BIOLOGICAL EVALUATION FOR TRAINING AND TESTING ACTIVITIES ASSOCIATED WITH USE OF SURVEILLANCE TOWED ARRAY SENSOR SYSTEM LOW FREQUENCY ACTIVE (SURTASS LFA) SONAR; REINITIATION OF SECTION 7 CONSULTATION

DEPARTMENT OF THE NAVY
CHIEF OF NAVAL OPERATIONS

AMENDED DECEMBER 2018

BIOLOGICAL EVALUATION FOR SURVEILLANCE TOWED ARRAY SENSOR SYSTEM LOW FREQUENCY ACTIVE (SURTASS LFA) SONAR, 2019 TO 2024

ENDANGERED SPECIES ACT SECTION 7 CONSULTATION

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ABBREVIATIONS AND ACRONYMS

Acronym	Definition
°	degrees
µ	micro
<	less than
>	greater than
AEP	auditory evoked potential
AIM	Acoustic Integration Model©
AM	amplitude modulated
APPS	Act to Prevent Pollution from Ships
ASW	anti-submarine warfare
BE	Biological Evaluation
BIA	biologically important area
BO	Biological Opinion
CH	critical habitat
CI	confidence interval
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLFA	Compact Low Frequency Active
CFR	Code of Federal Regulations
CNP	Central North Pacific
CPUE	catch per unit effort
CV	coefficient of variation
CW	continuous wave
CWA	Clean Water Act
dB	decibel
dB re 1 µPa @ 1 m	decibels relative to 1 microPascal at 1 meter from the source
dB re 1 μPa^2-sec	decibels of the time integral (summation) of the squared pressure of a sound event
DoN	United States Department of the Navy
DPS	distinct population segment
ECS	East China Sea
EEZ	exclusive economic zone
EIS	Environmental Impact Statement
ENP	Eastern North Pacific
ESA	Endangered Species Act
ESU	evolutionarily significant unit
ETP	Eastern Tropical Pacific
FAO	Food and Agriculture Organization of the United Nations
ft	foot/feet
FM	frequency modulated
HF	high frequency
HF/M3	high frequency marine mammal monitoring
HLA	horizontal line array
Hz	Hertz
IMMAs	Important Marine Mammal Areas
IND	Indian
ITS	Incidental Take Statement
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
J	joule(s)
km	kilometer(s)
km^2	kilometers squared
kph	kilometer(s) per hour
kt	knot(s)
LF	low frequency
LFA	Low Frequency Active
LFS SRP	Low-Frequency Sound Scientific Research Program
LOA	Letter of Authorization
m	meter(s)
M	million(s)
MARPOL 73/78	International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978
MF	mid-frequency
MHI	Main Hawaiian Islands

Acronym	Definition
MILCREW	military crew
min	minute(s)
MMPA	Marine Mammal Protection Act
MPA	marine protected area
msec	millisecond(s)
Navy	U.S. Department of the Navy
NDAA	National Defense Authorization Act
NDE	National Defense Exemption
NIND	Northern Indian
NMSDD	Navy Marine Species Density Database
NMFS	National Marine Fisheries Service
nmi	nautical mile(s)
nmi^2	square nautical miles
NOAA	National Oceanic and Atmospheric Administration
NP	North Pacific
NWHI	Northwest Hawaiian Islands
OAWRS	Ocean Acoustic Waveguide Remote Sensing
OBIA	offshore biologically important area
OEIS	Overseas Environmental Impact Statement
OPR	Office of Protected Resources
OW	otariid underwater
Pa	Pascal
PCE	primary constituent element
PO	phocid in water
PTS	permanent threshold shift
PW	phocid underwater
rms	root-mean-square
RL	received level
SAR	Stock Assessment Report
sec	second(s)
SEIS	Supplemental Environmental Impact Statement
SEL	sound exposure level
SEL_{cum}	cumulated sound exposure level
SIND	Southern Indian
SL	source level
SOEIS	Supplemental Overseas Environmental Impact Statement
SPE	single ping equivalent
SPL	sound pressure level
SURTASS	Surveillance Towed Array Sensor System
T-AGOS	Tactical-Auxiliary General Ocean Surveillance
TL	transmission loss
TL-29	twin line
TTS	temporary threshold shift
UNEP	United Nations Environment Programme
U.S.	United States
U.S.C.	United States Code
USFWS	United States Fish and Wildlife Service
USNS	United States Naval Ship
VLA	vertical line array
WAU	Western Australia
WNP	Western North Pacific
yd	yard(s)
yr	year(s)

1 PURPOSE AND NEED

1.1 Introduction

The Department of the Navy (DoN; hereafter, the Navy) is requesting initiation of Section 7 consultation under the Endangered Species Act (ESA) for the continued use of Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) and compact LFA sonar (CLFA) sonar systems onboard Navy surveillance ships for training and testing activities conducted under the authority of the Secretary of the Navy in the western and central North Pacific and eastern Indian oceans. This does not include use of SURTASS LFA sonar in armed conflict, direct combat support operations, or use of SURTASS LFA sonar in support of military operations directed by the National Command Authority. In this Biological Evaluation (BE), the terms "SURTASS LFA sonar" or "SURTASS LFA sonar systems" are inclusive of both the LFA and CLFA sonar systems, each having similar acoustic operating characteristics.

The testing and training activities[1] associated with the use of SURTASS LFA sonar, particularly the transmission of underwater sound, have the potential to affect ESA-listed marine and anadromous fish, sea turtle, and marine mammal species and their critical habitat in the western and central North Pacific and eastern Indian oceans. As a result, this BE was prepared by the Navy to address the training and testing activities using SURTASS LFA sonar and the associated potential effects in compliance with Section 7 of the ESA, which ensures that, through consultation with the National Marine Fisheries Service (NMFS), federal actions are not likely to jeopardize the continued existence of any threatened or endangered species under the ESA or result in the destruction or adverse modification of critical habitat. The Navy has considered the potential effects to ESA-listed species or distinct population segments (DPSs) and critical habitat likely to be present in the study area for SURTASS LFA sonar training and testing activities and has concluded that its training and testing activities using SURTASS LFA sonar 1) may affect but are not likely adversely affect marine and anadromous fishes and sea turtles, 2) may affect and are likely to adversely affect marine mammals, and 3) may affect but are not likely to adversely affect the primary constituent elements of designated critical habitat. Accordingly, the Navy requests consultation and a Biological Opinion (BO) from NMFS on the likelihood of the Navy's proposed training and testing activities using SURTASS LFA sonar from August 13, 2019 into the foreseeable future to jeopardize ESA-listed species or destroy or adversely modify their designated critical habitat. The Navy also requests an Incidental Take Statement (ITS) for the taking of ESA-listed marine mammals and sea turtles incidental to the use of SURTASS LFA sonar for training and testing activities for the time period of August 13, 2019 through August 12, 2026.

