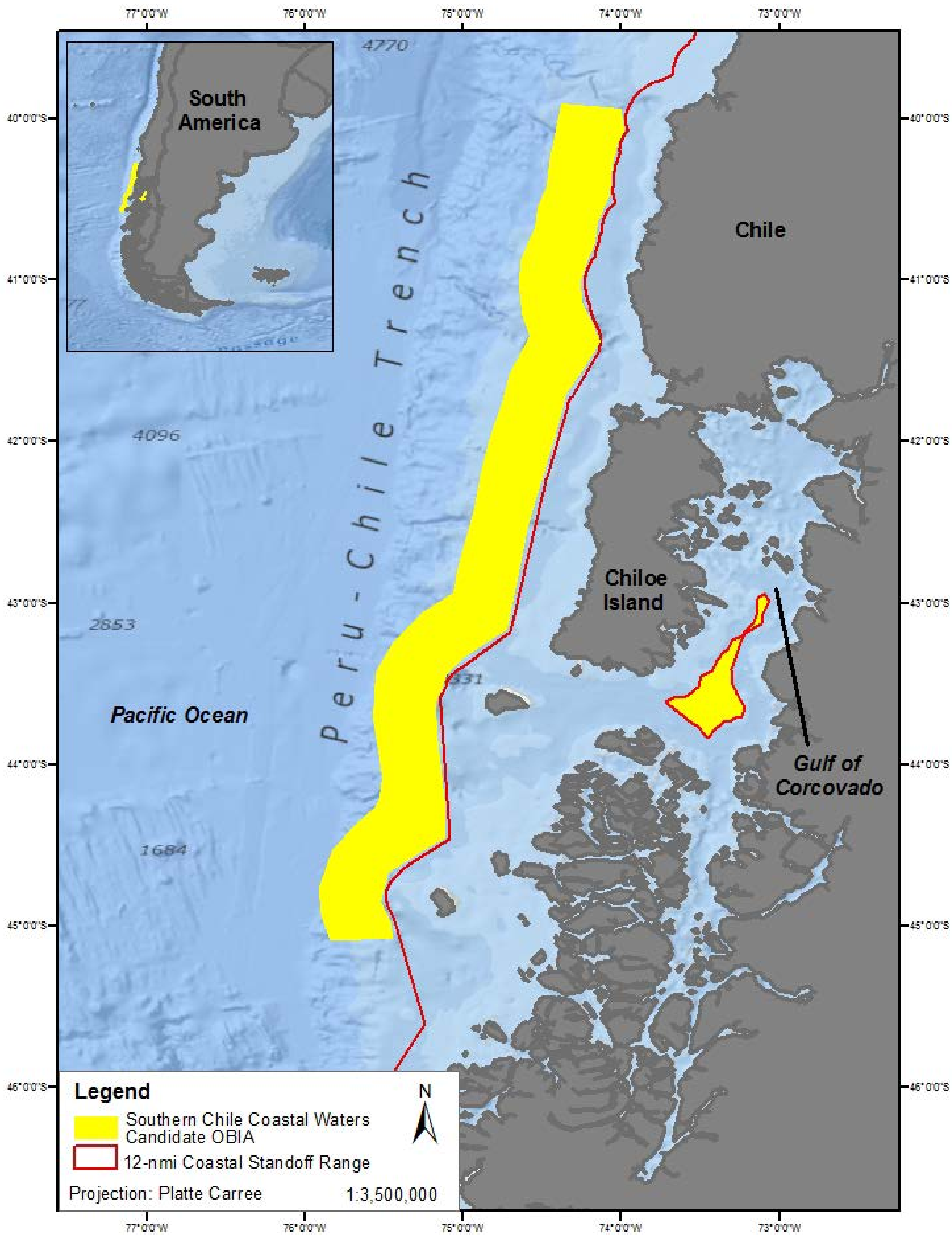


Figure C-6. Southern Chile potential OBIA 6.

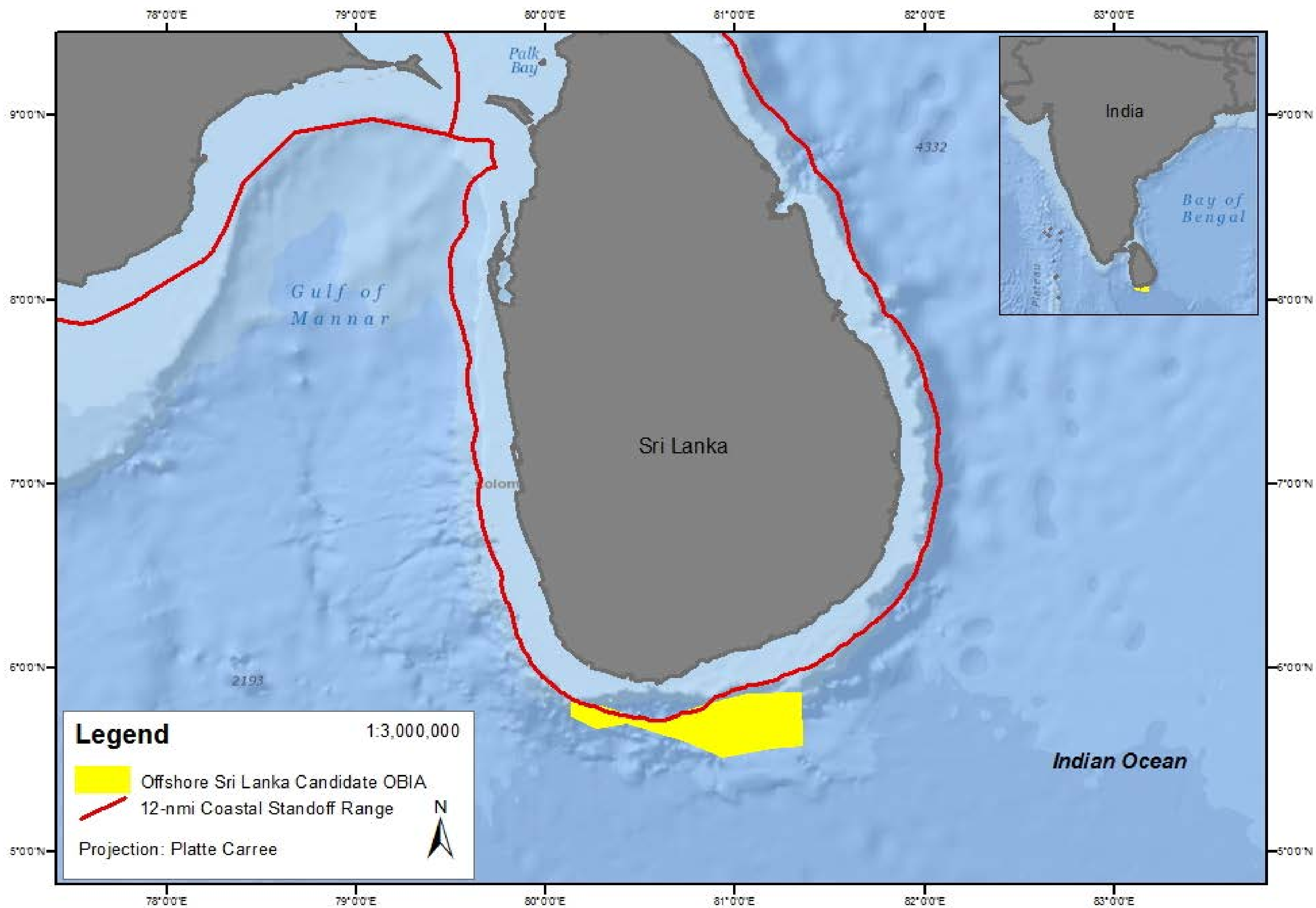


Figure C-7. Offshore Sri Lanka potential OBIA 7.

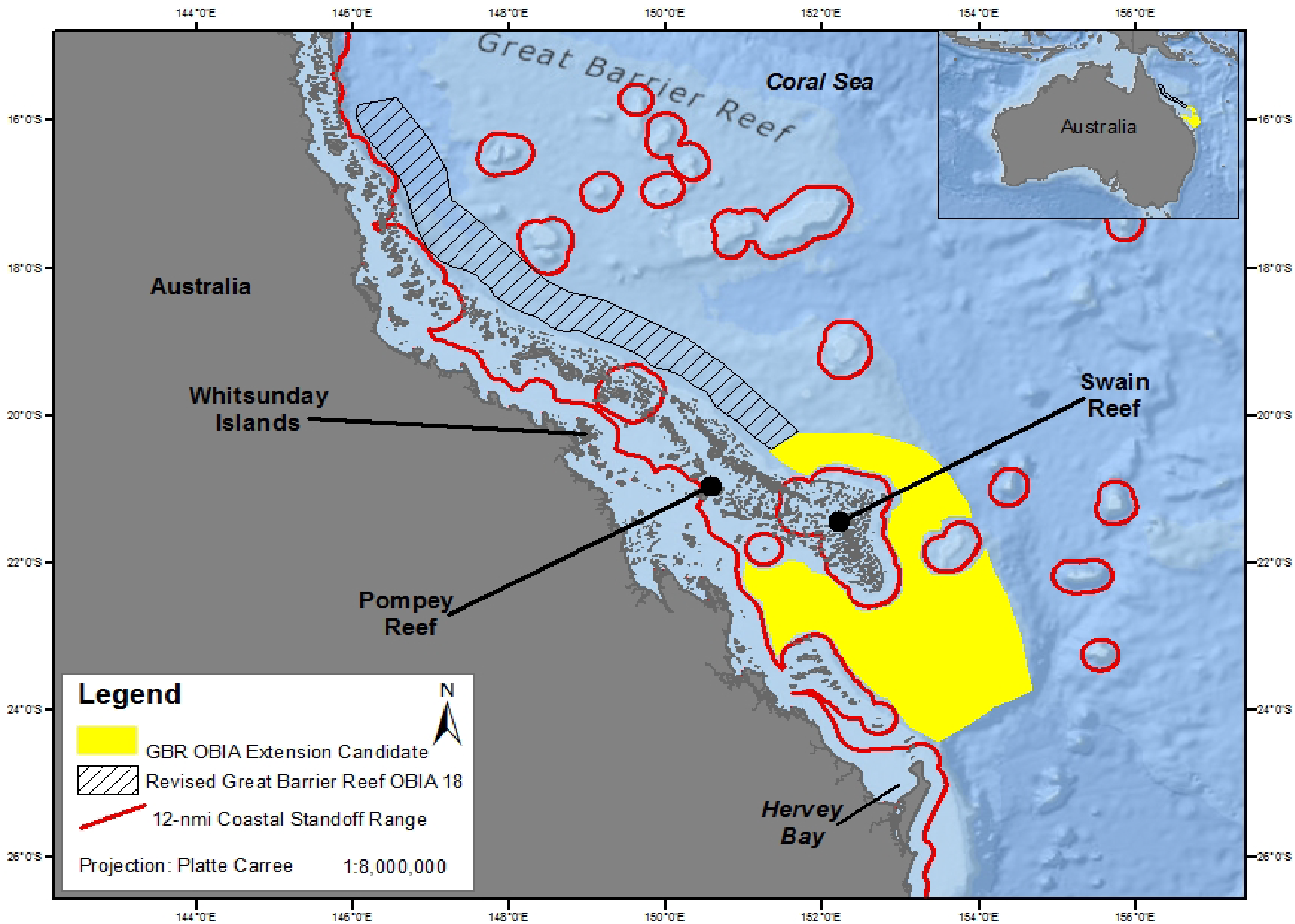


Figure C-8. Great Barrier Reef potential OBIA 8; expansion of OBIA 18 (revised OBIA 18 boundary).

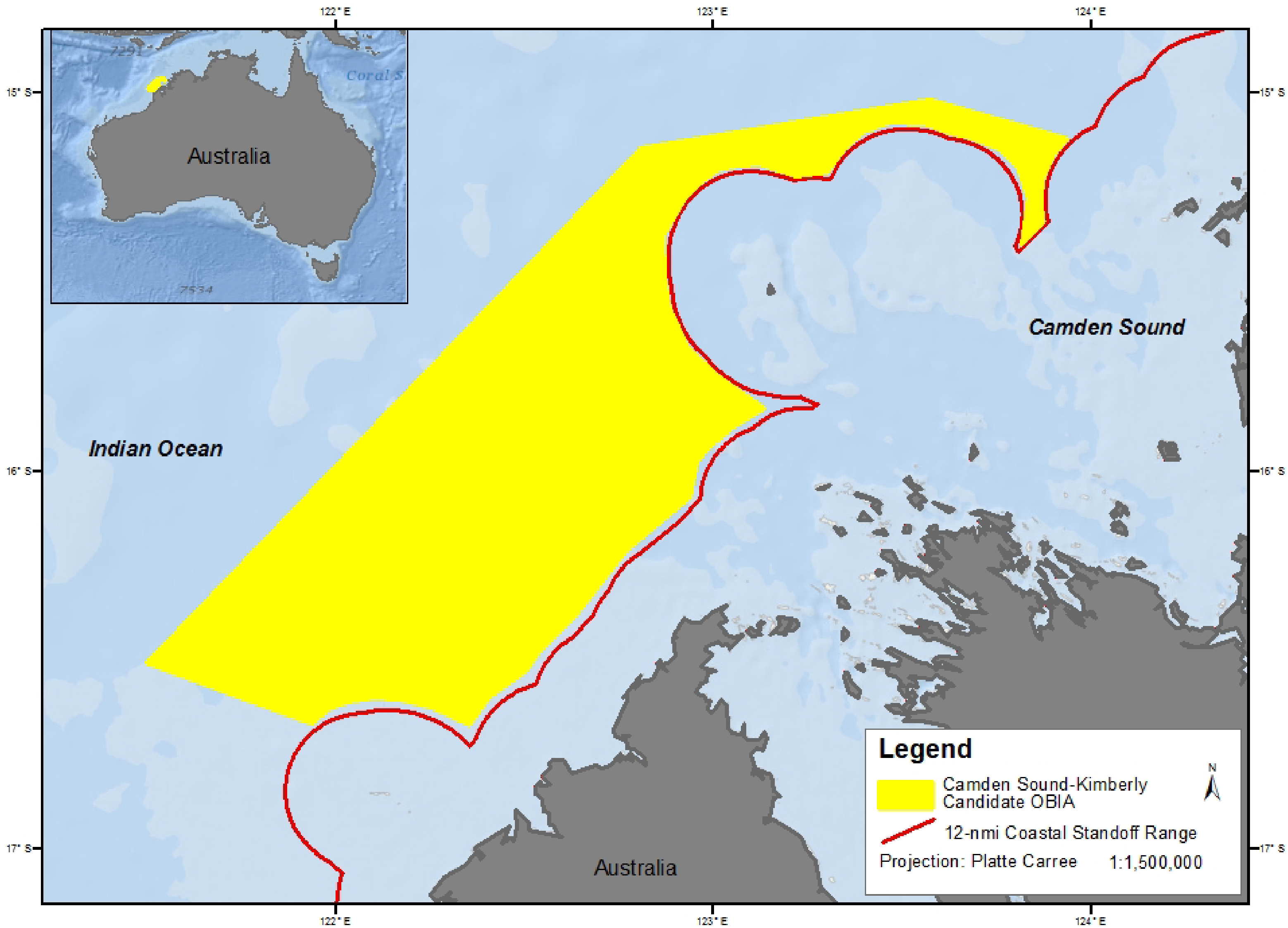


Figure C-9. Camden Sound/Kimberly Region potential OBIA 9.