In conjunction with this BE, the Navy has developed a Draft Supplemental Environmental Impact Statement/Overseas Environmental Impact Statement (SEIS/SOEIS) to comprehensively consider and assess the environmental impacts associated with use of SURTASS LFA sonar systems into the foreseeable future. NMFS Office of Protected Resources (OPR) is a cooperating agency, in accordance with 40 CFR section 1501.6, on the development of the SEIS/SOEIS for SURTASS LFA sonar. In addition, the Navy has submitted an application for rulemaking and a Letter of Authorization (LOA) under the Marine Mammal Protection Act (MMPA) for the incidental taking of marine mammals resulting from the continued use of SURTASS LFA sonar systems for training and testing activities in the western and central North Pacific and eastern Indian oceans for the period from August 13, 2019 through August 12,

1 Throughout this BE, the terms "training and testing activities" or "SURTASS LFA sonar activities" are used synonymously to describe the proposed action of training and testing conducted under the Secretary of the Navy's authority.

2026. The National Defense Authorization Act (NDAA) for Fiscal Year 2019 (Public Law 115-232) extended the periods of permitted incidental taking under the MMPA from five years to seven years for military readiness activities. The Navy's application for incidental taking of marine mammals under the MMPA resulting from SURTASS LFA sonar training and testing activities reflected this temporal extension, as does the period of ITS coverage requested in this BE.

The Navy is currently conducting SURTASS LFA sonar activities under the BO and ITS issued by NMFS on August 11, 2017 that covers the period from August 2017 through August 2022. Additionally, on August 10, 2017, in consultation with the Secretary of Commerce and pursuant to Title 16, Section 1371(f) U.S.C., the Secretary of Defense determined that it was necessary for national defense to exempt all military readiness activities that use SURTASS LFA sonar from compliance with the requirements of the MMPA for two years from August 13, 2017 through August 12, 2019, or until such time when NMFS issues regulations and a LOA under Title 16, Section 1371 for military readiness activities associated with the use of SURTASS LFA sonar, whichever is earlier. During the two-year exemption period, all military readiness activities that involve the use of SURTASS LFA sonar are required to comply with all mitigation, monitoring, and reporting measures set forth in the 2017 National Defense Exemption (NDE) for SURTASS LFA sonar.

The Navy has revised the geographic scope of SURTASS LFA sonar training and testing activities to reflect only those areas of the world's oceans where the Navy anticipates conducting SURTASS LFA sonar activities (i.e., training and testing conducted under the authority of the Secretary of the Navy); the Navy has provided detail on the types of SURTASS LFA sonar training and testing activities herein (Section 2.1). The revised geographic scope for this BE, the western and central North Pacific and eastern Indian oceans outside of foreign nations' territorial seas, would allow the Navy to more accurately assess and describe those effects associated with SURTASSS LFA sonar training and testing activities in ocean areas where the Navy expects to conduct these activities.

1.2 Purpose and Need of Proposed Action

The Navy's statutory mission is to train and equip naval forces that are combat-ready and capable of accomplishing America's strategic objectives, deterring maritime aggression, and maintaining freedom of navigation in ocean areas (10 U.S.C. Section 5062). By law, the Secretary of the Navy is responsible for functions such as training, supplying, equipping, and maintaining naval forces that are ready to achieve national security objectives as directed by the National Command Authority. Preparing and maintaining naval forces skilled in anti-submarine warfare (ASW) is a critical part of the Navy's 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, the distance at which submarine threats can be detected decreases due to these quieting technologies and 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 uses SURTASS LFA sonar to meet the need for long-range submarine detection and surveillance. SURTASS LFA sonar can be used day and night in a variety of weather conditions, and its active acoustic component is an important augmentation to passive and tactical Navy systems.

The purpose of the Navy's Proposed Action is to perform training and testing activities that ensure the Navy remains proficient in the use of SURTASS LFA sonar in support of the Navy's mission. The need for the Proposed Action is to maintain a system capable of detecting at long ranges the increasingly technologically advanced foreign submarine presence that threatens our national security.

2 DESCRIPTION OF THE PROPOSED ACTIVITIES AND STUDY AREA

2.1 Proposed Activities

The Navy proposes to continue utilizing SURTASS LFA sonar systems onboard United States Naval Ship (USNS) surveillance ships for training and testing activities conducted under the authority of the Secretary of the Navy in the western and central North Pacific and eastern Indian oceans into the foreseeable future. These training and testing activities do not include use of SURTASS LFA sonar in armed conflict, direct combat support operations, or use of SURTASS LFA sonar in support of military operations directed by the National Command Authority.

The Navy currently operates four ocean surveillance ships equipped with SURTASS LFA sonar systems: 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 Navy may develop and field additional SURTASS LFA sonar equipped vessels, either to replace or complement the Navy's current SURTASS LFA sonar-capable fleet. The Navy proposes to use SURTASS LFA sonar systems onboard these surveillance vessels to conduct training and testing activities within the study area, which includes the western and central North Pacific and eastern Indian oceans outside foreign nations' territorial seas.

Currently under the NDE, the Navy is approved to transmit a maximum of 255 hours of LFA sonar transmission hours per vessel per year, or 1,020 total sonar transmission hours per year. The Navy proposes to transmit a maximum of 496 total hours of LFA sonar transmissions per year pooled across all SURTASS LFA sonar-equipped vessels in the first four years of the authorization period, with increased sonar usage of a maximum of 592 total hours of LFA sonar transmissions in Year 5 through 7 and continuing into the foreseeable future, regardless of the number of vessels.

The increased sonar hours in Year 5 onward are planned to allow for potential testing of new sonar systems and vessels the Navy is planning to add to its SURTASS LFA sonar-capable fleet. In Years 5 through 7 of the proposed seven-year authorization period, the Navy is planning to add new vessels to its ocean surveillance fleet. As new vessels are developed, the onboard LFA and HF/M3 sonar systems may also need to be updated, modified, or even re-designed. As the new vessels and sonar system components are developed and constructed, at-sea testing would eventually be necessary. The Navy anticipates that new vessels or new or updated sonar system components may be ready for at-sea testing beginning in the fifth year of the effective period covered by this BE. Thus, the Navy's activity analysis included consideration of the sonar hours associated with future testing of new or updated LFA sonar system components and new ocean surveillance vessels. This consideration resulted in two scenarios of annual LFA sonar transmit hours: Years 1 to 4 would entail total 496 sonar hours per year across all SURTASS LFA sonar vessels, while Years 5 through 7 and continuing into the foreseeable future would include an increase to 592 sonar hours total across all vessels to accommodate the estimated future testing of new ocean surveillance vessels and new or updated sonar system components.

The SURTASS LFA sonar transmission hours represent a distribution across six training and testing activities including:

- Contractor crew proficiency training (80 hours per year)
- Military crew (MILCREW) proficiency training (96 hours per year)
- Participation in or support of naval exercises (96 hours per year)

- Vessel and equipment maintenance (64 hours per year)
- Acoustic research testing (160 hours per year)
- New SURTASS LFA sonar system testing (96 hours per year; only in year 5 and beyond)

Each of these activities utilizes the SURTASS LFA sonar system within the operating profile that follows. Thus, the number of hours estimated for each activity is intended only for planning purposes.