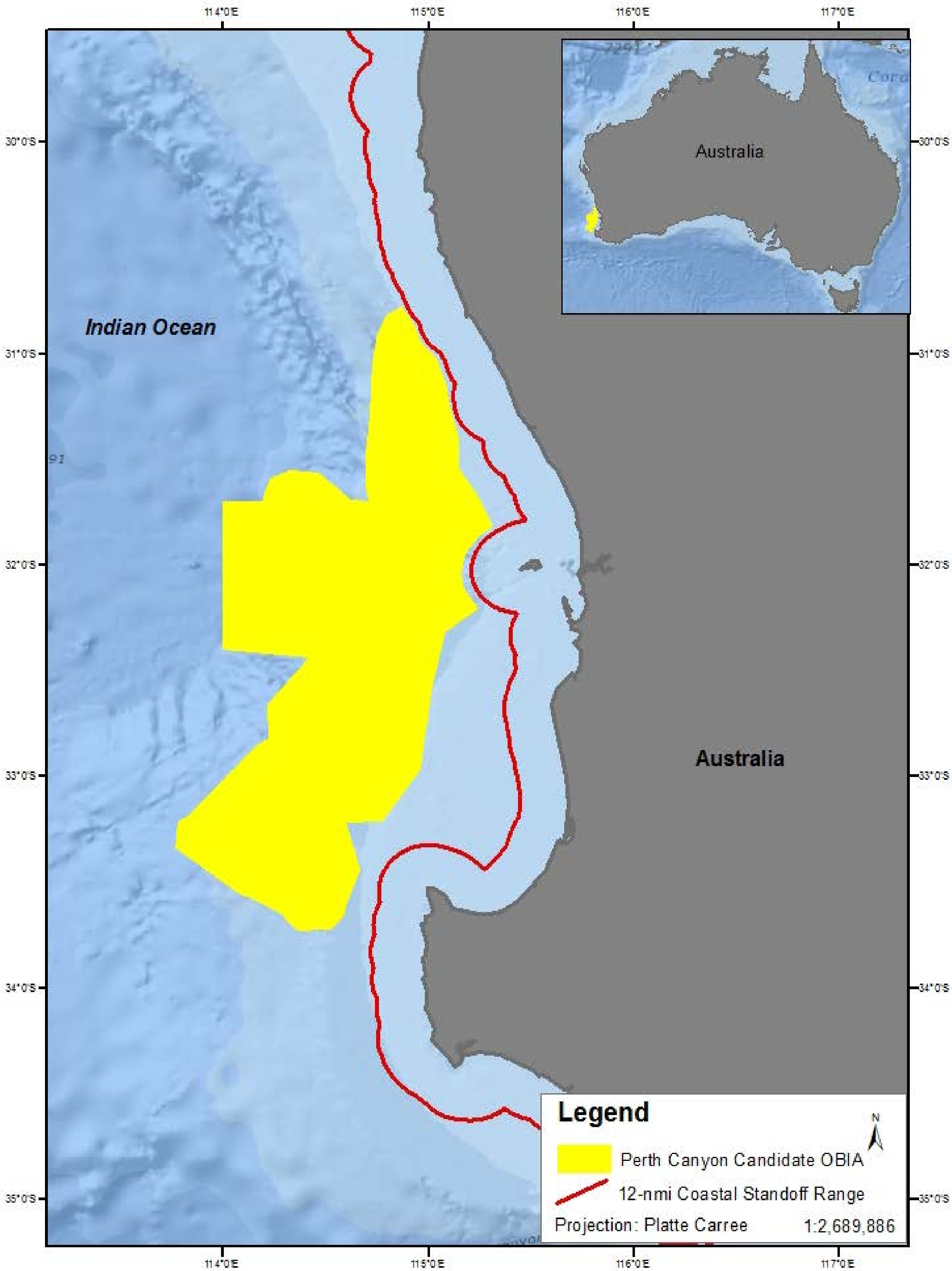
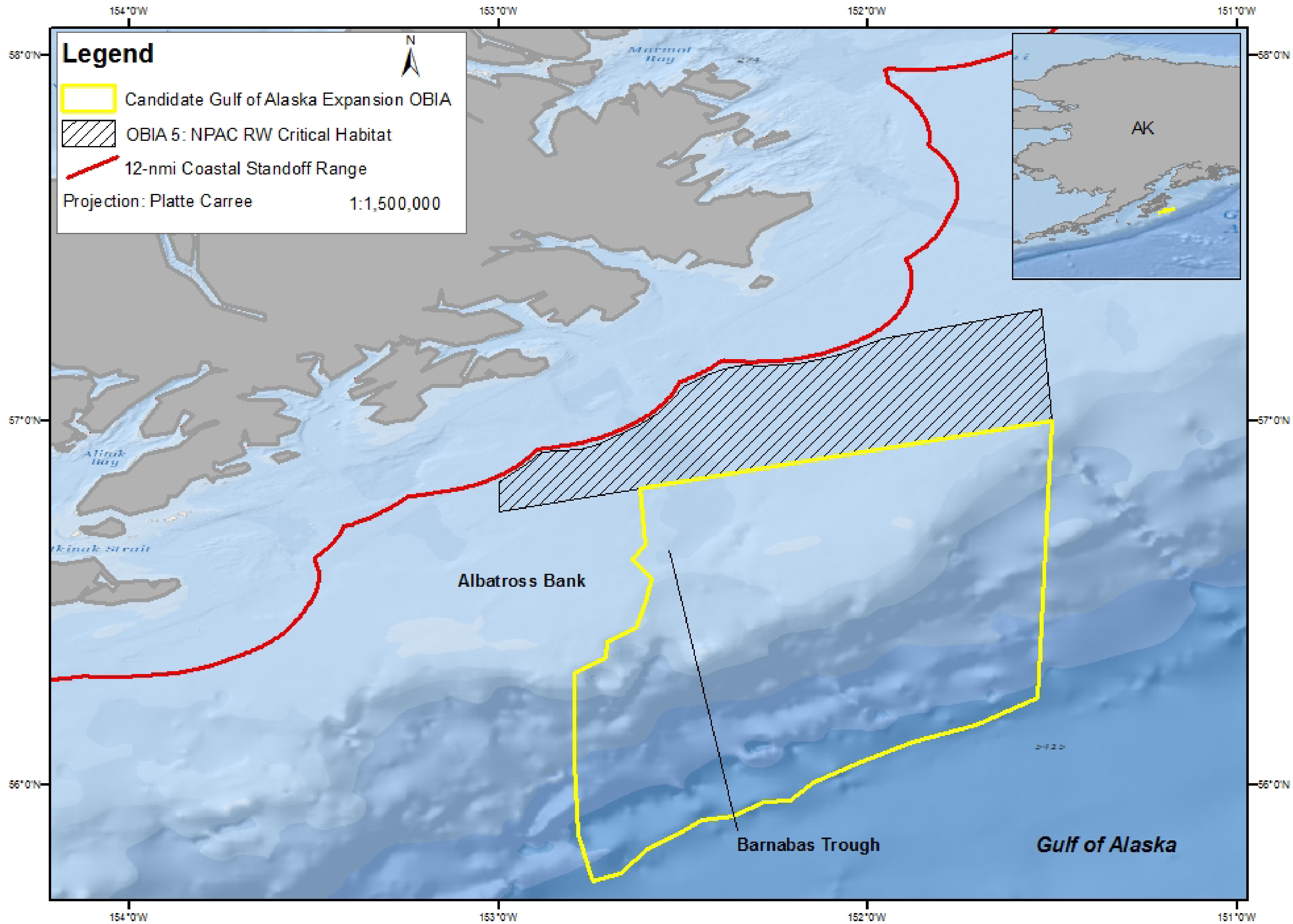


Figure C-10. Perth Canyon potential OBIA 10.



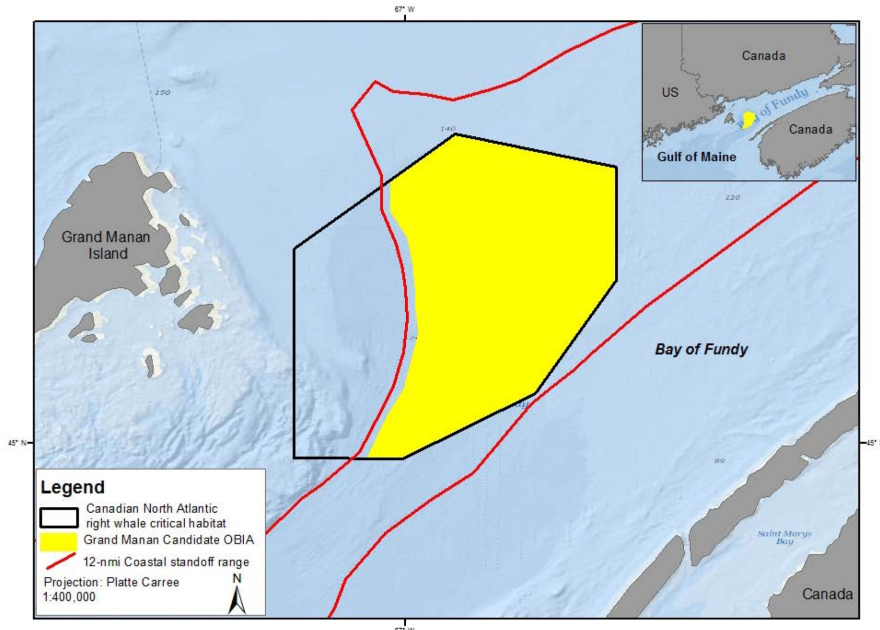
1 **Figure C-11. Gulf of Alaska potential OBIA 11; expansion of OBIA 5.**

Grand Manan North Atlantic Right Whale Critical Habitat

IUCN Marine Region: Northwest Atlantic **Country**: Canada

Species of Concern: North Atlantic right whale

Summary:



The Canadian government declared this area as a whale conservation area in 1993 and identified it as critical habitat in 2009 (Fisheries and Oceans Canada, 2014). Critical habitat was defined as "areas that possess the environmental, oceanographic and bathymetric conditions that aggregate concentrations of right whale prey, especially stage C5 *Calanus finmarchicus* copepodites, at interannually predictable locations." Grand Manan Basin was determined to be critical to successful feeding that would ensure sufficient energy reserves are accumulated to support the energetic cost of basal metabolism, growth, reproduction, and lactation.

The North Atlantic right whale annually migrates to the Grand Manan Basin to feed. Right whales are highly dependent on a narrow range of prey, which occur in variable patches. Long-term sightings data demonstrate that Grand Manan has physical and oceanographic conditions that are conducive to the creation of highly concentrated patches of copepods, despite short-term fluctuations that represent small-scale changes in oceanographic conditions and subsequent distribution.

The North Atlantic Oscillation (NAO) affects the advection of the copepod *Calanus* finmarchicus, the right whales' major prey, into foraging habitats such as Grand Manan Basin (Greene and Pershing 2000; Greene et al. 2003; Greene et al. 2004). *C. finmarchicus* availability differs between positive and negative NAO years, with higher abundance and predictability during positive NAO years (COSEWIC, 2015).

As a result of this inherent variability, Canada's Department of Fisheries and Oceans reported fewer whale sightings within the Grand Manan Basin over the last few years compared to previous years. In 2013, researchers only reported sighting 5 whales, which was a decrease from 42 whales sighted in 2012. In 2015, researchers from the New England Aquarium counted only 8 whales in the Bay of Fundy in August and September, while over 300 were spotted early in the spring in Cape Cod Bay, MA, where right whales typically feed earlier during each season. Moira Brown, senior scientist at the New England Aquarium in Boston hypothesized that the dearth of whale sightings in 2013 to 2015 could be a result of a declining prey base in the Bay of Fundy due to rising ocean temperatures. This recent decline in the occurrence of right whales in the Bay of Fundy is very likely an example of the natural variability in abundance of right whale favored prey, *C. finmarchicus* in the bay, which has occurred in other late-season right whale foraging habitats such as Roseway Basin. Right whales were largely absent from Roseway Basin from 1993 to 1999 during a period when *C. finmarchicus* was largely absent in those waters due to a change in oceanic circulation during that period that affected the advection of *C. finmarchicus* onto the Scotian Shelf (Patrician and Kenney 2010). Right whales have since returned to foraging in the waters of Roseway Basin.

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: Created by Navy/NMFS using coordinates from the Canadian boundaries of the right whale critical habitat. Approximately 700 km^2 extend outside the 12 nmi coastal standoff zones

Spatial File Type: GIS Shapefile

Date Obtained: 2/2/2016

Official Boundary: Critical habitat boundary from Canadian Government, Division of Fisheries and Oceans

Biological Criteria Status:

High Density: Not Eligible, insufficient data.

Breeding/Calving: Not Eligible, insufficient data.

Migration: Not Eligible, insufficient data.

Foraging: Eligible for consideration, adequate justification.

Distinct Small Population: Not Eligible, not applicable.

Critical Habitat: Eligible (Canadian critical habitat).

Seasonal Considerations

June through December (DFO, 2013, 2014, 2015)

Supporting Documentation:

Peer Reviewed Articles	
Mussoline, S., Risch, D., Hatch, L., Weinrich, M., Wiley, D., Thompson, M., Van Parijs, S. (2012). Seasonal and diel variation in North Atlantic right whale up-calls: implications for management and conservation in the northwestern Atlantic Ocean. Endangered Species Research, 17(1), 17-26.	Ships and right whales co-occur throughout their entire migratory route as they move 2240 km between 5 major geographic regions: southeast coast of the United States, Great South Channel, Massachusetts Bay, Bay of Fundy, and Scotian Shelf (e.g. Winn et al. 1986, Kenney et al. 2001). The distribution of right whales is well documented in these main habitats.
Davies, K. (2012). Variation in the prey field of North Atlantic right whales (*Eubalaena glacialis*) in Roseway Basin. Doctoral Thesis. 388 pp., Canada.	The North Atlantic right whale annually migrates to the Grand Manan Basin critical habitat to feed on diapausing calanoid copepods that are typically aggregated at depths of 100 to 150 m.

Silber, G., Vanderlaan, A., Tejedor Arceredillo, A., Johnson, L., Taggart, C., Brown, M., Sagarminaga, R. (2012). The role of the International Maritime Organization in reducing vessel threat to whales: Process, options, action and effectiveness. Marine Policy, 36, 1221-1233.	Discussed areas where north Atlantic right whales congregate and the need to reduce potential interactions such as ship strikes.
McKinstry, Caitlin AE, Andrew J. Westgate, and Heather N. Koopman. (2013). Annual variation in the nutritional value of Stage V *Calanus finmarchicus*: implications for right whales and other copepod predators. Endangered Species Research 20 (2013): 195-204.	Stage V (C5) *Calanus finmarchicus* is a central prey item for animals feeding at several trophic levels in the Bay of Fundy, Canada, especially the highly endangered North Atlantic right whale *Eubalaena glacialis*. The Bay of Fundy (BoF), located between Maine, USA, and Nova Scotia, Canada, is characterized by a large daily tidal flux (>16 m; Dalton 1951) that induces nutrient upwelling to fuel large blooms of spring and autumn primary production.
Patrician, M.A., R.D. Kenney. (2010). Using the Continuous Plankton Recorder to investigate the absence of North Atlantic right whales (*Eubalaena glacialis*) from the Roseway Basin foraging ground. Journal of Plankton Research, 32(12), 1685-1695.	North Atlantic right whales were absent from Roseway Basin for a 7-year period (1993–1999). The objective of this study was to examine the availability of the right whale's main prey, *Calanus finmarchicus*, in Roseway Basin during those 7 years to determine if the whales' absence was due to inadequate prey resources. Near-surface zooplankton abundance data from the Continuous Plankton Recorder were used to infer water-column abundances. In addition, environmental parameters that are often correlated with high zooplankton concentrations were examined. The hypotheses tested were that changes in these parameters would be detectable between three time periods: pre-1993, 1993–1999 and post-1999. *Calanus finmarchicus* abundance was found to be lowest during 1993–1999, suggesting that right whales were not foraging in Roseway Basin because of the near-absence of their main prey species. Decreased in situ salinity and density proved to be indicators of the changes in circulation in the 1990s that may have affected the advection of *C. finmarchicus* onto the Scotian Shelf.
Davies, Kimberley TA, Tetjana Ross, and Christopher T. Taggart. (2013) Tidal and subtidal currents affect deep aggregations of right whale prey, *Calanus* spp., along a shelf-basin margin. Marine Ecology Progress Series 479, 263-282.	Grand Manan Basin in the Bay of Fundy (Canada) is a right whale feeding habitat where, through the combined effort of many research programs, significant progress has been made in describing the mechanisms that maintain *Calanus* aggregations (e.g., Wood ley & Gaskin 1996, Laurinolli 2002, Baumgartner et al. 2003, Michaud & Taggart 2007, 2011, Aret xabaleta et al. 2008). Together, these and other studies have found that the planktonic food is advected by tidal currents in the basin that accumulate and maintain patches of C5 copepods at depths >100 m to the benefit of foraging whales.