The Navy proposes to implement procedural and geographic mitigation measures in association with the use of SURTASS LFA sonar for training and testing activities. Specifically, the Navy's geographic mitigation measures include no SURTASS LFA sonar training and testing activities being conducted within the territorial seas of foreign nations and ensuring that received levels (RLs) of LFA sonar transmissions are below 180 decibels relative to 1 microPascal (root-mean squared) (dB re 1 µPa [rms]) within 12 nautical miles (nmi) (22 kilometers [km]) of any emergent land and at the boundary of any designated offshore biologically important areas (OBIAs) for marine mammals during their effective periods of important biological activity. Of the 29 existing OBIAs for SURTASS LFA sonar, four are located within the proposed study area of the western and central North Pacific and eastern Indian oceans.

Procedural mitigation measures include visual, passive acoustic, and active acoustic (high frequency marine mammal monitoring [HF/M3] sonar) monitoring to minimize effects to marine animals during SURTASS LFA sonar training and testing activities by providing the means to detect marine mammals and sea turtles in the LFA mitigation zone and to then suspend or delay LFA sonar transmissions. Additionally, the RLs of LFA sonar training and testing transmissions would not exceed 145 dB re 1 µPa (rms) within known recreational dive sites.

2.2 Description of the SURTASS LFA Sonar System

SURTASS LFA sonar is a long-range system operating in the low frequency (LF) band (i.e., below 1,000 Hertz [Hz]) and includes both active and passive components (Figure 2-1). The active component is the LFA sonar source array while the passive component is the SURTASS receive array. Sonar is a term that is used define 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 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. Passive sonar detects the one-way transmission of sound waves through water from the source to the receiver. This is the same method by which people hear sounds that are created by a source and transmitted through the air to the human ear. Very simply, passive sonar "listens" or receives sound signals without sending or transmitting any sound signals itself.
- Active sonar detects objects by creating a sound pulse or "ping" that travels through the water and reflects off a target, then returns as an echo that is detected by a receiver (such as SURTASS). 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.

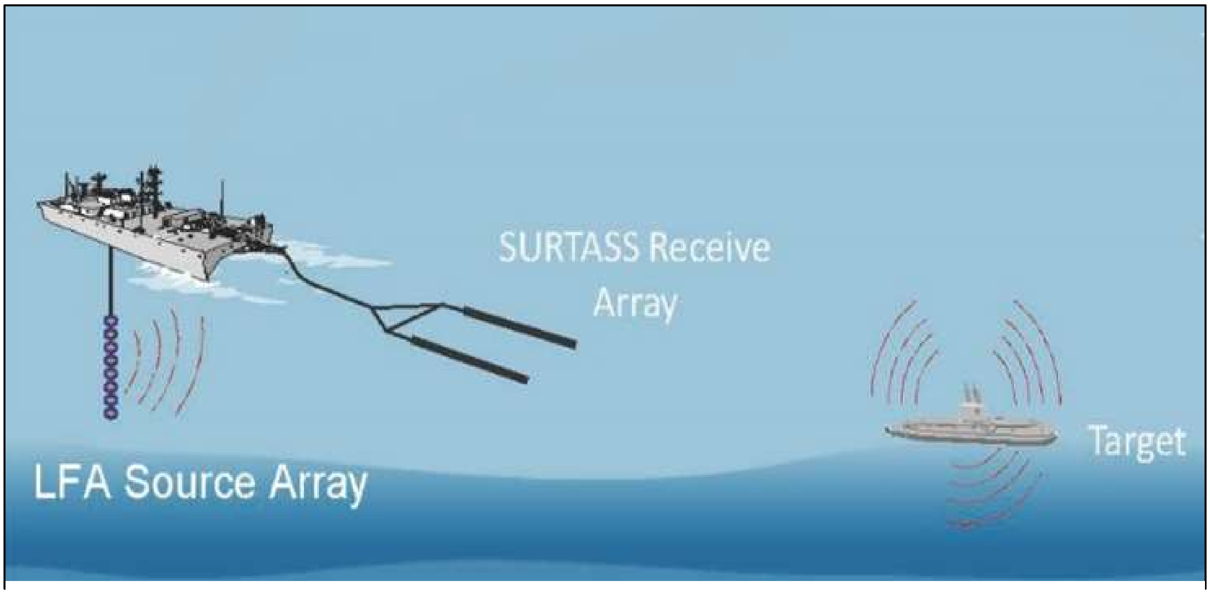

Figure 2-1. Schematic of a SURTASS LFA Sonar System Deployed from a T-AGOS Vessel Including the Passive SURTASS Horizontal Line Array (Receive Array) of Hydrophones and the Active Vertical Line Array of LF Sonar Projectors (Source Array).

The SURTASS LFA sonar system is installed on the USNS IMPECCABLE (T-AGOS 23), but as future undersea warfare requirements transitioned to littoral[2] ocean regions, a compact version of the LFA sonar system deployable on SURTASS surveillance ships was needed. The Navy developed the CLFA sonar system, which consists of smaller, lighter-weight source elements than the original SURTASS LFA sonar system. The CLFA sonar system is compact enough to be installed on the VICTORIOUS class platforms (i.e., T-AGOS 19, 20, and 21). CLFA sonar improvements include:

- Transmission 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 (44 percent lighter than the original LFA sonar system).

The operating characteristics of the CLFA sonar system are comparable to the full-sized LFA sonar system. As such, the potential effects associated with CLFA sonar are expected to be similar to, and not greater than, the effects associated with the LFA sonar system. For this reason, as previously noted, the term LFA sonar refers inclusively of both the LFA and/or the CLFA sonar systems, unless otherwise specified.

2 The Navy defines “littoral” as the region that horizontally encompasses the land/water interface from 50 statute miles (80 km) ashore to 200 nmi (370 km) at sea; this region extends vertically from the seafloor or land to the top of the atmosphere (Naval Oceanographic Office, 1999). The common definition of littoral refers to 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 perspective, not a geographical or environmental, that relates to overall coastal operations, including all assets supporting a particular operation regardless of how close, or far, from the shore they may be operating.

2.2.1 Passive Sonar System Components: SURTASS

SURTASS is the passive, or listening, component of the system that detects returning echoes from submerged objects, such as threat submarines, by 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 is a twin-line, “Y” shaped horizontal line array (HLA) with two apertures that is approximately 1,000 feet (ft) (305 meters [m]) long (Figure 2-1). The SURTASS HLA can be towed in shallow, littoral environments; provides significant directional noise rejection; and resolves bearing ambiguities without the vessel having to change course. To tow the HLA, a Navy ocean surveillance 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.

2.2.2 Active Sonar System Components

The active sonar component of the SURTASS LFA sonar system, LFA sonar, is an adjunct to the SURTASS passive capability and is employed when active sound signals are needed to detect and track underwater targets. The characteristics and operating features of the active component of LFA sonar are:

- The sonar source is a vertical line array (VLA) of up to 18 source projectors suspended beneath the vessel. LFA’s transmitted sonar beam is omnidirectional (i.e., 360 degrees) in the horizontal, with a narrow vertical beamwidth that can be steered above or below the horizontal.
- The source frequency is between 100 and 500 Hz.
- The source level (SL) of an individual source projector in the SURTASS LFA sonar array is approximately 215 decibels relative to one microPascal measured at 1 m (dB re 1 µPa @ 1 m) sound pressure level (SPL) or less. As measured by SPL, the sound field of the LFA sonar array can never be higher than the SL of an individual source projector.
- The typical LFA sonar signal is not a constant tone but is a transmission of waveforms that vary in frequency and duration. A complete sequence of sound transmissions is referred to as a wavetrain (also known as a “ping”). These wavetrains last between 6 and 100 seconds (sec) with an average length of 60 sec. 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 is no longer than 10 sec.
- The maximum duty cycle (ratio of sound “on” time to total time) is 20 percent. The typical duty cycle, however, based on historical LFA sonar use (2003 to 2018), is 7.5 to 10 percent.
- The time between wavetrain transmissions is typically 6 to 15 minutes (min).