	Further, the historical right whale sighting probability distribution in Grand Manan Basin is elliptical and oriented parallel to the cross-isobath tidal ellipse, with the distribution center located near the geographic center of the basin (Fig. 1b,d). This is strong evidence that advection by tidal currents consistently affects the distribution of whales and, by inference, their food on inter-annual time scales (Michaud & Taggart 2011).
Michaud, Josée, and Christopher T. Taggart. "Lipid and gross energy content of North Atlantic right whale food, *Calanus finmarchicus*, in the Bay of Fundy." Endangered Species Research 3.1 (2007): 77-94.	Addresses spatial and temporal distribution of abundance, lipid and caloric content and water column energy density of the copepod *Calanus finmarchicus*, a major food source for the north Atlantic right whale in a primary feeding habitat—Grand Manan Basin, Bay of Fundy. The focus is on the lipid-rich diapausing copepodite stage 5 (C5) that dominates the zooplankton community during the summer and autumn whale-feeding period. Using right whale sighting per unit effort data in 2002, they note that the whales occupy the Grand Manan feeding habitat in direct proportion ($r2> 0.88$, $p <0.05$) to the abundance and quality (i.e. energy density) of food available in the habitat.
Hinch, P. R., & De Santo, E. M. (2011). Factors to consider in evaluating the management and conservation effectiveness of a whale sanctuary to protect and conserve the North Atlantic right whale (*Eubalaena glacialis*). Marine Policy, 35(2), 163-180.	This paper examines key factors used in protecting the migratory North Atlantic right whale within the context of a marine protected area (MPA) system, using the Grand Manan Whale Conservation Area, in New Brunswick Canada, as a case study example. Recommended activities include: continued Canadian participation in cross-border research and actions to mitigate threats to the right whales over their migratory range; development of a regional right whale management and monitoring strategy; and designation of additional critical habitats in national/international waters.
Subject Matter Experts / e-NGO Reports / Regional Expertise	
Hoyt, E. (2005). Marine protected areas for whales, dolphins, and porpoises: a world handbook for cetacean habitat conservation: Earthscan/James & James.	This edition does not provide exact boundary coordinates.
Hoyt, E. (2011). Marine protected areas for whales, dolphins and porpoises: a world handbook for cetacean habitat conservation and planning (2nd ed. ed.). New York, NY: Earthscan.	This edition does not provide exact boundary coordinates.
Committee or Government Reports	
CCG. (2013). Annual Edition, Notices to Mariners 1 to	https://www.notmar.gc.ca/eng/services/annual/annual

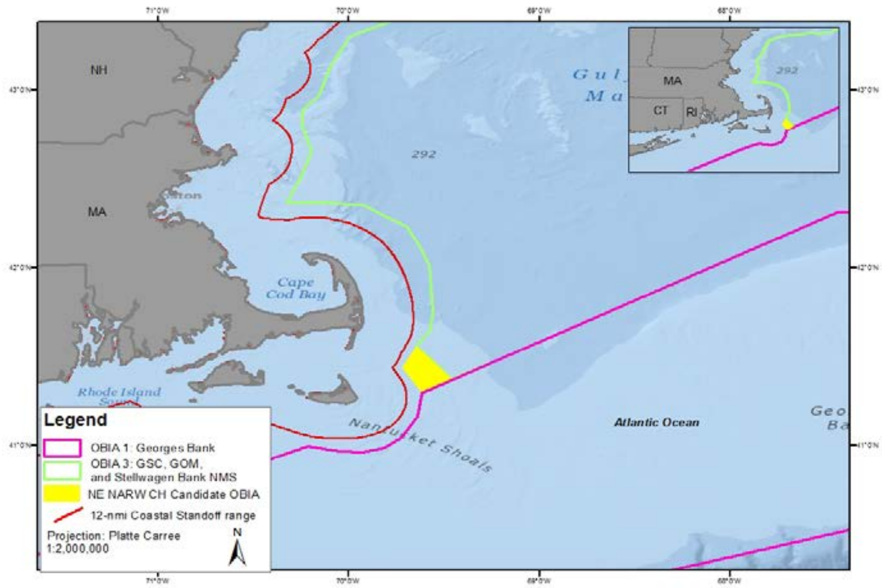
46, April 2013 to 2014. (Cat # - Fs151-4/2013E 1498-4687). Ottawa, Ontario: Fisheries and Oceans Canada, Canadian Coast Guard.	-notices-to-mariners-eng.pdfL
DFO. (2013). Fisheries and Oceans, Canada. Special Management Areas. 2013	http://www.inter.dfo-mpo.gc.ca/Maritimes/Oceans/OCMD/Atlas/Special-Management-Areas
DFO. (2014). Annual Edition Notices to Mariners 1 to 46 April, 2014 to March, 2015.	http://sararegistry.gc.ca/virtual_sara/files/plans/rs_ban_narw_am_0414_e.pdf
COSEWIC Assessment and Status Report on the North Atlantic Right Whale *Eubalaena glacialis* in Canada - 2013.	http://www.registrelep-sararegistry.gc.ca/default.asp?lang=En&n=56C3488F-1
Surveys and Other Publications and Media	
Parks, S., Conger, L., Cusano, D., & Van Parijs, S. (2014). Variation in the acoustic behavior of right whale mother- calf pairs. The Journal of the Acoustical Society of America, 135(4), 2240-2240.	The authors conducted behavioral focal follows coupled with acoustic recording of right whale mother calf pairs off the coast of Florida and Georgia in January–March, Cape Cod Bay in April, and the Bay of Fundy in August–September from 2011 to 2014. Results show modifications in both call structure and call rate with increasing calf maturity and independence.
Davies, K. (2012). Variation in the prey field of North Atlantic right whales (*Eubalaena glacialis*) in Roseway Basin. Doctoral Thesis. 388 pp., Canada.	
CWI. (2009). Canadian Whale Institute. Conservation Areas. 2009	http://www.rightwhale.ca/conservationarea-zoneconservation_e.php
CBC News Article: Oct 28, 2015. Right whale sightings still on the decline in Bay of Fundy.	http://www.cbc.ca/news/canada/new-brunswick/right-whale-bay-fundy-1.3292053

Northeastern U.S. North Atlantic Right Whale Critical Habitat (OBIA 3 Expansion)

IUCN Marine Region: Northwest Atlantic **Country**: United States

Species of Concern: North Atlantic right whale **OBIA in Regulations/LOA:** Yes

Summary:



In 2016, NMFS issued final regulations to replace the critical habitat for right whales in the North Atlantic with two new areas. The expansion areas designated as critical habitat contain approximately 29,763 nautical miles of marine habitat in the Gulf of Maine and Georges Bank region (Unit 1) and off the Southeast U.S. coast (Unit 2).

The boundaries of Unit 1 encompass the combination of physical and biological features of foraging habitat that are essential to right whale conservation. This boundary expansion is codified by national law or regulation (e.g., regulatory boundaries pursuant to the U.S. Endangered Species Act of 1973). Current OBIAs 1, Georges Bank and 3, Gulf of Maine / Stellwagen NMS encompass most of Unit 1 with the exception of small area to the northwest of Nantucket Island (shown in red on the map).

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: NMFS GARFO. GIS shapefile clipped at 12 nmi boundary.

Spatial File Type: GIS shapefile

Date Obtained: 2/2/2016

Official Boundary: Critical habitat boundary from NMFS

Biological Criteria Status:

High Density: Eligible for consideration, adequate justification.

Breeding/Calving: Eligible for consideration, requires more data.

Migration: Not Eligible, not applicable.

Foraging: Eligible for consideration, strong justification

Distinct Small Population: Not Eligible, not applicable.

Critical Habitat: Eligible for consideration, strong justification.

Seasonal Considerations

January 1 through November 14

Supporting Documentation:

Peer Reviewed Articles	
Kenney, R. D., & Wishner, K. F. (1995). The south channel ocean productivity experiment. Continental Shelf Research, 15(4), 373-384.	The Great South Channel (GSC) area lies east of Cape Cod, Massachusetts, U.S.A. between Nantucket Shoals on the west and Georges Bank on the east. Right whales are the world's most endangered large whale species, and the GSC is the principal feeding ground of the western North Atlantic population. The South Channel Ocean Productivity Experiment (SCOPEX), a multidisciplinary study of a whale-zooplankton predator-prey system in the southwestern Gulf of Maine, confirmed the co-occurrence of right whales with high density *Calanus finmarchicus* patches. Also, the whales fed on patches with higher proportions of larger lifestages of *C. finmarchius*.
Bort, J., Van Parijs, S. M., Stevick, P. T., Summers, E., & Todd, S. (2015). North Atlantic right whale *Eubalaena glacialis* vocalization patterns in the central Gulf of Maine from October 2009 through October 2010. Endangered Species Research, 26, 271-280.	The central Gulf of Maine was recently identified as a persistent wintering ground and potential mating ground for non-calving North Atlantic right whales *Eubalaena glacialis* based on aerial survey data. However, these surveys were limited by bad weather and light. The authors used passive acoustic monitoring to examine the long-term persistence of right whales in this area throughout a nearly continuous period from October 2009 through October 2010. Three archival marine acoustic recording units were deployed in the Outer Fall/central Gulf of Maine. The data were manually reviewed for right whale up-calls and gunshots to investigate seasonal and diel patterns. Up-calls and gunshots occurred seasonally, with the most calls recorded from October through January and fewer calls detected from February through July, increasing again in August through October. Up-calls were most frequent in November, and gunshots in December. There was a clear bimodal diel pattern in up-calls, with the majority of calls occurring between 04:00 through 08:00 h and 13:00 through 22:00 h. There was a clear peak in diel distribution of gunshots, with the majority of calls occurring between 16:00 and 22:00 h. The authors suggest that the data demonstrate the continuous presence of right whales in the central Gulf of Maine during the winter months. The rate of gunshots during winter months in Outer Fall supports the hypothesis that male advertisement and/or right whale mating behavior may be taking place

	in this region at that time.
Committee or Government Reports	
Final Rule: Endangered and Threatened Species; Critical Habitat for Endangered North Atlantic Right Whale (2016). 81 FR 4837, January 27, 2016. https://www.federalregister.gov/articles/2016/01/27/2016-0163	The physical and biological features essential to the conservation of the North Atlantic right whale, which provide foraging area functions in Unit 1 are: The physical oceanographic conditions and structures of the Gulf of Maine and Georges Bank region that combine to distribute and aggregate *C. finmarchicus* for right whale foraging, namely prevailing currents and circulation patterns, bathymetric features (basins, banks, and channels), oceanic fronts, density gradients, and temperature regimes; low flow velocities in Jordan, Wilkinson, and Georges Basins that allow diapausing *C. finmarchicus* to aggregate passively below the convective layer so that the copepods are retained in the basins; late stage *C. finmarchicus* in dense aggregations in the Gulf of Maine and Georges Bank region; and diapausing *C. finmarchicus* in aggregations in the Gulf of Maine and Georges Bank region.
NMFS. (2014). North Atlantic Right Whale (*Eubalaena glacialis*) Source Document for the Critical Habitat Designation: A review of information pertaining to the definition of "critical habitat" July 2014. http://www.regulations.gov/ -!documentDetail;D=NOAA-NMFS-	The Gulf of Maine and Western Scotian Shelf region presents right whales with a highly variable feeding environment (Greene et al. 2003). This region lies within an oceanographic transition zone, located between cold subpolar waters influenced by fluctuations in the Labrador Current to the northeast and warm temperate waters influenced by fluctuations in the Gulf Stream to the south (MERCINA, 2001, Greene et al. 2003). Within the Gulf of Maine, right whale foraging activities are concentrated in areas where physical oceanographic conditions and structures, namely prevailing currents and circulation patterns, bathymetric features (basins, banks, and channels), oceanic fronts, density gradients, and temperature regimes operate to concentrate copepods (Wishner et al. 1988, Mayo and Marx 1990, Murison and Gaskin 1989, Baumgartner et al. 2003, Jiang et al. 2007, Pace and Merrick 2008).
Pace III, R. M., & Merrick, R. L. (2008). Northwest Atlantic Ocean habitats important to the conservation of North Atlantic right whales (*Eubalaena glacialis*). Northeast Fisheries Science Center Reference Document 08, 7. Chicago https://nefsc.noaa.gov/nefsc/publications/crd/crd0807/crd0807.	This document provides a spatial and temporal description of the habitats important to the conservation of North Atlantic right whales (*Eubalaena glacialis*) in US waters of the Northwest Atlantic Ocean. Analysis are based on the premise that the biological and physical feature of habitat essential to the conservation of right whales in the region (i.e., the primary constituent element [PCE] which a species needs to survive and reproduce) is the presence of dense patches of calanoid copepods (notably *Calanus finmarchicus*).

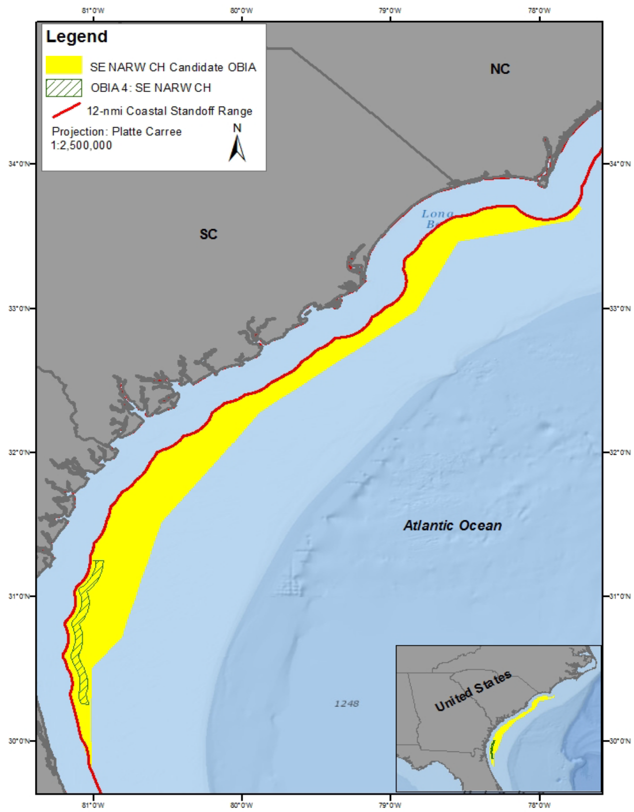
	Based on systematic sighting surveys for right whales conducted from 1970 through 2005, the authors identified concentrations of foraging right whales in US Atlantic waters north of 40° N latitude. They used the data to define Dynamic Area Management (DAM) zones, which indicated that most of the area north of the Great South Channel on Georges Bank was used at least seasonally for foraging. This region included seasonal foraging subareas generally identified as Cape Cod Bay, Great South Channel, Northern Edge of Georges Bank, Western Gulf of Maine, Wilkinson Basin, and Jordan Basin. Wilkinson and Jordan Basins are also considered essential to the conservation of right whales because these two basins are source areas for the dense copepod concentrations upon which right whales prey in U.S. Northwest Atlantic waters.