LFA sonar complements SURTASS passive activities by actively detecting and tracking submarines when they are in quiet operating modes, measuring accurate target range, and re-acquiring lost contacts.

2.3 Study Area for SURTASS LFA Sonar

The study area of the Navy’s proposed SURTASS LFA sonar training and testing activities is the western and central North Pacific and eastern Indian oceans (Figure 2-2), not including polar waters, the Sea of Okhotsk, or the territorial seas of any foreign nation. The Navy has scoped the geographic extent of its

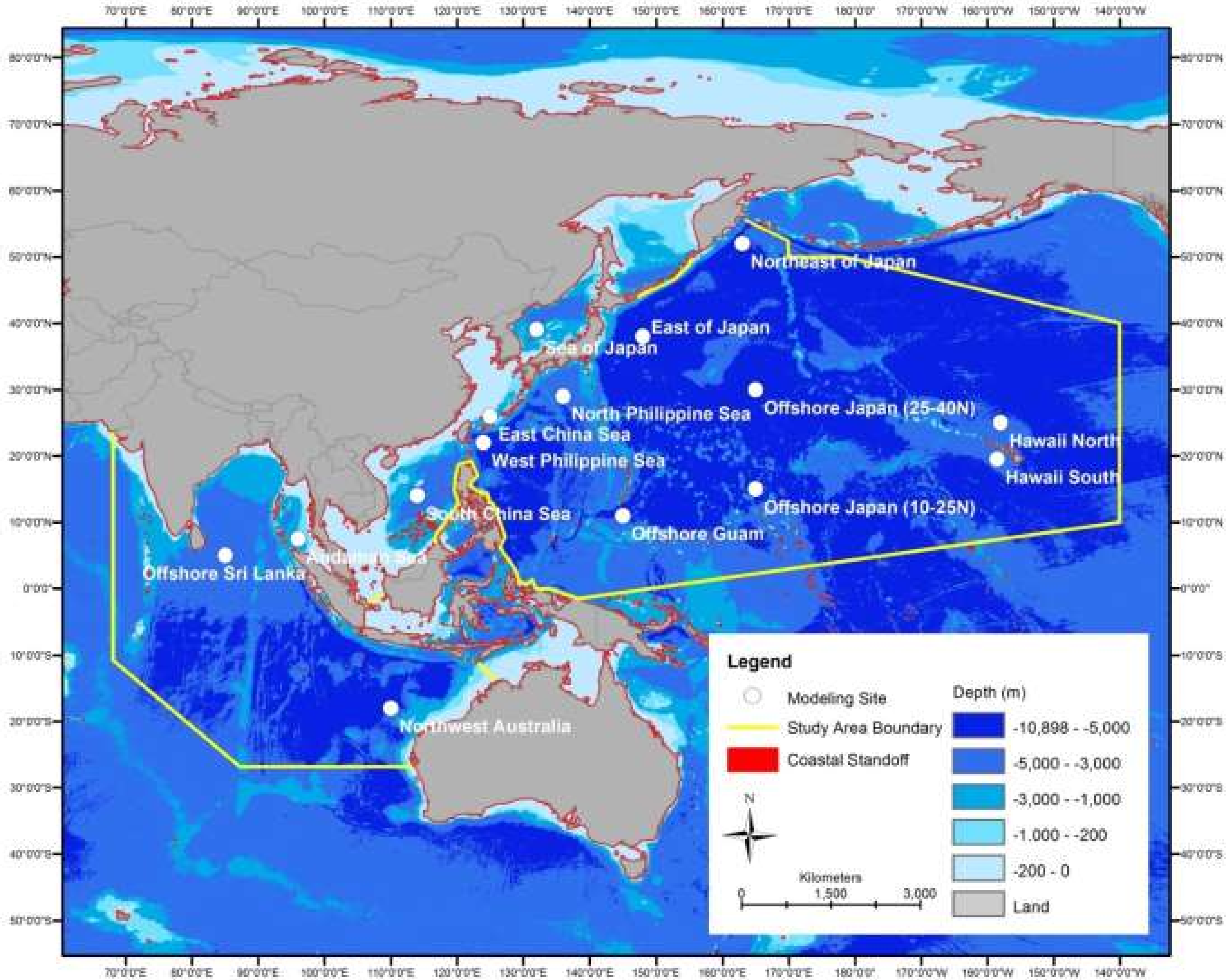

Figure 2-2. Location of the Study Area for SURTASS LFA Sonar in the Western and Central North Pacific and Eastern Indian Oceans, Including Locations of Nominal Modeling Sites.

References to Underwater Sound Levels

- References to underwater sound pressure level (SPL) in this application 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 (ANSI, 2006; Urick, 1983).
- In this application, 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 (ANSI, 2006; Southall et al., 2007; Urick, 1983).
- 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 exposure to SURTASS LFA sonar transmissions as well as an approximation of the effect of repeated exposure accumulation. As such, the SPE metric incorporates both physics and biology. 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), FSEIS/SOEIS (DoN, 2015), and FSEIS/SOEIS (DoN, 2017).

study area for SURTASS LFA sonar to better reflect the marine areas where the Navy anticipates conducting SURTASS LFA sonar training and testing activities into the foreseeable future. The study area for SURTASS LFA sonar has been divided into 15 representative regions, with nominal modeling sites located in each region (Figure 2-2).

2.4 Mitigation Measures

Mitigation measures implemented for the use of SURTASS LFA sonar are designed to minimize or eliminate effects to protected marine species and habitats by limiting the degree or magnitude of the effects that may be associated with SURTASS LFA sonar training and testing activities. Mitigation measures for SURTASS LFA sonar activities include procedural measures, geographical mitigation measures, and mitigation monitoring. Mitigation and monitoring ensure that SURTASS LFA sonar training and testing activities:

- Do not expose coastal waters within 12 nmi (22 km) of emergent land to SURTASS LFA sonar RLs ≥180 dB re 1 µPa (rms) SPL;
- Do not expose OBIAs to SURTASS LFA sonar RLs ≥180 dB re 1 µPa (rms) during biologically important seasons; and
- Minimize exposure of marine animals to LFA sonar transmissions by providing the means to detect marine mammals in the LFA mitigation zone and suspending or delaying LFA sonar transmissions should a marine animal be detected.

Strict adherence to these measures would minimize effects on ESA-listed species as well as on recreational or commercial divers, swimmers, snorkelers, or fisheries.