Southeastern U.S. North Atlantic Right Whale Critical Habitat (OBIA 4 Expansion)

IUCN Marine Region: Northwest Atlantic **Country**: United States

Species of Concern: North Atlantic right whale **OBIA in Regulations/LOA:** Yes

Summary:



In 2016, NMFS issued final regulations to replace the critical habitat for right whales in the North Atlantic with two new areas. The expansion areas designated as critical habitat contain approximately 29,763 nautical miles of marine habitat in the Gulf of Maine and Georges Bank region (Unit 1) and off the Southeast U.S. coast (Unit 2).

The boundaries of Unit 2 encompass the combination of physical and biological features of breeding/calving habitat that are essential to right whale conservation. This boundary expansion is codified by national law or regulation (e.g., regulatory boundaries pursuant to the U.S. Endangered Species Act of 1973). Current OBIA , Southeastern U.S. Right Whale Seasonal Habitat encompasses some of Unit 2 with the exception of an area that extends to Cape Fear, NC (shown in red on the map).

Unit 2 includes marine waters from Cape Fear, North Carolina, southward to 28° N . Latitude (approximately 31 miles south of Cape Canaveral, Florida) within the area bounded on the west by the shoreline and the 72 COLREGS lines, and on the east by rhumb lines connecting the following points in the order stated from north to south.

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: NMFS GARFO shapefile clipped at 12 nmi boundary

Spatial File Type: GIS shapefile

Date Obtained: 2/2/2016

Official Boundary: Critical habitat boundary from NMFS

Biological Criteria Status:

High Density: Eligible for consideration, adequate justification.

Breeding/Calving: Eligible for consideration, requires more data.

Migration: Not Eligible, not applicable.

Foraging: Not Eligible, insufficient data.

Distinct Small Population: Not Eligible, not applicable.

Critical Habitat: Eligible for consideration, strong justification.

Seasonal Considerations

November 15 through April 15

Supporting Documentation:

Peer Reviewed Articles	
Keller, C. A., Garrison, L., Baumstark, R., Ward-Geiger, L. I., & Hines, E. (2012). Application of a habitat model to define calving habitat of the North Atlantic right whale in the southeastern United States. Endangered Species Research, 18(1), 73-87.	The authors developed a habitat model of the relationship between the winter distribution of North Atlantic right whales *Eubalaena glacialis*, one of the most endangered large whales in the world, and environmental characteristics in its only identified calving ground, the waters off Florida and Georgia. This was to provide a scientific basis for revising critical habitat boundaries in the southeastern USA (SEUS) and to predict potential habitat in the mid-Atlantic region north of the study area through a better understanding of the relationship of observed right whale distribution to environmental conditions. A long-term data set of right whale sightings from aerial surveys within the SEUS (conducted seasonally, December through March, from 1992/1993 to 2000/2001) was used in a generalized additive model to evaluate right whale distribution in relation to sea surface temperature, bathymetry, wind data, and several spatial variables. Model results indicated that sea surface temperature and water depth were significant predictors of calving right whale spatial distribution. The habitat relationships were unimodal, with peak sighting rates occurring at water temperatures of 13 to 15°C and water depths of 10 to 20 m. Model results indicated areas of potentially important calving habitat outside currently defined critical habitat.
Committee or Government Reports	
Final Rule: Endangered and Threatened Species; Critical Habitat for Endangered North Atlantic Right Whale (2016). 81 FR 4837, January 27, 2016. https://www.federalregister.gov/articles/2016/01/27/2016-0163	The physical features essential to the conservation of the North Atlantic right whale, which provide calving area functions in Unit 2, are: (i) Sea surface conditions associated with Force 4 or less on the Beaufort Scale; (ii) Sea surface temperatures of 7 °C to 17 °C; and (iii) Water depths of 6 to 28 meters, where these features simultaneously co-occur over contiguous areas of at least 231 nmi^2 of ocean waters during the months of November through April. When these features are available, they are selected by right whale cows and calves in dynamic combinations that are suitable for calving, nursing, and rearing, and which vary, within the ranges specified, depending on factors such as weather

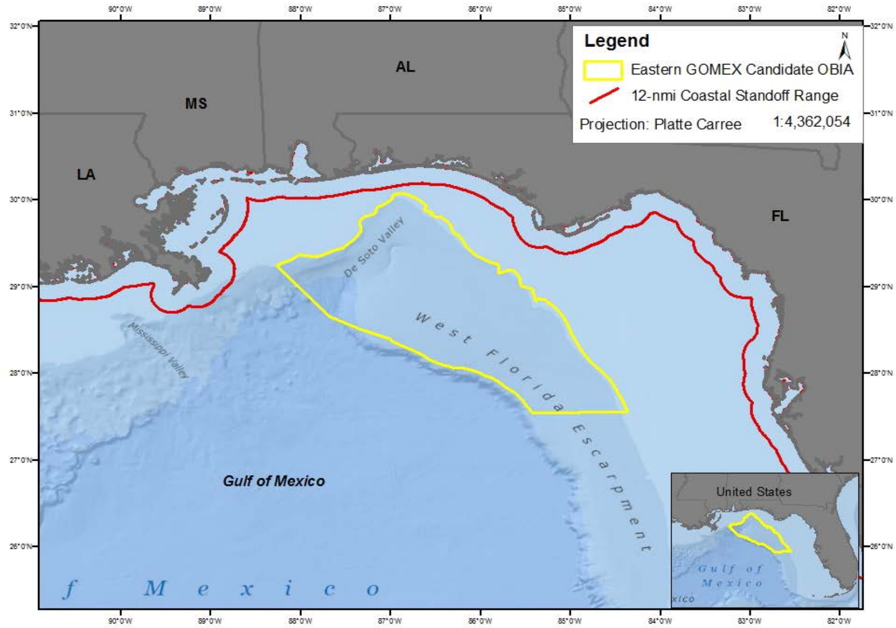
	and age of the calves.
Other Publications and Media	
Good, C. P. (2008). Spatial Ecology of the North Atlantic Right Whale (*Eubalaena glacialis*). ProQuest.	Final rule references Good (2008) which reported that at least 85% of all observed right whale mother-calf pair sightings from January 2000 through March 2005 are located within the modified calving area critical habitat. "Generally, by the end of March, mother-calf pairs have begun moving northward out of the area."

Northeastern Gulf of Mexico

IUCN Marine Region: Gulf of Mexico/Caribbean **Country**: United States

Species of Concern: Bryde's whale **CetMAP BIA**: Yes

Summary:



LaBrecque et al. (2015) identified Bryde's whales as a small and resident population in the special issue on Biologically Important Areas (BIAs) that identified foraging and reproductive areas, migratory corridors, and areas with small and resident populations for cetacean species within the U.S. EEZ. BIAs are not a regulatory designation and have no direct implications for regulatory processes. Supplemental tables suggest that the area between the 100- and 300-m isobaths in the eastern Gulf of Mexico from south of Pensacola (head of DeSoto Canyon) to northwest of Tampa Bay, FL is a year-round biologically important area for the species. However, they note that Bryde's whales are only seen between the 100- and 300- m isobaths from the head of DeSoto Canyon to south of Tampa, Florida.

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: Created by Navy based on isobaths, physiography of DeSoto Canyon, and scientific literature

Spatial File Type: GIS shapefile

Date Obtained: 5/14/2016

Biological Criteria Status:

High Density: Not Eligible, insufficient data.

Breeding/Calving: Not Eligible, insufficient data.

Migration: Not Eligible, insufficient data.

Foraging: Not Eligible, insufficient data.

Distinct Small Population: Eligible for consideration, adequate justification.

Critical Habitat: Not Eligible, not applicable.

Seasonal Considerations

Year-round

Supporting Documentation:

Peer Reviewed Articles	
LaBrecque, Erin, et al. "3. Biologically Important Areas for cetaceans within US waters–Gulf of Mexico region." Biologically Important Areas for cetaceans within US waters (2015): 30-38.	Most sightings of Bryde's whales in the Gulf of Mexico are from shipboard and aerial line-transect surveys conducted by NOAA Fisheries (Waring et al., 2013). These surveys were conducted at various times throughout all seasons and covered waters from the 20-m isobath to the seaward extent of the U.S. EEZ (Fulling et al., 2003; Mullin & Fulling, 2004; Maze-Foley & Mullin, 2006; Waring et al., 2013). Although survey effort covered all of the oceanic waters of the U.S. Gulf of Mexico, Bryde's whales were only observed between the 100- and 300-m isobaths (max. depth 302 m; Maze- Foley & Mullin, 2006) in the eastern Gulf of Mexico from south of Pensacola (head of DeSoto Canyon) to northwest of Tampa Bay, Florida (Waring et al., 2013; Rosel & Wilcox, 2014; Figure 3.1; Table S3.1). Additionally, Rice et al. (2014) deployed several autonomous recording units south of Panama City, Florida, from June through October 2010 and recorded three types of sounds putatively associated with Bryde's whales over the entire period.
Širović, Ana, et al. "Bryde's whale calls recorded in the Gulf of Mexico." Marine Mammal Science 30.1 (2014): 399-409.	Bryde's whales are the only balaenopterid regularly found in the U.S. waters of the Gulf of Mexico (GOM), with their range likely constrained to the shallow, northeastern part of the GOM around DeSoto Canyon.
Mullin, K. D., and G. L. Fulling. 2004. Abundance of cetaceans in the oceanic northern Gulf of Mexico, 1996–2001. Marine Mammal Science 20:787–807.	Ship-based, line-transect abundance surveys were conducted in oceanic waters (>200 m deep) of the northern Gulf within U. S. waters (380,432 km2) during spring from 1996 to 1997 and from 1999 to 2001. The only large whales sighted were *P. macrocephalus* (1,349; 0.23) and Bryde's whale, *Balaenoptera edeni* (40; 0.61). Cetaceans were sighted throughout the oceanic northern Gulf and, whereas many species were widely distributed, some had more regional distributions.
Maze-Foley, K. and K. D. Mullin. 2006. Cetaceans of the oceanic northern Gulf of Mexico: Distributions, group sizes and interspecific associations. Journal of Cetacean Research and Management 8:203–213.	All sightings of Bryde's whales except one were concentrated along the northeastern shelf-edge in the DeSoto Canyon area, and were in a very narrow water depth range (199-302 m), more narrow than for any other taxonomic group.
Rosel, Patricia E., and Lynsey A. Wilcox. "Genetic evidence reveals a unique lineage of Bryde's whales in	The authors compared 23 individual Bryde's whale genetic samples obtained in the Gulf of Mexico from

the northern Gulf of Mexico." Endangered Species Research 23 (2014): 19-34.	1992 to 2011 and two genetic samples from Bryde's whales that stranded in North Carolina and South Carolina to genetic sequences of Eden's whale and Bryde's whale reported by Sasaki et al. (2006). They found that the Gulf of Mexico Bryde's whale population has a unique lineage and appears to be phylogenetically most closely related to Eden's whale (*B. e. edeni*), the smaller form found in coastal and continental shelf waters of the northern Indian Ocean and the western Pacific Ocean. Bryde's whales in the Gulf of Mexico are genetically distinct from other Bryde's whales and not genetically diverse within the Gulf of Mexico.
Rice, Aaron N., et al. "Potential Bryde's whale (*Balaenoptera edeni*) calls recorded in the northern Gulf of Mexico." The Journal of the Acoustical Society of America 135.5 (2014): 3066-3076.	Several marine autonomous recording units (MARUs) were deployed in northeastern Gulf of Mexico from 2010–2012 to study the acoustic ecology of Bryde's whales (*Balaenoptera edeni*) following the Deepwater Horizon oil spill. However, the acoustic repertoire of this sub-population is poorly documented, presently limiting the efficacy of acoustic monitoring applications. Numerous stereotyped, low-frequency signals from a putative biological sound source were found throughout the recordings. Sounds fell into three categories distinguished by spectral and temporal properties. Multiple calls overlapped temporally on individual MARUs, suggesting that multiple sources produced these sounds. The basic features are similar to those from other mysticetes, but they differ from any previously published sounds. Since Bryde's whales are the most common mysticete in the Gulf and have previously been observed within the recording area on multiple occasions, it is likely that Bryde's whales are the most probable source of these sounds. These results potentially identify a suite of previously undocumented calls from Bryde's whales, which could facilitate future passive acoustic monitoring efforts to better understand the population dynamics and status of this sub-population.
Subject Matter Experts / e-NGO Reports / Regional Expertise	
Natural Resources Defense Council Notice of Petition: A petition to list the Gulf of Mexico Bryde's whale (*Balaenoptera edeni*) as endangered under the Endangered Species Act. September 18, 2014.	Petitioners requested listing of the species under the ESA as well as designation of critical habitat.
Committee or Government Reports	
NMFS, 80 FR 18343, April 06, 2015 https://www.federalregister.gov/articles/2015/04/06/2015-0783	NMFS announced the petitioned action of listing the Gulf of Mexico Bryde's whale (*B. e. edeni*) as an endangered DPS may be warranted.
Other Publications and Media	

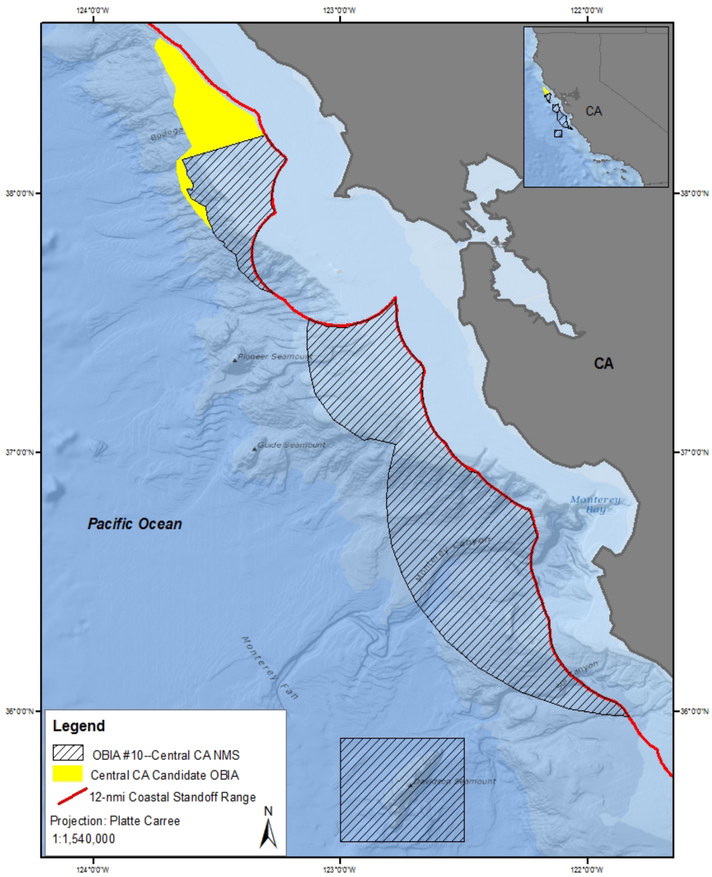
Mother Nature Network "50 whales may be a new (and very endangered) species"	http://www.mnn.com/earth-matters/animals/blogs/50-whales-may-be-a-new-and-very-endangered-species

Central California (OBIA 10 Expansion)

IUCN Marine Region: Northwest Pacific **Country**: United States

Species of Concern: Blue and humpback whales **OBIA in Regulations/LOA:** Yes

Summary:



High concentrations of blue and humpback whales have been observed foraging in an area north of and slightly west of the northern OBIA 10 boundary (Becker et al., 2012; Calambokidis et al., 2015). OBIA 10 was expanded northward and slightly west of the original northern boundary to encompass these persistent feeding aggregations of blue and humpback whales that “exceed normal averages” in the productive waters. The expansion area extends along the coastline from Sonoma County's Bodega Bay to the 39th latitude, a few miles north of Point Arena, CA. This area encompasses productive upwelling zones originating off of Point Arena and Bodega Bay, CA. The area adjacent to and offshore of Point Arena, due to seasonal winds, currents and oceanography, drives one of the most prominent and persistent upwelling centers in the world, supporting the productivity of the sanctuary (NOAA, 2014). The offshore waters of the expansion area support large populations of krill.

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: Navy created based on aggregation data of humpback and blue whales from NOAA CetMAP BIAs (NOAA, 2014) with alterations to encompass merged blue and humpback foraging areas and clipped to 12-nmi extent.

Spatial File Type: GIS shapefile

Date Obtained: 3/29/2016

Biological Criteria Status:

High Density: Not Eligible, not applicable.

Breeding/Calving: Not Eligible, not applicable.

Migration: Not Eligible, insufficient data.

Foraging: Eligible for consideration, strong justification.

Distinct Small Population: Not Eligible, not applicable.

Critical Habitat: Not Eligible, not applicable.

Seasonal Considerations

June through November (Same as existing OBIA 10)

Supporting Documentation:

Peer Reviewed Articles	
Calambokidis, J., Steiger, G. H., Rasmussen, K., Urban, J., & Darling, J. D. (2000). Migratory destinations of humpback whales that feed off California, Oregon and Washington. Mar Ecol Prog Ser, 192, 295-304.	Identified Cordell Bank, Bodega Bay, and Gulf of the Farallones as feeding areas in a study on migratory destinations of humpback whales that feed off California, Oregon, and Washington using photo-identification. Of the whales identified off Central America, 84% were resighted off California-Washington.
Calambokidis, J., Steiger, G. H., Evenson, J. R., Flynn, K. R., Balcomb, K. C., Claridge, D. E., & Dahlheim, M. E. (1996). Interchange and isolation of humpback whales off California and other North Pacific feeding grounds. Marine Mammal Science, 12(2), 215-226.	The authors identified 597 individual humpback whales off California (1986-1992, Jul - Nov and Apr-Dec) in waters extending out to 60 km from shore.
Calambokidis, J., Steiger, G. H., Curtice, C., Harrison, J., Ferguson, M. C., Becker, E., & Van Parijs, S. M. (2015). 4. Biologically Important Areas for Selected Cetaceans Within US Waters-West Coast Region. Aquatic Mammals, 41(1), 39.	Based on 9,054 visual sightings of 17,178 blue whales and 11,757 visual sightings of 27,224 humpback whales primarily from small boat surveys conducted from 1986 to 2011 by Cascadia Research and collaborators along the U.S. West Coast, the authors identified two common and persistent feeding areas of high blue and humpback whale concentrations: an area from Point Arena to Fort Bragg, CA (170 and 184 sightings respectively) and Gulf of the Farallones (1,565 and 5,196 sightings respectively). The BIA for blue whales within the Gulf of the Farallones encompasses Cordell Bank and waters west of Bodega Bay. This BIA is in agreement with areas of highest density identified in the habitat-based density (HD) models for blue whales generated from NMFS Southwest Fisheries Science Center ship surveys (see Becker et al., 2012). The BIA for humpback whales for the same region agreed closely with the single region of highest density in the mean HD models generated from NMFS Southwest Fisheries Science Center ship surveys (see Becker et al., 2012). While there is some evidence of annual variation in blue whale occurrence in sighting locations, the areas identified represent those with the more consistent occurrence year to year.
Calambokidis, J., Schorr, G. S., Steiger, G. H., Francis, J.,	The authors examined the underwater behavior of blue

Bakhtiari, M., Marshall, G. and Oleson, E. (2008). Insights into the underwater diving, feeding, and calling behavior of blue whales from a suction-cup attached video-imaging tag (Crittercam). MTS J. 31, 15 -25.	whales using a suction-cup CRITTERCAMs. They made 13 successful deployments (defined as tag duration of >15 min and successful recovery of the tag and data) totaling 19 hours of CRITTERCAMs on blue whales off California (including Bodega Canyon, Pt. Arena, Ft. Bragg, and Cordell Bank) from spring through fall between 1999-2003. Whale diving depth and behavior varied widely by region and period, although deployments on different individuals in the same area and period often showed very similar feeding behavior.
Calambokidis, J., Steiger, G. H., Cubbage, J. C., Balcomb, K. C., Ewald, C., Kruse, S., & Sears, R. (1990). Sightings and movements of blue whales off central California 1986-88 from photo-identification of individuals. Report of the International Whaling Commission (special issue 12), 343-348.	Blue whales identified in the Gulf of the Farallones have also been seen off Monterey Bay (more than 60 nmi to the south) and Point Arena (about 50 nmi to the north). Eighteen identified whales were observed in both Monterey Bay and the Gulf of the Farallones and nine whales were sighted at both Point Arena and the Gulf of the Farallones. Many of the matches between Monterey Bay and the Gulf of the Farallones span a number of years. Blue whale sightings and the matches from photo-identification indicate that the blue whales seen in the Gulf of the Farallones and Monterey Bay share a common migratory route. The timing of the sightings allows some generalizations to be made about the movements of at least a subset of the population. Blue whales enter the Sea of Cortez from February to April and occur along the west coast of Baja California from March to at least June. They begin to appear in Monterey Bay and the Gulf of the Farallones area in June and July. The resighting data from Monterey Bay to Point Arena indicate that blue whales range widely from August to November, w
Committee or Government Reports	
Office of National Marine Sanctuaries. 2014. Cordell Bank and Gulf of the Farallones National Marine Sanctuaries Expansion Final Environmental Impact Statement. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD.	Bodega Canyon has a direct ecological link with Cordell Bank NMS. It is well documented that biological productivity along the west coast is enhanced in areas down current from submarine canyons (Pereyra et al. 1969). Each night, krill and other organisms migrate from the canyon edge into the upper layers of the water column. Prevailing currents carry the zooplankton to the south over the continental shelf and away from the canyon during the night. At first light when the krill descend, instead of returning to the canyon, they are trapped on the continental shelf where they are vulnerable to shelf dwelling predators (Chess et al. 1988). This vertical migration of zooplankton out of Bodega Canyon every night provides a constant supply of food for a variety of predators

	within CBNMS. Krill is an important link in the Cordell Bank food web and primary prey for blue and humpback whales.

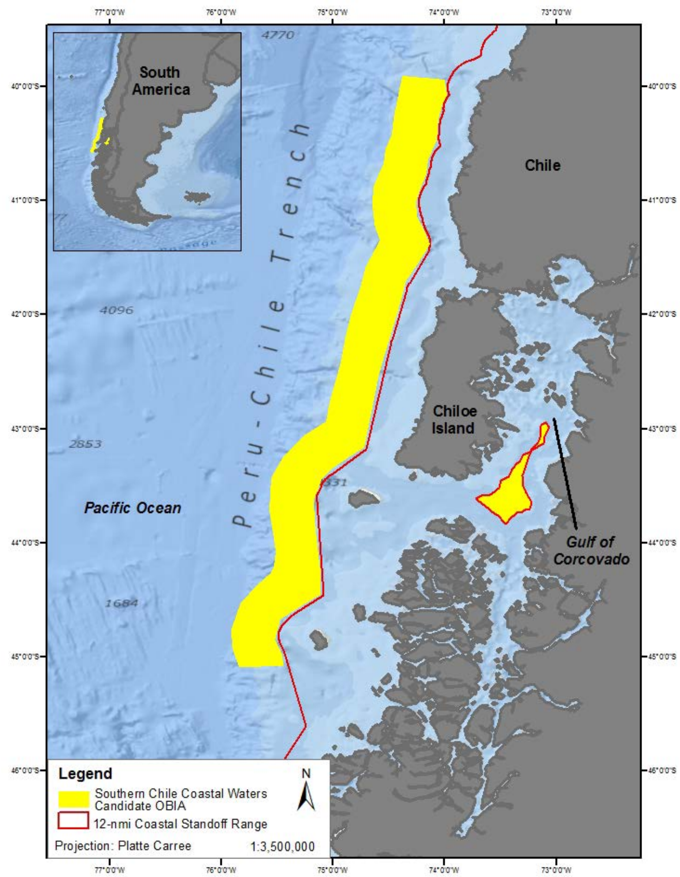
Southern Chile

IUCN Marine Region: Southeast Pacific **Country**: Chile

Species of Concern: Blue whales

Summary:

Marine mammal boat and aerial surveys have been conducted in the Gulf of Corcovado and the offshore waters along the Chile coast, especially off Chiloe Island, over the last ten years have demonstrated that these offshore area and gulf waters are the most important aggregation and foraging areas for foraging and calving blue whales in Chile and one of the largest in the Southern Hemisphere (Galletti Vernazzani et al., 2012). During aerial surveys in the Gulf of Corcovado, Hucke-Gaete et al. (2004) observed blue whale mother-calf pairs in the austral summer and early fall. These highly productive waters are not only important to the blue whale for foraging but the protected waters of gulf and inshore fjords provide the protected environment optimal for mothers nursing calves.



In addition to blue whales, other cetaceans that are fairly common in the area include humpback, sei, minke and killer whales, Peale´s, dusky and bottlenose dolphins, and Burmeister´s porpoises.

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: Navy created based on sighting data from scientific literature and clipped to 12-nmi extent.

Spatial File Type: GIS shapefile

Date Obtained: 5/4/2016

Biological Criteria Status:

High Density: Not Eligible, insufficient data.

Breeding/Calving: Eligible for consideration, adequate justification.

Migration: Not Eligible, not applicable.

Foraging: Eligible for consideration, adequate justification.

Distinct Small Population: Not Eligible, not applicable.

Critical Habitat: Not Eligible, not applicable.

Seasonal Considerations

June through November (Same as existing OBIA 10)

Supporting Documentation:

Peer Reviewed Articles	
Branch, T. A., Stafford, K. M., Palacios, D. M., Allison, C., Bannister, J. L., Burton, C. L. K., & Hucke-Gaete, R. (2007). Past and present distribution, densities and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean. Mammal Review, 37(2), 116-175.	Blue whale locations in the Southern Hemisphere were obtained from catch data, sighting records, strandings, discovery marks and recoveries, and acoustic recordings. Sighting surveys included 7,480,450 km of effort plus 14,676 days with unmeasured effort. Sighting rates (groups per 1,000 km from many platform types) varied by four orders of magnitude and were highest around Indonesia, Sri Lanka, Chile, southern Australia and south of Madagascar. This population is supported by the rich upwelling along the extent of the Humboldt Current (Carr & Kearns, 2003). Recent sighting rates from an offshore survey (Findlay et al., 1998) and from the Chiloé Island-Corcovado region (e.g. Hucke-Gaete et al., 2003; Galletti Vernazzani et al., 2006) are one to two orders of magnitude higher than those recorded in the Antarctic (from the IDCR/SOWER, JARPA and JSV surveys).
Viddi, F. A., Hucke-Gaete, R., Torres-Florez, J. P., & Ribeiro, S. (2010). Spatial and seasonal variability in cetacean distribution in the fjords of northern Patagonia, Chile. ICES Journal of Marine Science: Journal du Conseil, 67(5), 959-970.	Between December 2000 and November 2001, surveys on platforms of opportunity were undertaken in southern Chile to evaluate species richness and the spatial and seasonal distribution of cetaceans. Nine species were recorded, blue, humpback, and minke whales, Peale's dolphin, Chilean dolphin, killer whale, false killer whale, bottlenose dolphin, and Cuvier's beaked whale. The pattern of cetacean distribution displayed significant seasonal differences, with most baleen whales (mysticetes) observed during late summer and autumn, and toothed cetaceans (odontocetes) mostly during spring. Generalized additive models, used to assess the spatial distribution of cetaceans, showed that mysticetes were distributed disproportionately along a north–south gradient, in open gulfs with oceanic influence, and close to shore. In contrast, odontocetes were observed mainly within narrow channels, areas with complex coastal morphology, peaking at different water depths.
Hucke-Gaete, R., Osman, L. P., Moreno, C. A., Findlay, K. P., & Ljungblad, D. K. (2004). Discovery of a blue whale feeding and nursing ground in southern Chile. Proceedings of the Royal Society of London B: Biological	The authors conducted five aerial and two boat-based surveys during the austral summer and early autumn of 2003 to identify the general distribution of blue whales and their seasonal occurrence patterns along the

Sciences, 271(Suppl 4), S170-S173.	western coast of Chiloe´ Island, Gulf of Corcovado, Guaitecas and Chonos Archipelagos and the Moraleda Channel located in southern Chile. Aerial surveys were conducted within ~40 km from the coastline and followed saw-tooth and linear protocols. All surveys were undertaken in sea states less than 2 on the Beaufort scale at a speed of 90–130 kt and, in general, maintaining a fixed altitude of ~ 500 m (1500 ft) above sea level. Between 5 January and 1 April 2003, 47 groups comprising 153 blue whales were sighted (mean group size of 3.255; range of 1–12; including at least 11 mother–calf pairs between 0.8 and 16 km from the shore in water depths ranging between 45 and 219 m.) Although the surveys were not designed to provide an abundance estimate for blue whales in the area, the maximum number of blue whales seen in any one day suggests that the area was populated by at least 35 animals. During the study period we observed blue whale mother–calf pairs, together with feeding behavior and defaecation, which suggests that the area is mainly used by blue whales for behaviors that include feeding and nursing their young.
Torres-Florez, J. P., Hucke-Gaete, R., Rosenbaum, H., & Figueroa, C. C. (2014). High genetic diversity in a small population: the case of Chilean blue whales. Ecology and evolution, 4(8), 1398-1412.	The authors studied the genetic variability of blue whales within the southern Chilean feeding grounds of the Chilean blue whale aggregation site in order to verify the expectation of low genetic diversity in small populations. A total of 59 blue whale tissue samples were obtained from the Corcovado Gulf area, located at the northern Chilean Patagonia during the blue whale feeding seasons over seven consecutive summers (January to April, 2004–2010). The genetic variability of blue whales on their southern Chile feeding grounds was similar to that found in other Southern Hemisphere blue whale feeding grounds. Recently, a feeding ground consisting of 232 individual blue whales (coefficient of variation CV = 0.68) was discovered off the coast of southern Chile (Corcovado Gulf) (Hucke-Gaete et al. 2004, 2010). This area corresponds to one of the most important feeding aggregation areas for blue whales in the Southern Hemisphere (i.e., feeding hotspot) and is characterized by the presence of mother-calf pairs as well as solitary individuals during the austral summer and early fall season (Hucke-Gaete et al. 2004; Galletti Vernazzani et al. 2012).
Bárbara Galletti Vernazzani, B., Carlson, C. A., Cabrera,	A collaborative research program (the Alfaguara