2.4.1 Re-Evaluation of Mitigation Basis for LFA Sonar

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 NMFS (2018f) acoustic guidance defines a new method for estimating onset of permanent threshold shift (PTS), which lead the Navy to re-evaluate the basis for the LFA sonar mitigation threshold. The results of the new guidance are such that, based on simple spherical spreading (i.e., transmission loss[TL] based on 20 × $\log_{10}$ [range {m}]), all hearing groups except LF cetaceans would need to remain within 22 ft (7 m) for the duration of an entire LFA sonar ping (60 sec) to potentially experience PTS. LF cetaceans would need to remain at the greatest distance from the transmitting LFA sonar, 135 ft (41 m) for this example, before experiencing the onset of injury. If an LF cetacean were exposed to two full pings of SURTASS LFA sonar, the resulting SPL would be 179.7 dB re 1 µPa (rms). This exposure scenario is unlikely, as a marine mammal would have to remain close, <200 ft (61 m), to the slowly moving and transmitting LFA sonar array for about 20 minutes to experience two full pings (one ping every 10 min). However, to be conservative, the Navy intends to retain the existing mitigation basis of 180 dB re 1 µPa (rms) for SURTASS LFA sonar transmissions. Further details on these calculations follow.

The NMFS (2018f) specifies auditory weighted (SEL_{cum}) values for the onset of PTS, which is considered the onset of injury. The NMFS acoustic guidance also categorized marine mammals into five hearing groups for which generalized hearing ranges were defined:

- Low-frequency (LF) Cetaceans—mysticetes (baleen whales)
- Mid-frequency (MF) Cetaceans—includes most dolphins, all toothed whales except *Kogia* spp., and all beaked and bottlenose whales
- High-frequency (HF) Cetaceans—consists of all true porpoises, river dolphins, *Kogia* spp., *Cephalorhynchus* spp., and two species of *Lagenorhynchus* dolphins (Peale's and hourglass dolphins)
- Phocids Underwater (PW)—consists of true seals
- Otariids Underwater (OW)—includes sea lions and fur seals

NMFS's (2018f) acoustic guidance presents the auditory weighting functions developed for each of these functional hearing groups that reflect the best available data on hearing, impacts of sound on hearing, and data on equal latency. When estimating the onset of injury (PTS), the NMFS (2018f) acoustic guidance defines weighted thresholds as SELs. To determine what the SEL for each hearing group would be when exposed to a 60-sec (length of a nominal LFA sonar transmission or 1 ping), 300 Hz (the center frequency in the possible transmission range of 100 to 500 Hz) SURTASS LFA sonar transmission, the auditory weighting functions must be applied to account for each hearing group's sensitivity. Applying the auditory weighting functions to the nominal LFA sonar signal results in the thresholds increasing by approximately 1.5, 46, 56, 15, and 20 dB for LF, MF, HF, PW, and OW groups, respectively. Based on simple spherical spreading (i.e., transmission loss [TL] based on 20 × $\log_{10}$ [range {m}]), all hearing groups except LF cetaceans would remain within 22 ft (7 m) for an entire 60 sec-LFA sonar ping to potentially experience PTS. LF cetaceans would need to be located and remain at the greatest distance, 135 ft (41 m), from the transmitting LFA sonar for a 60-sec transmission before experiencing the onset of injury, for this example. 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 illustrates what the SPL RL would be at the distance an LF cetacean would begin to experience PTS from transmitting LFA sonar. Per NMFS (2018f) acoustic guidance, the LF cetacean threshold is 199 dB re 1 μPa^2-sec (weighted). The magnitude of the LF auditory weighting function at 300 Hz for SURTASS LFA sonar is 1.5 dB, with the equivalent unweighted SEL_{cum}[3] 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:

$$SPL = SEL_{cum} - 10 \log_{10}(T) \qquad \text{Where } T \text{ is the duration in seconds.}$$

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 SEL_{cum} 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 µPa (rms) isopleth would be somewhat smaller than that associated with the previously used 180 dB re 1 µPa (rms) isopleth. If an LF cetacean were 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 remain in proximity 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]), as is the SPL value for one ping, 182.7 dB re µPa (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, the Navy proposes to retain the current, conservative mitigation basis of 180 dB re 1 µPa (rms) for SURTASS LFA sonar transmissions.

2.4.2 Procedural Mitigation Measures

The sound signals transmitted by the SURTASS LFA sonar source would 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. The Navy is currently authorized to transmit the maximum number of 1,020 hours of LFA sonar transmission per year for all vessels. However, the Navy proposes to reduce the annual number of LFA sonar transmit hours to 496 hours total in years 1 through 4 of the requested ITS period for all vessels, with the total number of sonar transmit hours increasing to 592 hours in Years 5 through 7 and into the foreseeable future, regardless of the number of vessels.

2.4.2.1 LFA Mitigation Zone

In previous documentation for SURTASS LFA sonar, including previous BEs, the Navy proposed a mitigation zone covering a volume of water ensonified to the 180 dB re 1 µPa isopleth (i.e., the volume subjected to sound pressure levels of 180 dB rms or greater) and noted that the approximate, nominal outer horizontal boundary of this volume of water is approximately 0.54 nmi (1 km), depending upon environmental conditions. In each of the MMPA Final Rules and LOAs and as conditions of the ESA ITS's for SURTASS LFA sonar, NMFS added a 0.54-nmi (1-km) buffer zone beyond the Navy's proposed LFA sonar mitigation zone, so the total resulting mitigation/buffer zone was nominally 1.08 nmi (2 km).

Navy is again proposing a mitigation zone for the volume of water ensonified to the 180 dB re 1 µPa isopleth. However, if NMFS intends to propose a buffer zone for the 2019 MMPA Final Rule and as a condition of the ITS as well, the Navy requests that NMFS instead establish a single, fixed, combined mitigation/buffer zone of 2,000 yards (yd) (0.99 nmi) (1,829 m/1.83 km) rather than a combined mitigation/buffer zone of nominally 1.08 nmi (2 km). This 2,000 yd (1.83 km) single fixed

3 SEL_{cum}=cumulative sound exposure level

mitigation/buffer zone would cover virtually all the previous combined mitigation/buffer zone of nominally 1.08 nmi (2 km), since the difference between 2,000 yd and 2 km is only about 187 yd (or 0.09 nmi [167 m]). Likewise, the difference in the sound field of the combined mitigation/buffer zones of 2,000 yd (1.83 km) versus 1.08 nmi (2,187 yd; 2 km) would also be negligible. At 2,000 yd (1.83 km), modeling shows that the sound field would be about 174.75 dB while at 1.08 nmi (2 km), the sound field would be 173.98 dB, which is a difference of only 0.77 dB. This very slight sound field difference would not be perceptible to a marine mammal or a sea turtle.

Establishing a single, fixed, combined mitigation/buffer zone for SURTASS LFA sonar training and testing activities would standardize and thus simplify implementation of this monitoring requirement, including a buffer zone, using standard Navy metrics (yards not meters), while continuing to ensure protection to marine mammals in all acoustic environments, even in the rare event of a strong acoustic duct in which the volume of water ensonified to 180 dB could be somewhat greater than 0.54 nmi (1 km) (DoN, 2001). With the combined mitigation/buffer zone of 2,000 yd (1.83 km), there is no potential for marine animals to be exposed to received levels greater than 180 dB rms.