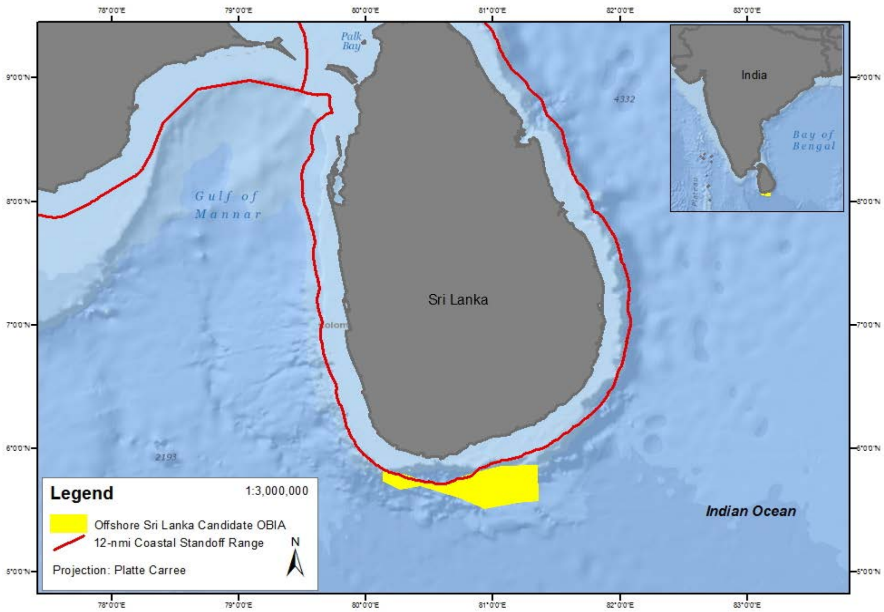
E., and Brownell, Jr., R. L. (2012). Chilean blue whales off Isla Grande de Chiloe, 2004-2010: Distribution, site-fidelity and behaviour. Journal of Cetacean Research 12(3), 353-360.	Project) has collected information on Chilean blue whales (*Balaenoptera musculus*) off Isla Grande de Chiloe, in southern Chile, through eight aerial and 85 marine surveys. A total of 363 individual blue whales was photo-identified from 2004 to 2010. Approximately 20% of all catalogued individuals were resighted within the same season and 31% were resighted between years. Recaptures of photo-identified individuals from other areas to the north and south of the main study area support the hypothesis that the feeding ground off southern Chile is extensive and dynamic. The high overall annual return and sighting rates highlight the waters off northwestern Isla de Chiloe and northern Los Lagos as the most important aggregation areas currently known for this species in Chile and one of the largest in the Southern Hemisphere. Observations on feeding and social behaviour also were recorded. These results provide important information on the conservation status of Chilean blue whales and highlight the necessity that long-term photographic identification research and line-transect surveys to monitor health conditions and population trends be continued off northwestern Isla de Chiloe. The high frequency of large vessels in the mouth of the Chacao Channel (along the north side of Isla de Chiloe) and the high number of blue whales in the area raises the possibility of vessel collisions. Therefore, it is necessary to develop and implement a conservation plan for these whales to address this and other potential threats.
Subject Matter Experts/ eNGO Reports/Regional Expertise	
IUCN Cetacean Specialist Group. (2014). Blue whales protected in the largest marine park in continental Chile	http://www.iucn-csg.org/index.php/2014/04/03/blue-whales- protected-in-the-largest-marine-park-in-continental-chile/
Theses	
Hucke-Gaete, R. (2004). Distribucion, preferencia de habitat y dinamica espacial de la ballena azul en Chile: 1997-2004.	http://146.83.150.183/handle/10533/15039
Other Publications and Media	
MPA Atlas webpage	http://www.mpatlas.org/mpa/sites/68808108/

Offshore Sri Lanka

IUCN Marine Region: Central Indian Ocean **Country**: Sri Lanka

Species of Concern: Blue whales

Summary:



Blue whale populations undertake long-range migrations between feeding and breeding grounds, those in the northern Indian Ocean remain in low latitude waters throughout the year with the implication that the productivity of these waters is sufficient to support their energy needs. A part of this population remains around Sri Lanka as supported by year-round sightings, strandings, and acoustic detections (de Vos, et al., 2014a). Studies suggest that the population remains resident because there is sufficient food in the area to offset the need to migrate (de Vos, et al., 2014a). Also, blue whales off the south coast of Sri Lanka are frequently seen to defecate and show the same high proportion of dives initiated with a fluke up suggesting that the south coast could be an important feeding area (Priyadarshana et al., 2015). Blue whales feed off the southern coast of Sri Lanka during the NE monsoon period (de Vos et al., 2014b).

The major Indian Ocean shipping lanes lie off the southern coast of Sri Lanka with separation zones extending approximately 10 km to 30 km offshore and blue whales are consistently recorded within the shipping lanes (Priyadarshana et al., 2015).

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: NMFS created shapefile based on scientific data and clipped to 12-nmi extent.

Spatial File Type: GIS shapefile

Date Obtained: 2/2/2016

Biological Criteria Status:

High Density: Eligible for consideration, adequate justification.

Breeding/Calving: Not Eligible, insufficient data.

Migration: Not Eligible, insufficient data.

Foraging: Eligible for consideration, adequate justification.

Distinct Small Population: Not Eligible, not applicable.

Critical Habitat: Not Eligible, not applicable.

Seasonal Considerations

December through April based on the inter-monsoon and NE monsoon periods

Supporting Documentation:

Peer Reviewed Articles	
Priyadarshana, T., Randage, S. M., Alling, A., Calderan, S., Gordon, J., Leaper, R., & Porter, L. (2015). Distribution patterns of blue whale (*Balaenoptera musculus*) and shipping off southern Sri Lanka. Regional Studies in Marine Science.	Surveys were conducted off the southern coast of Sri Lanka in 2014 and 2015 to investigate the distribution patterns of blue whales (*Balaenoptera musculus* spp.) in relation to current shipping lanes and further offshore. There have been several reported ship strikes of blue whales in this area and the IWC Scientific Committee has recognized the potential for ship strikes to have population level impacts on blue whales in the northern Indian Ocean. A total of 3268 km of visual survey effort was conducted on 35 survey days along north–south transects between 5°28′N and 5°53′N. A total of 193 groups of blue whales was seen during this effort with a mean group size of 1.46, resulting in a total of 281 individuals. These data were used to model patterns of whale density. The highest densities of blue whales were observed in the current shipping lanes, peaking at an average of 0.1 individuals km−2 along the westbound shipping lane. These high densities of whales combined with one of the busiest shipping routes in the world suggest a severe risk of ship strikes. Previous data on blue whale distribution and coastal upwelling indicate consistent and predictable patterns of whale distribution. Although blue whales occur in much higher densities in this area than other large whale species, the distribution of other potentially vulnerable species should be taken into account. There were eleven sightings of Bryde's whales during this study and all of these were north of 5° 36′N. Whale watching data also suggest a more coastal distribution for Bryde's whales compared to blue whales. Two large groups of sperm whales were seen during the survey transects, in both cases close to the 1000 m depth contour.
de Vos, A., Pattiaratchi, C. B., & Harcourt, R. G. (2014a). Inter-annual variability in blue whale distribution off southern Sri Lanka between 2011 and 2012. Journal of Marine Science and Engineering, 2(3), 534-550.	Given the importance of krill to foraging blue whales, and the close relationship between physical oceanographic variables and krill distribution, the authors investigated the links between salinity, sea surface temperature and blue whale distribution and abundance over the years 2009, 2011 and 2012.

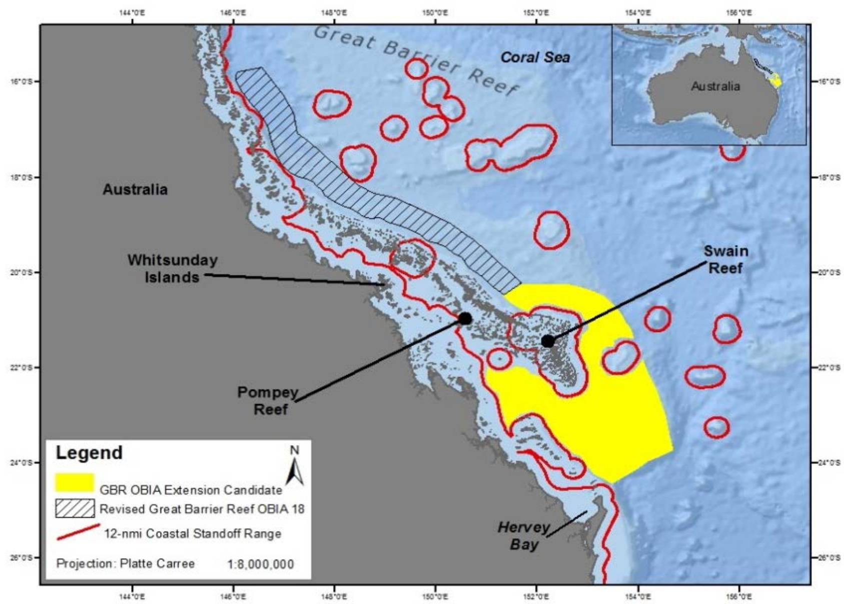
	The authors suggest that blue whale distribution off southern Sri Lanka may be influenced by anomalous rainfall resulting in excessive freshwater runoff through river discharge into the coastal waters. They also suggest that a freshwater cap may potentially influence the productivity of the inshore areas thus increasing blue whales sightings in the more saline waters.
de Vos, A. D., Pattiaratchi, C. B., & Wijeratne, E. M. S. (2014b). Surface circulation and upwelling patterns around Sri Lanka. Biogeosciences, 11(20), 5909-5930.	The major upwelling region, during both monsoon periods, is located along the southern coast, and results from flow convergence and the associated offshore transport of water. Higher surface chlorophyll concentration values were observed during the SW monsoon. The model also predicts productivity during the NE monsoon and may explain the presence of feeding blue whales during this period.
Subject Matter Experts/ eNGO Reports/Regional Expertise	
Martenstyn, H., 2013. Sri Lanka marine mammal records: Centre for Research on Indian Ocean Marine Mammals (CRIOMM), 140 pp.	A compilation of over 3,700 historical and contemporary records relating to marine mammal observation and occurrence in Sri Lankan and adjacent waters. Notes concentrations of sightings recorded around submarine canyons where whales are thought to aggregate for feeding. Martenstyn (2013) reports that blue whales are widely distributed in Sri Lankan waters, occurring in pelagic waters as well as near the continental shelf break and on the continental shelf.
Other Publications and Media	
The Centre for Research on Indian Ocean Marine Mammals	http://iomarinemammals.wix.com/criomm

Great Barrier Reef (OBIA 18 Expansion)

IUCN Marine Region: Australia/New Zealand **Country**: Australia

Species of Concern: Humpback whales **OBIA in Regulations/LOA:** Yes

Summary:



The expansion of OBIA 18, Great Barrier Reef, encompasses the Eastern Australian or E1 (IWC) breeding stock of humpback whale's breeding and calving grounds in the Great Barrier Reef-Coral Sea region off northeastern Australia. During austral winter months, E1 humpback whales migrate northward from feeding grounds in Antarctica along the eastern Australian coast to arrive in the waters of the Great Barrier Reef region, where they overwinter and also calve and breed. The first of the migratory whales enter reef waters in May, with numbers peaking in August, and then subsiding in austral spring months, with most humpback whales having returned to southern waters by late October (Great Barrier Reef Marine Park Authority 2014). Burns et al. (2014) suggested that on average, E1 humpback whales spend four weeks in the breeding/calving grounds of the Great Barrier Reef region. On the northward migration, E1 humpbacks bypass Hervey Bay and travel directly to the breeding and calving grounds further north where they apparently widely disburse; however, on the return southward migration, an estimated 30 to 50% of the returning humpbacks enter and remain in Hervey Bay for days to weeks to rest before continuing their southbound migration (Chaloupka et al. 1999; Rankin et al. 2013; Burns et al. 2014).

Although specific and clearly defined breeding and calving areas for the E1 humpback whale stock have not been detailed as they have been for stocks in other areas due largely to the vast area, the current data and information indicate that breeding and calving for the E1 humpback whale stock occur between ~16°S to 24.5°S in coastal waters of northeastern Australia east to the lagoonal waters inside the Pompey/Swains Reef complex (Chaloupka and Osmond, 1999; Fleming and Jackson 2011; Smith et al. 2012; Smith and Hedley 2013; Great Barrier Reef Marine Park Authority 2014). This area is expanded from what was previously thought to be the extent of the calving area, between ~20°S and 21°S (Simmons and Marsh 1986; Marsh et al. 1997), although a similar spatial extent from 19.5°S to 21.5°S was shown by Smith et al. (2012) and Smith and Hedley (2013) in habitat modeling and verified with survey data to provide the most suitable overwinter habitat for humpbacks. The location of the calving grounds for the Eastern Australian humpbacks can also be inferred by observation of mother-calf pairs. Mother-calf pairs are typically observed in Hervey Bay later in late-August to early October (Corkeron et al. 1994; Rankin et al. 2013) than observed for other post-yearling individuals, with 14% of the humpback groups observed in Hervey Bay including calves (Corkeron et al 1994).

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: Navy created shapefile using Australia government GIS data for emergent coral and land features, scientific literature, and clipped to 12-nmi extent.

Spatial File Type: GIS shapefile

Date Obtained: 5/4/2016

Biological Criteria Status:

High Density: Not Eligible, not applicable.

Breeding/Calving: Eligible for consideration, adequate justification.

Migration: Eligible for consideration, adequate justification.

Foraging: Not Eligible, not applicable.

Distinct Small Population: Not Eligible, not applicable.

Critical Habitat: Not Eligible, not applicable.

Seasonal Considerations

May to September, annually (same as OBIA 18)

Supporting Documentation:

Peer Reviewed Articles	
Simmons, M.L., and H. Marsh. (1986). Sightings of humpback whales in Great Barrier Reef waters. Scientific Reports of the Whales Research Institute 37:31-46.	Oral history interviews indicate that humpback whales used to winter in Great Barrier Reef waters in such numbers that they were considered a hazard to fishing, and that numbers declined dramatically coincident with whaling on the east coast of Australia in the 1950's and early 1960's. Anecdotal evidence suggests a recent increase in whale sightings in reef waters as well as at the latitudes of the former shore stations. These data suggest that most of the humpbacks which migrate along the east coast of Australia, winter in the Great Barrier Reef lagoon. Recent sightings of humpbacks tend to reflect human usage of the region. In recent years, they have been sighted near many reefs, islands and inshore areas, however, winter concentrations comparable to those seen in some other parts of the world have not been reported. This probably reflects both the vastness of the area and the low whale numbers. Calves have been seen at many places in the Great Barrier Reef lagoon. Some females apparently calve before they reach reef waters. Humpbacks have also been sighted near the northern end of the Great Barrier Reef (10°31' S) between October and January after the end of the main north-south migration.
Marsh, H., P. Arnold, C. Limpus, A. Birtles, B. Breen, J. Robins and R. Williams. (1997). Endangered and	The charismatic megafauna of the Great Barrier Reef includes 20 species of whales and dolphins, the dugong,

charismatic megafauna. Proceedings, Great Barrier Reef Science Use and Management 1:124–138.	and six species of sea turtles, several of which are listed as threatened. This fauna is highly valued by both Indigenous inhabitants and the wider community. The importance of the region to marine turtles and marine mammals was included in the World Heritage nomination. A questionnaire survey of 460 regular visitors to and workers in the Cairns Section of the Great Barrier Reef Marine Park identified the presence of megafauna as the second most important dimension in their perception of reef quality after ecological landscape. For some species, particularly loggerhead and green turtles and humpback and minke whales, tourism uses are increasingly important. Aborigines and Torres Strait Islanders wish to maintain their traditions of hunting green turtles and dugongs. Their interest in these species transcends hunting and they seek involvement in all aspects of their management. All the megafauna are long-lived, have low reproductive rates, and are difficult to monitor. Changes in population size must be large before they can be proved statistically. Declines have been detected in breeding female loggerhead turtles and in dugongs south of Cooktown. There are indications of declines in nesting green and hawksbill turtles in the Great Barrier Reef. Experimental work to separate the relative importance of impacts including habitat loss and degradation, incidental capture in fishing nets and traditional hunting (dugongs and green turtles only) is ethically unacceptable and will not provide results in a useful time frame. Consequently, it is important to minimise all these impacts.
Chaloupka, M.Y., and M. Osmond. (1999). Spatial and seasonal distribution of humpback whales in the Great Barrier Reef region. American Fisheries Society Symposium 23: 89-106.	
Smith, J. N., Grantham, H. S., Gales, N., Double, M. C., Noad, M. J., & Paton, D. (2012). Identification of humpback whale breeding and calving habitat in the Great Barrier Reef. Marine Ecology: Progress Series, 447, 259-272.	During the winter months, from June to September, humpback whales *Megaptera novaeangliae* breed and calve in the waters of the Great Barrier Reef (GBR) after migrating north from Antarctic waters. Clearly defined wintering areas for breeding and calving comparable to those identified in other parts of the world have not yet been identified for humpback whales in the GBR Marine Park (GBRMP), mainly because of its large size, which prohibits broad-scale surveys. To identify important wintering areas in the GBRMP, we developed a predictive spatial habitat model using the Maxent modelling method and presence-only sighting data from non-dedicated aerial surveys. The model was further validated using a small independent satellite tag data

	set of 12 whales migrating north into the GBR. The model identified restricted ranges in water depth (30 to 58 m, highest probability 49 m) and sea surface temperature (21 to 23°C, highest probability 21.8°C) and identified 2 core areas of higher probability of whale occurrence in the GBRMP, which correspond well with the movements of satellite tagged whales. We propose that one of the identified core areas is a potentially important wintering area for humpback whales and the other a migration route. With an estimated increase in port and coastal development and shipping activity in the GBRMP and a rapidly increasing population of whales recovering from whaling off the east Australian coast, the rate of human interactions with whales is likely to increase. Identifying important areas for breeding and calving is essential for the future management of human interactions with breeding humpback whales.
Smith, J. and Hedley, S. (2013) Breeding grounds of humpback whales in the Great Barrier Reef World Heritage Area: validation of a predictive spatial habitat model. In: 20th Biennial Conference on the Biology of Marine Mammals, 9 - 13 December, Dunedin, New Zealand.	The wintering areas for humpback whales within the Great Barrier Reef World Heritage Area (GBRWHA) have been poorly defined, mainly because of the large size of the area which prohibits broad-scale surveys. This information gap was addressed by applying predictive spatial habitat modelling using presence-only sighting data from an opportunistic sightings database. The model identified high habitat suitability for breeding humpback whales in the southern GBRWHA, which decreased as latitude decreased. However, predictive habitat modelling is seldom validated and the accuracy of models is often unchecked. We recently validated this predictive model by conducting a dedicated line transect aerial survey that subsampled three regions in the GBRWHA predicted to represent areas of low, medium and high habitat suitability. The distribution and relative abundance of whales was investigated in relation to environmental variables using GIS and generalized additive models (GAMs). Data from the dedicated survey supports the predictive habitat model, with areas of high density closely reflecting areas of high habitat suitability identified by the predictive model. Encounter rates from the aerial survey were highest (0.04 per sq. km) in the southern GBRWHA and lowest (0.002 per sq. km) in the northern GBRWHA, according to unmodelled data. Calving areas were not separate from mating areas, and groups containing calves were distributed throughout the entire GBRWHA within the same range of groups sighted without calves. The area of highest density of whales on the breeding grounds corresponded to an offshore area adjacent to two coastal cities undergoing major port expansions,

	and within the GBRWHA inner shipping route. There are many proposed and several approved port expansions along the coastline adjoining the GBRWHA. With an associated increase in shipping activity and a rapidly recovering population of whales, ship strikes with breeding humpback whales are likely to be an emerging issue in Australia.
Subject Matter Experts/ eNGO Reports/Regional Expertise	
International Fund for Animal Welfare (IFAW). (2015). Seeking sanctuary: Protecting whales in Australia's marine reserves	This report provides a national snapshot of whether marine protected areas are working for whales and dolphins in Australia. It analyses the level of protection offered by marine reserves in areas which are biologically important to these animals, and makes recommendations to the Australian Government about how these reserves could maintain or improve that protection.
Committee or Government Reports	
Australian Government. Great Barrier Reef Marine Park Authority, Great Barrier Reef Marine Park. (2014). A vulnerability assessment for the Great Barrier Reef: Humpback whales.	During the winter months, east Australian humpback whales give birth to calves and breed in the warmer waters along the east coast of Australia. The Great Barrier Reef complex represents a critical calving habitat for the East Australian humpback whale stock previously thought to be concentrated between approximately 19°S and 21°S. However, in a subsequent assessment undertaken into the distribution of humpback whales throughout the Great Barrier Reef, Chaloupka, and Osmond suggested the main area for breeding and calving extended from the islands and reefs of the Whitsunday group, south to Bundaberg and east to the lagoonal waters inside the Pompey/Swains Reef complex. The location of key calving areas was modelled in 2012 by Smith and colleagues. Their modelling indicated that areas of the highest habitat suitability for humpback whale wintering is between 19.5°S to 21.5°S,especially the area approximately 100 kilometres east of Mackay. This was supported by satellite telemetry work undertaken as part of the study. The Capricorn and Bunker group of islands were indicated to be an important migratory route and not necessarily habitat for breeding and calving
Biologically Important Areas in the Temperate East Marine Region. Commonwealth of Australia, Australian Government Department of the Environment, 2011. http://www.environment.gov.au/fed/catalog/search/resource/d	Work has been undertaken through the marine bioregional planning program to identify, describe, and map biologically important areas (BIAs) for protected species under the EPBC Act. BIAs spatially and temporally define areas where protected species display biologically important behaviours (including

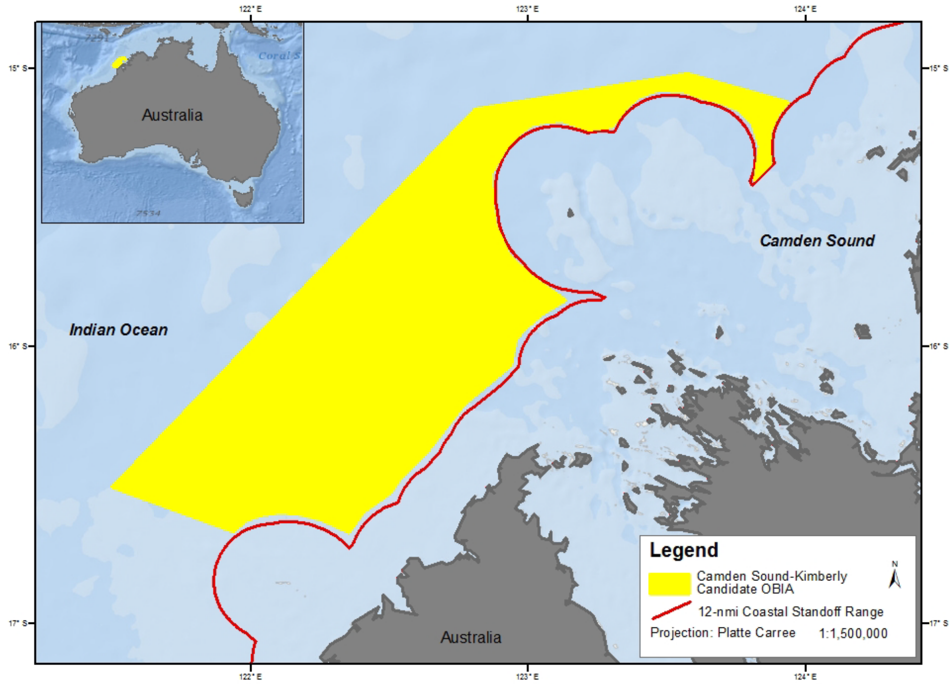
	breeding, foraging, resting or migration), based on the best available scientific information. These areas are those parts of a marine region that are particularly important for the conservation of protected species. In collecting information on BIAs, the Department has explicitly aimed to collect information about known important areas and areas that are likely to be important for a protected species. This approach was taken to ensure that the BIAs identified did not simply represent survey effort but identified areas that scientists consider are likely to be biologically important for a protected species. BIAs are accompanied by comprehensive data attributes which enable decision makers and people proposing to undertake actions that may have a significant impact on matters of national environmental significance to assess the relevance of the information to their specific circumstances. BIAs have been identified in the Temperate East Marine region for humpback whales.
Fleming, A. and and J. Jackson. (2011). Global review of humpback whales (*Megaptera novaeangliae*). NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-474. National Marine Fisheries Service, Southwest Fisheries Science Center. 209 pages.	Humpback whales along the east coast of Australia are thought to breed primarily in the waters inside the Great Barrier Reef (16-21°S) (Chittleborough, 1965; Simmons and Marsh, 1986) and are seen as far north as Murray Island at ~10°S (Simmons and Marsh, 1986). Among groups containing calves observed in the Whitsunday Islands, 47% were seen at <20m depth, while only 5.5% of non-calf groups were observed at this depth (Forestell *et al.*, 2003). An association of mothers and calves with near-shore regions in the Whitsunday Islands was observed, while non-calf groups were more widely distributed offshore (Forestell *et al.*, 2003). The range of the eastern Australian breeding ground has been hypothesized to include the Chesterfield Reefs (eastern Coral Sea 19-22S, 158-160E, Dawbin and Falla, 1949), although no studies have been conducted there.

Camden Sound

IUCN Marine Region: Australia/New Zealand **Country**: Australia

Species of Concern: Humpback whales

Summary:



The largest calving area for humpback whales in the southern hemisphere is located in the Camden Sound/Kimberley area off Northwest Australia. Each year between June and September, humpback whales arrive in very significant numbers to breed, calve and nurse their young in the warm tropical waters and protected embayments of Camden Sound, after migrating north from their feeding grounds in the Antarctic.

The humpback whale stock that winters off Western Australian is known as the Group IV population (Breeding Group D). Their migratory path covers some 3,600 nmi from calving grounds in the Kimberley (Jenner and Jenner, 1996), to feeding grounds south of 56° S and between 70° E and 110° E (Chittleborough, 1965).

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: Navy created shapefile based on Australian government GIS map data and clipped to 12 nmi extent.

Spatial File Type: GIS shapefile

Date Obtained: 5/4/2016

Biological Criteria Status:

High Density: Eligible for consideration, adequate justification.

Breeding/Calving: Eligible for consideration, adequate justification.

Migration: Eligible for consideration, adequate justification.

Foraging: Not Eligible, insufficient data.

Distinct Small Population: Not Eligible, not applicable.

Critical Habitat: Not Eligible, not applicable.

Seasonal Considerations

June through September (calving August to September)

Supporting Documentation:

Peer Reviewed Articles	
Jenner, K. C. S., Jenner, M. N., & McCabe, K. A. (2001). Geographical and temporal movements of humpback whales in Western Australian waters. Appea Journal, 38(1), 692-707.	The migratory paths of humpback whales along the Western Australian coast lie within the continental shelf boundary or 200 m bathymetry. Major resting areas along the migratory path have been identified at Exmouth Gulf (southern migration only) and at Shark Bay. The northern endpoint of migration and resting area for reproductively active whales in the population appears to be Camden Sound in the Kimberley. A 6,750 km2 area of the Kimberley region, inclusive of Camden Sound, has also been identified as a major calving ground. The northern and southern migratory paths have been shown to be divergent at the Perth Basin, Dampier Archipelago, and Kimberley regions. In all cases the northern migratory route is further off-shore. CWR data collected between 1995 and 1997 indicate that the Kimberley area is used as calving grounds by Group IV humpback whales between June and mid November. The period of peak northern migration into the calving grounds is during the last week of July. The peak of the southern migration out of the calving grounds is during the first and second weeks of September. Over this four month period, the highest numbers of cows with calves were present from the middle of August to the middle of September and were amongst the last whales to leave the calving area each year. During the CWR 1995–96 exploratory surveys of the Kimberley coast the authors sighted a total of 593 pods representing 1,039 whales, of which 110 were calves. Three identified high-density areas are within the area that NMFS and the Navy have identified for consideration. In 1997, the authors note positions of 562 pods of humpback whales sighted in the 1997 survey season within the high density areas identified in 1995-96. This includes a total of 904 individuals, inclusive of 83 calves.
Salgado Kent C.S, Jenner C.U., Jenner M.I., Bouchet P.H., Rexstad E.R. (2012). Southern Hemisphere breeding stock D humpback whale population estimates from North West Cape, Western Australia. Journal of	Aerial surveys were conducted between June and November west of NWC during 2000, 2001, 2006, 2007, and 2008, in an area where humpback whales travel within close proximity to the shore to determine migration models. A total of eight tracks 10 km apart

Cetacean Research and Management, 12(1), 29-38.	and taking about four hours to complete were surveyed consistently every year in a direction against that of the general whale migration during the northern migration and in the direction of the migration during the southern migration. A total of 3,127 whale detections were made during 74 surveys conducted over the five years. The number of whale detections varied substantially amongst survey days which resulted in highly variable daily abundance estimates. As a consequence of the high variability, the migration models also varied widely in how well they fit the daily estimates. Pod abundance for each flight was computed using a Horvitz Thompson like estimator and converted to an absolute measure of abundance after corrections were made for estimated mean cluster size, unsurveyed time, swimming speed and animal availability. Resulting estimates from the migration model of best fit with the most credible assumptions were 7,276 (CI = 4,993–10,167) for 2000, 12,280 (CI = 6,830–49,434) for 2001, 18,692 (CI =12,980–24,477) for 2006, 20,044 (CI = 13,815–31,646) for 2007, and 26,100 (CI = 20,152–33,272) for 2008.
Chittenborough, R. G. (1965). Dynamics of two populations of the humpback whale (*Megaptera novaeangliae*). Australian Journal of Marine and Freshwater Research 16, 33-128.	Results of studies of the structure and dynamics of two humpback whale stocks of the southern hemisphere are drawn together. Estimates are made of recruitment and mortality rates, and an assessment is made of the yields to be taken from these stocks under various conditions. The two stocks are shown to be, in the main, independent of one another although there is a negligible sporadic exchange between them. The group V stock is shown to fragment, but probably randomly, in its northern migration. Decline in the abundance of these groups, group IV steadily since 1954 and group V sharply since 1959, is described. The group IV stock probably consisted of 12,000-17,000 individuals in its unfished stale, of about 10,000 individuals in 1949, and no more than 800 in 1962. The group V stock probably contained about 10,000 individuals in its unfished state, but only 500 or less in 1962. In its present state, group IV could give a sustainable yield of 18 (range 4-32) whales, and group V of 12 (range 3-21) whales. The maximum yields these stocks could sustain in completely regenerated state are: group IV, 390 whales per year; group V, 330 whales per year. Group IV would require 28-49 years to reach that state, group V would require 36-63 years.
Subject Matter Experts/ eNGO Reports/Regional Expertise	