2.4.2.2 Buffer Zone

As noted above, in prior SURTASS LFA sonar MMPA rulemaking (NOAA, 2002, 2007, 2012) and ESA ITS's (NMFS, 2002, 2007, 2012, 2017), NMFS added a mitigation measure to further preclude the potential for injury to marine mammals and sea turtles from resonance effects by establishing a 0.54-nmi (1-km) buffer shutdown zone surrounding the LFA mitigation zone. The Terms and Conditions of the associated ITSs for SURTASS LFA sonar, including the existing 2017 to 2022 ITS, required implementation of the buffer zone. Per the requirement of both the 2017 ITS and 2017 NDE for SURTASS LFA sonar, the Navy is currently applying the buffer zone mitigation measure and monitors and shuts down LFA sonar transmissions if a marine mammal or sea turtle is detected within the LFA mitigation plus buffer zones.

Although this additional buffer zone mitigation measure has proven to be practical for the Navy to implement, Navy's analysis provided in Subchapter 2.5.1 of the 2007 SURTASS LFA Sonar FSEIS (DoN, 2007) demonstrated that the addition of the buffer zone did not appreciably minimize adverse effects below 180 dB re 1 µPa (rms) RL (incorporated herein by reference). Thus, the Navy has concluded that removal of this additional mitigation measure would not generate a change of any significance in the percentage of marine mammals potentially affected. However, the Navy would adhere to a buffer zone if implemented by NMFS in the 2019 MMPA Rule and ITS; although as noted above, if NMFS imposes a buffer zone, Navy requests that NMFS impose a fixed, single, combined mitigation/buffer zone of 2,000 yd (1.8 km).

2.4.2.3 Ramp-up of High Frequency Marine Mammal Monitoring (HF/M3) Sonar

The Navy intends to implement the ramp-up procedure for the HF/M3 sonar system to ensure that no inadvertent exposures of marine animals to RLs ≥180 dB re 1 µPa (rms) would occur if an animal were to occur near the transmitting HF/M3 sonar system. Prior to full-power transmissions, the HF/M3 sonar power level would be ramped up over a period of no less than 5 minutes from a SL 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 would commence at least 30 minutes prior to initiation of any SURTASS LFA sonar transmissions during testing and training activities, 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 SPL may not increase once a marine mammal or sea turtle is detected. The ramp-up process may resume once marine animals are no longer detected by any of the monitoring methods.

2.4.2.4 LFA Sonar Suspension/Delay

During training and testing activities, SURTASS LFA sonar transmissions would be delayed or suspended only if a marine mammal or sea turtle is detected by visual, passive acoustic, or active acoustic monitoring entering or already located within the LFA mitigation zone (i.e., the 180 dB re 1 µPa isopleth or the Navy-requested fixed, single, combined mitigation/buffer zone of 2,000 yd if NMFS imposes a buffer zone). When a sea turtle or marine mammal is detected within the LFA mitigation zone (or mitigation/buffer zone), the senior military member-in-charge would order the immediate suspension of LFA sonar transmissions. During the delay/suspension of LFA sonar transmissions, active acoustic, visual, and passive acoustic monitoring for marine mammals and sea turtles would continue. LFA sonar transmissions would be allowed to commence/resume no sooner than 15 minutes after marine mammals/sea turtles are no longer detected within the LFA mitigation zone (or combined mitigation/buffer zones).

If a marine mammal or sea turtle is detected outside the LFA mitigation zone but is thought to be closing on the LFA mitigation (or buffer) zone, the range and projected track (bearing) of the detected animal is determined and reported to the senior military member-in-charge, but LFA sonar is not yet suspended/delayed. The position of the detected marine animal is closely monitored for intersection with the LFA mitigation zone. When the marine animal enters the LFA mitigation (or buffer) zone, then LFA training and testing sonar transmissions would be suspended or delayed.

2.4.3 Geographical Mitigation Measures

The Navy intends to continue applying the following geographic mitigation measures during SURTASS LFA sonar training and testing activities:

- SURTASS LFA sonar training and testing activities would not occur within the territorial seas of foreign nations;
- SURTASS LFA sonar-generated sound field below RLs of 180 dB re 1 µPa (rms) (SPL) within 12 nmi (22 km) of any emergent land (including islands);
- SURTASS LFA sonar-generated sound field below RLs of 180 dB re 1 µPa (rms) (SPL) from the outer boundary of OBIAs during the biologically important period that have been determined by NMFS and the Navy4;
- When in the vicinity of known recreational or commercial dive sites or in Hawaii State waters, SURTASS LFA sonar would be operated such that the sound fields at those sites/waters would not exceed RLs of 145 dB re 1 µPa (rms) (SPL);
- SURTASS LFA sonar would not be used in the waters over Penguin Bank, Hawaii, to the extent of the 600 ft (183 m) depth contour; and
- SURTASS LFA sonar operators would 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)

4 In past authorizations for SURTASS LFA sonar, NMFS has required a 0.54 nmi (1-km) buffer zone on the seaward boundary of OBIAs in which the sound field generated by LFA sonar would be below RLs of 180 dB re 1 µPa (rms); the 2017 NDE and ITS maintained this requirement.

and 145 dB re 1 µPa (rms) isopleths are known. However, if NMFS imposes a buffer zone and implements the requested fixed, single, combined mitigation/buffer zone of 2,000 yd (1.8 km), then sound field modeling to define the mitigation zone would not be necessary because the volume of water ensonified to 180 dB would be subsumed in the fixed, single combined mitigation/buffer zone of 2,000 yd (1.8 km). Accordingly, sound field modeling to estimate the distance to the 180-dB isopleth would not be conducted as it would be unnecessary.

2.4.3.1.1 Coastal Standoff Distance

Since most areas of biological importance to protected marine mammal species and stocks are in coastal waters, the Navy first established the policy of the coastal standoff range, in which waters within 12 nmi (22 km) of any emergent land would not be ensonified with SURTASS LFA sonar at levels at or above 180 dB re 1 µPa (rms). This distance and sound field measure were established to lower the risk to many marine mammals and especially sea turtles, which aggregate in coastal waters. The Navy would continue to implement the 12 nmi (22 km) coastal standoff range while using SURTASS LFA sonar for training and testing activities. In addition, the Navy would not conduct SURTASS LFA sonar training and testing activities within foreign nations' territorial seas.

2.4.3.1.2 Dive Sites

During training and testing activities, SURTASS LFA sonar transmissions near known recreational dive sites would be transmitted such that the sound field at such sites does not exceed RLs of 145 dB re 1 µPa (rms). Although 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), the Navy recognizes that other dive sites may be outside this boundary.

2.4.3.1.3 Sound Field Modeling

The SURTASS LFA sonar crew would estimate SURTASS LFA sonar sound field RLs (SPL) prior to and during training and testing sonar transmissions to provide the information necessary to modify transmissions, including the delay or suspension of transmissions, so that the sound field criteria are not exceeded. If NMFS imposes a buffer zone and implements the requested fixed, single, combined mitigation/buffer zone of 2,000 yd (1.83 km), then sound field modeling to determine the mitigation shutdown range to the 180 dB re 1 µPa (rms) isopleth would not be necessary and would not be conducted. Sound field limits would 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. Acoustic model updates would nominally be made every 12 hours or more frequently, depending upon the variance in meteorological or oceanographic conditions.