International Fund for Animal Welfare (IFAW). (2015). Seeking sanctuary: Protecting whales in Australia's marine reserves.	This report provides a national snapshot of whether marine protected areas are working for whales and dolphins in Australia. It analyses the level of protection offered by marine reserves in areas which are biologically important to these animals, and makes recommendations to the Australian Government about how these reserves could maintain or improve that protection.
Hoyt, E. (2011). Marine protected areas for whales, dolphins and porpoises: a world handbook for cetacean habitat conservation and planning (2nd Ed.). Earthscan, London.	A large special purpose zone (whale conservation) is designated. Special management arrangements will enhance protection of the humpback mothers and calves in the whale calving area of Camden Sound. This zone covers approximately 649 sq mi (1680 sq km) of the proposed marine park.
Knowles, T., and R. Campbell. "What's a whale worth." Valuing whales for National Whale Day (2011). Final Report prepared for the International Fund for Animal Welfare.	Whales between Broome and Camden Sound. The Kimberley CetaceanSurvey was conducted by local operators and other stakeholders in 2009 (Costin and Sandes, 2009). They estimated the number of whales from south of Broome to the Prince Regent River, an area including Camden Sound, an important resting and calving area and the northernmost point of the western Australian humpback population's migration (Jenner et al, 2001). Costin and Sandes sighted 969 humpback whales between Broome and the Prince Regent River. Many of these whales were sighted in the Camden Sound (Jenner et al, 2001).
Holyoake, C., N. Stephens, and D. Coughran. "Collection of baseline data on humpback whale (*Megaptera novaeangliae*) health and causes of mortality for long-term monitoring in Western Australia." (2012).	The aim of this project was to initiate the collection of data by post- mortem examination of stranded whales in 2011 in order to: 1) identify and characterise factors associated with strandings; and 2) determine baseline and epidemiological information on disease and the nutritional status of stranded whales. In 2011 there were 17 strandings consisting of 14 calves and 3 juveniles/sub-adults. Unlike the age categories reported for 1989 – 2009 (44% of strandings were calves of that year [i.e. calves born in that calendar year/breeding season], 37% were juveniles/sub-adults and 19% were adults) and in 2010 (31% of strandings were calves of that year, 63% were juveniles/sub-adults and 6% were adults) most of the strandings in 2011 were neonates with most animals thought to be less than 48 hours of age. Furthermore, there was no evidence of anthropogenic activity (e.g. ship strike/entanglement) associated with any of the 2011 strandingsAll reported strandings occurred between Exmouth and Stokes Inlet east of Esperance. Thus all stranded neonates were born at least 1000 km south of the currently known breeding grounds between Broome and the northern

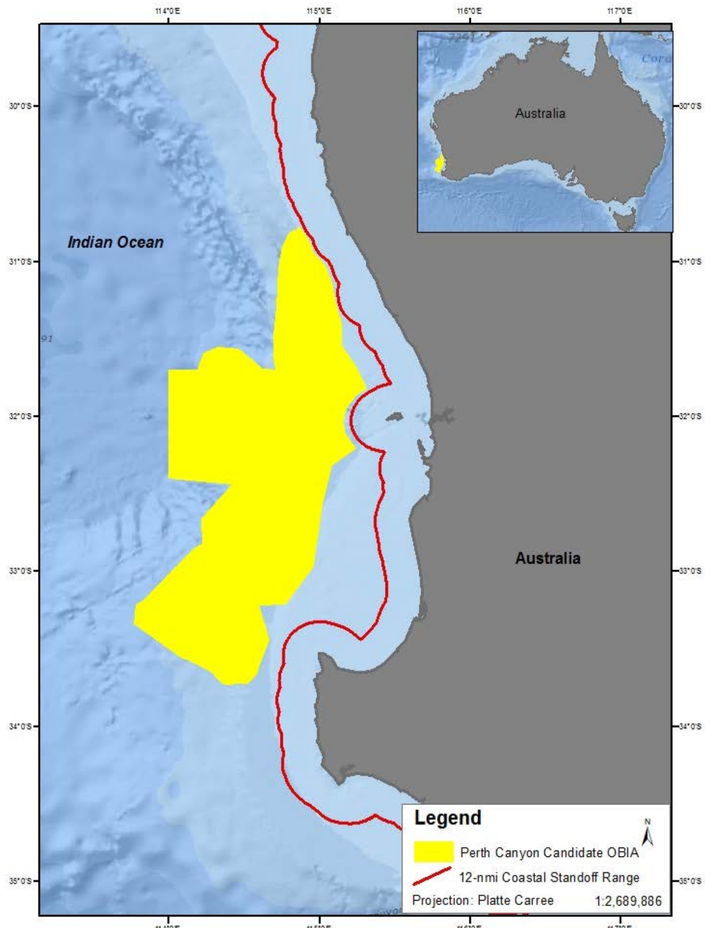
	end of Camden Sound. The Southern Kimberley between Broome and the northern end of Camden Sound are the current known calving grounds for BSD (Jenner et al. 2001). The neonates that stranded in 2011 were thus born very far south of the known breeding grounds. There are however historic reports of calves being born as far south as Albany (Chittleborough, 1965) but it is unknown whether they survived. Chittleborough (1965) reported that following parturition in the Albany region the cows continued to move northwards during the first few weeks of lactation.
Other Publications and Media	
Australian Marine Conservation Society: Camden Sound Marine Park	http://www.marineconservation.org.au/pages/camden-sound-marine-park.html

Perth Canyon

IUCN Marine Region: Australia/New Zealand **Country**: Australia

Species of Concern: Pygmy blue whales (added protection for sperm whales)

Summary:



The declaration of the Perth Canyon Marine Reserve, off Western Australia established a marine sanctuary for the biologically important feeding grounds for blue and sperm whales. This includes some of the feeding grounds between Cape Naturaliste and Jurien Bay.

Perth Canyon promotes localized upwelling and enhances both pelagic production and physical aggregation of plankton to attract the whales. Canyon processes contribute favorably to the appearance of feeding blue whales in the Perth Canyon during the summer. McCauley et al. (2001) reported deep feeding pygmy blue whales in the Perth Canyon (32° S on the Western Australian coast). Rennie et al. (2009) reports on the biological oceanography of the Perth Canyon and how it's related to observations of feeding pygmy blue whales.

Perth Canyon represents a significant feeding ground for pygmy blue whales between January and April (McCauley and Jenner, 2010) where these whales feed at depths of 200 to 300 meters in the canyon from January to May (with feeding peaking in the area from March to May).

Geographic Criteria Status:

Location Status: Eligible. Biologically important behaviors occur beyond 12 nmi from any land/emerged feature.

Spatial File Source: WDPA shapefile for Perth Canyon Marine Park as the basis, with NMFS adjusted boundaries based of IFAW maps of foraging areas for blue and sperm whales, and Navy clipping shapefile to 12 nmi extent.

Spatial File Type: GIS shapefile

Date Obtained: 5/4/2016

Biological Criteria Status:

High Density: Eligible for consideration, requires more data.

Breeding/Calving: Not Eligible, not applicable.

Migration: Not Eligible, not applicable.

Foraging: Eligible for consideration, adequate justification.

Distinct Small Population: Not Eligible, not applicable.

Critical Habitat: Not Eligible, not applicable.

Seasonal Considerations

January through May

Supporting Documentation:

Peer Reviewed Articles	
Gales NI, Double MC, Robinson SA, Jenner CU, Jenner MI, King ER, Gedamke JA, Childerhouse SI, Paton DA. (2010). Satellite tracking of Australian humpback (*Megaptera novaeangliae*) and pygmy blue whales (*Balaenoptera musculus brevicauda*). White paper presented to the Scientific Committee of the International Whaling Commission.	The authors describe the deployment of satellite tags on southbound Stock D (west Australian) humpback whales, northbound Stock E (east Australian) humpback whales and on pygmy blue whales in the Perth Canyon off Western Australia. These studies aimed to describe the migratory pathways of humpback and blue whales migrating along the coast of Australia and to identify possible calving areas for the eastern Australian humpback whales which have yet to be clearly identified
Rennie, S., Hanson, C. E., McCauley, R. D., Pattiaratchi, C., Burton, C., Bannister, J., & Jenner, M. N. (2009). Physical properties and processes in the Perth Canyon, Western Australia: Links to water column production and seasonal pygmy blue whale abundance. Journal of Marine Systems, 77(1), 21-44.	The oceanography of the Perth Canyon, off southwestern Australia, was examined through two major field excursions in austral spring/summer 2003/2004 combined with previous results from field analysis and numerical simulations. Water properties were used to identify water masses and vertical displacement. The field cruises and numerical simulation indicated unique circulation features of the Leeuwin Current and Undercurrent within the canyon associated with the topographic features. The input of nutrients to the euphotic zone occurred sporadically as the Leeuwin Current generally suppressed upwelling, although the Perth Canyon had increased nutrient concentrations within its rims. The distribution of chlorophyll in the surface layers indicated high spatial variability, with a prevalent deep chlorophyll (and phytoplankton biomass) maximum at ~ 80 m. Depth-integrated primary production within the study region ranged from 360 to 760 mg C m− 2 d− 1, which was on average 2.5 times higher than rates measured in continental shelf and offshore waters north of the canyon. Aggregations of krill and other acoustic backscatter targets were concentrated near the head of the canyon at a range of depths, which may have been promoted by the circulation. The findings here are consistent with seasonal variations in wind and insolation, along with variations

	in the Leeuwin Current, influencing the seasonal changes and mesoscale features within the region, while the canyon promotes localized upwelling, and enhances both pelagic production and physical aggregation of plankton to attract the whales. Canyon processes must be combined with outside factors to allow upwelled nutrients to reach the photic zone. It is concluded that a combination of factors, rather than one factor alone, contributes favorably to the appearance of feeding blue whales in the Perth Canyon during the summer.
Rennie, S. J., McCauley, R. D., & Pattiaratchi, C. B. (2006). Thermal structure above the Perth Canyon reveals Leeuwin Current, Undercurrent and weather influences and the potential for upwelling. Marine and freshwater research, 57(8), 849-861.	The Perth Canyon is a focal feeding area for pygmy blue whales on the Western Australian coast. Studies aimed at elaborating oceanographic mechanisms within the canyon were conducted between 2002 and 2005. Strings of temperature loggers set around the canyon rim were used to examine the water column's response to climatological forcing, current meanders, upwelling and downwelling. Six moorings were positioned on a plateau in 500 m of water on the northern canyon rim, and one was positioned at the canyon head. Loggers were positioned to sample the whole water column, including the Leeuwin Current and Undercurrent. Moorings revealed spatial temperature differences between the plateau and canyon head. Observed temperature features ranged temporally from seasonal to <1 day. Seasonal changes in water temperature agreed with published Leeuwin Current studies.
McCauley, Robert D., et al. (2000) "Blue whale calling in the Rottnest trench, Western Australia, and low frequency sea noise." Australian Acoustical Society Conference, Joondalup, Australia. 2000. Prepared for Environment Australia, from Centre for Marine Science and Technology, Curtin University, R2001-6, 55 pp.	Through January-April 2000 research was carried out off the Rottnest trench to search for blue or pygmy blue whales. A consortium of researchers carried out aerial surveys, boat based studies and acoustical measures. Historical records led us to believe that a Western Australian population of pygmy blue whales (*Balaenopteridae musculus brevicauda*, subspecies of the true blue whale, *B. m. musculus*) existed, while a preliminary boat survey in 1994 suggested that some of these animals aggregated in the Rottnest trench west of Perth. This was confirmed in the early 2000 observations, in 30 days boat based searching 17 pygmy blue whales were sighted. Five thousand acoustic records were made, almost all of which had blue/pygmy blue whale calling in, some having up to six animals calling at once. Although of a slightly different format, recorded call components were of a similar character to those described from other populations. Also common were impulsive 'clicking' calls which were shorter than the 12-23 s blue whale call components and of low to very low

	frequency (< 1 Hz to 20 Hz). The literature suggests these are produced by fin whales but none were sighted. The low frequency (< 100 Hz) sea noise spectra from a series of 90 s recordings made every 10 minutes for 33.5 days was dominated was dominated by blue whale calling
Subject Matter Experts/ eNGO Reports/Regional Expertise	
Double, M. C., Jenner, K. C. S., Jenner, M. N., Ball, I., Laverick, S., & Gales, N. (2012). Satellite tracking of pygmy blue whales (*Balaenoptera musculus brevicauda*) off Western Australia. Final Report. Australian Marine Mammal Centre, Australian Antarctic Division.	This study aimed to describe the migratory distribution and behaviour of pygmy blue whales that feed in the Perth Canyon region off the coast of Western Australia. A total of twelve tags were successfully deployed on blue whales between the 14th March and the 6th April although four performed poorly with no uplinks, only Z class data or the tag ceased transmitting within a few days of deployment. The 10 whales that provided some location data were tracked from 1 to 162 days (mean = 43.3 days; SD = 47.8) for a total of 20,621 km (mean = 2,291 km; max: 8,815) and the total net distance moved from the first to last location was 9,606 km (mean = 1,067 km; max: 3227 km). Following tagging several whales remained in the Perth Canyon Naturaliste Plateau for over a month whereas others migrated north immediately. On their migration north the tagged whales were located offshore (usually between 40 and 100 km) and showed distinct changes from high (~100 km/day) to lower (<50 km/day) travel distances. These data also show that the greater Perth Canyon Naturaliste Plateau region of Western Australia is a region of high and often prolonged activity for these whales.
Center for Whale Research - Western Australia. (2005). Perth Canyon Update.	John Bannister (Team scientist for the Western Australian Blue Whale Project) discovered a congregation of blue whales near the Canyon in 1994 and eventually secured funding from Environment Australia (now Department of Environment and Heritage) to conduct a pilot study over 2 seasons, beginning in 2000. Once the team established that there were consistent and relatively high densities of blue whale sightings in their main exercise area, the Defense Department established a proactive partnership with a consortium of research groups in 2002.
Committee or Government Reports	

McCauley, R. D., & Jenner, C. (2010). Migratory patterns and estimated population size of pygmy blue whales (*Balaenoptera musculus brevicauda*) traversing the Western Australian coast based on passive acoustics. IWC SC/62/SH26.	Passive acoustic data sets along the Western Australian coast have revealed annual south-north migrations of pygmy blue whales. At the latitude of Exmouth (21 o 30' S) a sharp southerly travelling pulse of pygmy blue whales is experienced each year over October to late December, while a more protracted northerly pulse of returning animals is detected over the following April to August. It is believed the south-bound pulse of animals passing Exmouth is steadily migrating. The passive acoustic detections of pygmy blue whales off Exmouth have been converted to instantaneous counts of the number of individual whales calling. By assuming a range of proportions of animals calling of from 8.5-20% of total pygmy blue whales in the area, the number of individual whales calling has been converted to estimates of the number of whales in the noise logger listening area, at 15 minute increments across the southerly migratory pulse. This curve was integrated across the migratory season. The listening range of the noise logger and the whale swim speed along a known route were used to give whale residency time in the noise logger listening area. The integrated curve of whale days was divided by the residency time to give an estimate of 662-1559 pygmy blue whales passing the noise logger site during the 2004 southerly migratory pulse down the Western Australian coast. We know pygmy blue whales reside along the east Australian coast and in the southern Indian Ocean, thus the population estimate for Western Australia is a portion of the larger Indian and western Pacific pygmy blue whale population