2.4.3.1.4 Offshore Biologically Important Areas (OBIAs)

In recognition that certain areas of biological importance lie outside the coastal standoff range, the Navy and NMFS developed the concept of OBIAs. To further protect marine mammals conducting biologically important activities, at the outer (seaward) boundary of designated marine mammal OBIAs during the biologically important period specified for each OBIA, the Navy would transmit SURTASS LFA sonar during training and testing activities such that the LFA sound field would be below RLs of 180 dB re 1 µPa (rms). OBIAs for SURTASS LFA sonar were established solely as a mitigation measure to reduce incidental takings of marine mammals associated with the use of SURTASS LFA sonar and do not apply to other Navy sonar operations or activities (NOAA, 2007, 2012).

OBIAs are part of the comprehensive suite of conservation and mitigation measures developed to minimize adverse effects to marine mammal populations potentially associated with SURTASS LFA sonar training and testing activities. OBIAs were defined and designated 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 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. An effective period or season is defined for each OBIA as the time during which the marine mammal(s) for which the OBIA was designated carries out biologically significant activities including calving, foraging, breeding, or migrating in that specific geographic area. Only during this effective period of biologically significant activity does the Navy constrain LFA sonar transmissions to the RL of 180 dB re 1 µPa (rms) within OBIA boundaries.

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 mitigation measures for these taxa above those already established for use of SURTASS LFA sonar (DoN, 2012). This same conclusion was reached following the most recent comprehensive evaluation of marine areas as potential OBIAs, in which the analysis of the potential for impacts to fishes and sea turtles 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 (DoN, 2017, DoN, 2018).

Twenty-nine OBIAs for marine mammals have been established for SURTASS LFA sonar globally (Table 2-1). Four of these OBIAs lie within the proposed study area for SURTASS LFA sonar.

➢ <u>OBIA Selection Criteria</u>

The process of identifying potential marine mammal OBIAs involves an assessment by both Navy and NMFS to identify marine areas that meet established criteria. In their comprehensive reassessment of potential OBIAs for marine mammals conducted for the 2012 SEIS/SOEIS for SURTASS LFA sonar (DoN, 2012), Navy and NMFS established geographical and biological criteria as the basis for consideration of an area's eligibility as a candidate OBIA and the measures against which the available data on marine areas are evaluated. This BE carries forward those criteria, including some refinements.

<u>Geographic Criteria for OBIA Eligibility</u>

The Navy has defined the study area in which SURTASS LFA sonar would be used. For a marine area to be eligible for consideration as an OBIA for marine mammals, the area must be located where SURTASS LFA sonar training and testing activities would occur. As such, a potential marine area cannot be located in:

- Coastal standoff range—the area within 12 nmi (22 km) of the coastline of any emergent land, including islands or island systems. This part of the study area already receives the same protection as OBIAs where sound levels would not exceed 180 dB re 1 µPa (rms) SPL.
- Polar regions—including waters of the Arctic (such as the Bering Sea) and Antarctic (south of 60° S latitude). Polar regions are outside of the study area.

Table 2-1. Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar, Their Location, Relevant Marine Mammal Species, and Effective Biologically Significant Period.

OBIA Number	*OBIA Name*	*Location/ Water Body*	*Relevant Marine Mammal Species*	*Effective Period*
1	Georges Bank	Northwest Atlantic Ocean	North Atlantic right and Sei whales	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 National Marine Sanctuary (NMS)	Northwest Atlantic Ocean/ Gulf of Maine	North Atlantic right whale	January 1 to November 14, annually; year-round for Stellwagen Bank NMS
4	Southeastern U.S. Right Whale Critical Habitat	Northwest Atlantic Ocean	North Atlantic right whale	November 15 to April 15, annually
5	Gulf of Alaska	Gulf of Alaska	North Pacific right whale	March through September, annually
6	Navidad Bank	Caribbean Sea/Northwest Atlantic Ocean	Humpback whale	December through April, annually
7	Coastal Western Africa (Cameron to Angola)	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	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	Offshore Piltun and Chayvo	Sea of Okhotsk	Western Pacific gray whale	June through November, annually
13	Eastern Madagascar Coastal Waters	Western Indian Ocean	Humpback whale and Blue whale	July through September, annually for humpback whale breeding; November through December for migrating blue whales

Table 2-1. Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar, Their Location, Relevant Marine Mammal Species, and Effective Biologically Significant Period.

OBIA Number	*OBIA Name*	*Location/ Water Body*	*Relevant Marine Mammal Species*	*Effective Period*
14	Southern Madagascar (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 NMS	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	Coral Sea/South-western 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 NMS, Barkley and Nitinat Canyons, and The Prairie,	Northeastern Pacific Ocean	Humpback whale	Olympic NMS: December, January, March, April, and May, annually; The Prairie, Barkley and Nitinat Canyons: 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
24	Eastern Gulf of Mexico	Eastern Gulf of Mexico	Bryde's whale	Year-round

Table 2-1. Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar, Their Location, Relevant Marine Mammal Species, and Effective Biologically Significant Period.

OBIA Number	*OBIA Name*	*Location/ Water Body*	*Relevant Marine Mammal Species*	*Effective Period*
25	Southern Coastal Chile	Gulf of Corcovado, Southeast Pacific Ocean; southwestern Chile	Blue whale	February to April, annually
26	Offshore Sri Lanka	North-Central Indian Ocean	Blue whale/pygmy blue whale	December through April, annually
27	Camden Sound/Kimberly Region	Southeast Indian Ocean; northwestern Australia	Humpback whale	June through September, annually
28	Perth Canyon	Southeast Indian Ocean; southwestern Australia	Pygmy blue whale, Blue whale, Sperm whale	January through May, annually
29	Southwest Australia Canyons	Southern Ocean; southwestern Australia	Sperm whale	Year-round

Low-Frequency Hearing Sensitivity Criterion

SURTASS LFA sonar transmissions are well below the range of best hearing sensitivity for most odontocetes and most pinnipeds based on measured hearing thresholds (Au and Hastings, 2008; Houser et al., 2008; Kastelein et al., 2009; Mulsow and Reichmuth, 2010; Nedwell et al., 2004; Richardson et al., 1995; Southall et al., 2007). The intent of OBIAs is to protect those marine mammal species, such as baleen whales, most likely to hear and be affected by LFA sonar transmissions and to provide them additional protections during periods when they are conducting biologically significant activities. Thus, the primary focus of the OBIA mitigation measure is on LF hearing sensitive species. Two OBIAs, however, have been designated to provide additional mitigation protection for non-LF hearing specialists, such as elephant seals and sperm whales, since the available data hearing data for these species indicate an increased sensitivity to LF sound (compared to most odontocetes and pinnipeds).

Biological Criteria for OBIA Eligibility

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. When direct data relevant to one of the following biological criteria are limited, other available data and information may be used if those data and information, either alone or in combination with the limited direct data, are sufficient to establish that the biological criteria are met:

- *High Densities:* An area of high density for one or more species of marine mammals. High density areas are those marine waters where the density within a definable area (and potentially, time) measurably and meaningfully exceeds the average density of the species or stock within the region. The exact basis for the identification of "high density areas" may differ across species/stocks and regions, depending on the available information and should be evaluated on a stock-by-stock or species-by-species basis, although combining species or stocks may be appropriate in some situations. The best source of data for this determination is publicly-available, direct measurements from survey data.
- *Known Breeding/Calving or Foraging Ground or Migration Route:* A geographic 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. "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.
- *Small, Distinct Populations of Marine Mammals with Limited Distributions*: Geographic areas in which small, distinct populations of marine mammal species or stocks occurs 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 the periods designated for the critical habitat area. As with the other biological criteria, critical habitat is considered as one of the possible factors in the OBIA process.

Navy Practicability Criterion

Once an area has been assessed to meet the OBIA criteria, it is considered a candidate marine mammal OBIA for SURTASS LFA sonar. The Navy then conducts a practicability review of the candidate OBIAs to assess personnel safety, practicality of implementation, and impacts on the effectiveness on military readiness activities. 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. If the Navy determines that it is not practicable to designate an area as an OBIA, the Navy would identify the concerns that lead to this conclusion and discuss with NMFS whether modifications could be made to the proposed OBIA to alleviate the Navy's practicability concerns.

➢ Existing Marine Mammal OBIAs for SURTASS LFA Sonar

Under the NDE, 29 marine mammals were observed as marine mammal OBIAs for SURTASS LFA sonar (Table 2-1; Figure 2-3; DoD, 2017). Some of these areas, such as the Antarctic Convergence Zone, were previously designated as OBIAs by the Navy and NMFS for SURTASS LFA sonar. The season or period in which the biological activity occurs annually is specified for each approved OBIA. Of these 29 worldwide OBIAs, four occur in the study area for SURTASS LFA sonar training and testing activities (Figure 2-4): OBIA #16 (Penguin Bank, Hawaiian Island Humpback Whale NMFS), OBIA #20 (Northern Bay of Bengal and Head of Swatch-of-No-Ground [SoNG]), OBIA #26 (Offshore Sri Lanka), and OBIA #27 (Camden Sound/Kimberly Region).

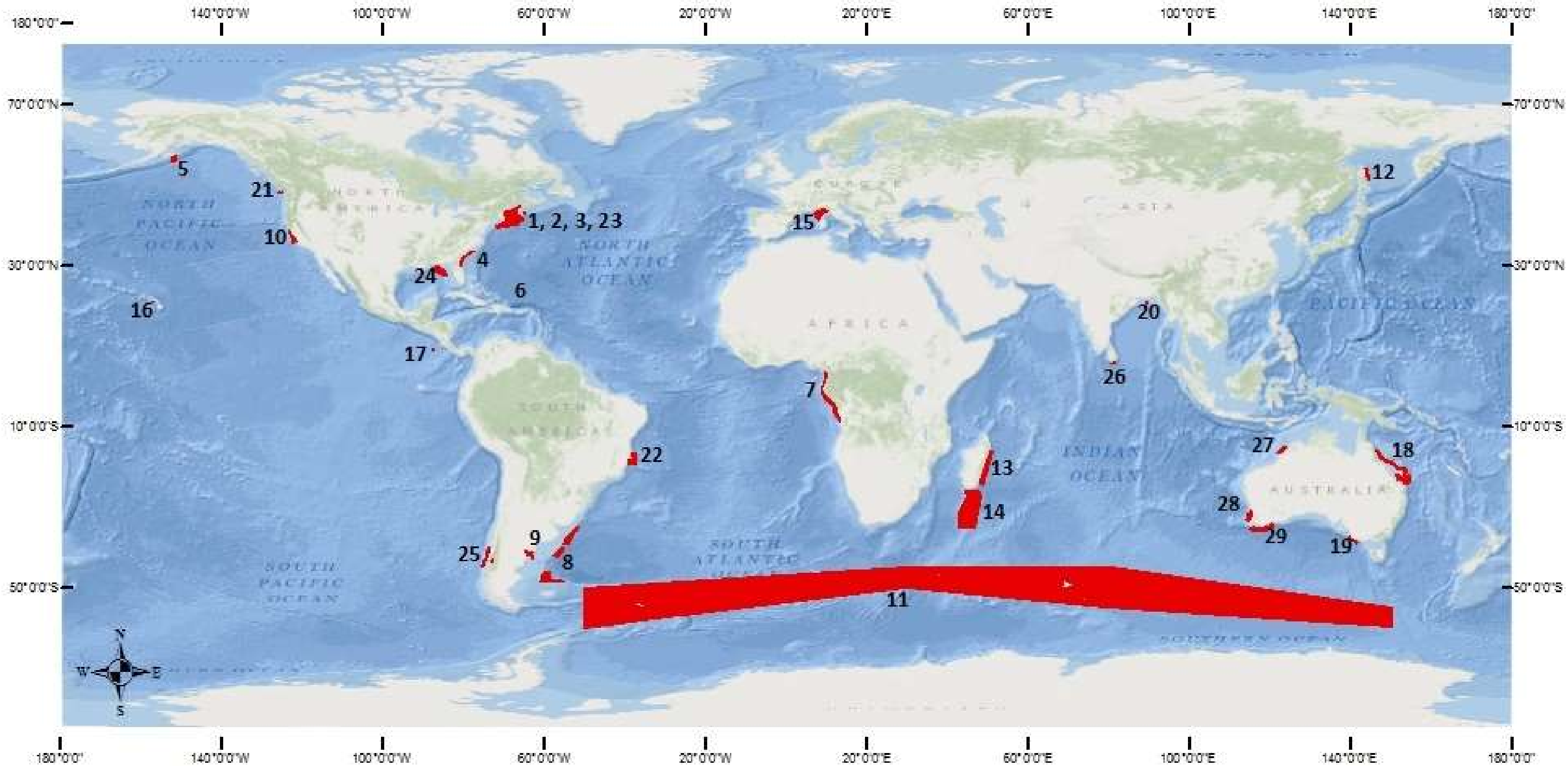

Figure 2-3. The Locations of the 29 Existing Marine Mammal Offshore Biologically Important Areas (OBIAs) for SURTASS LFA Sonar (Names of OBIAs by Number Follows).

FIGURE 2-3: 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. Gulf of Alaska
6. Navidad Bank
7. Coastal Western Africa (Cameroon to Angola)
8. Patagonian Shelf Break
9. Southern Right Whale Seasonal Habitat
10. Central California
11. Antarctic Convergence Zone
12. Offshore Piltun and Chayvo
13. Eastern Madagascar Coastal Waters
14. Southern Madagascar (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
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 Nitinat Canyon
22. Abrolhos Bank
23. Grand Manan North Atlantic Right Whale Critical Habitat
24. Eastern Gulf of Mexico
25. Southern Central Chile
26. Offshore Sri Lanka
27. Camden Sound/Kimberly Region
28. Perth Canyon
29. Southwestern Australia Canyons

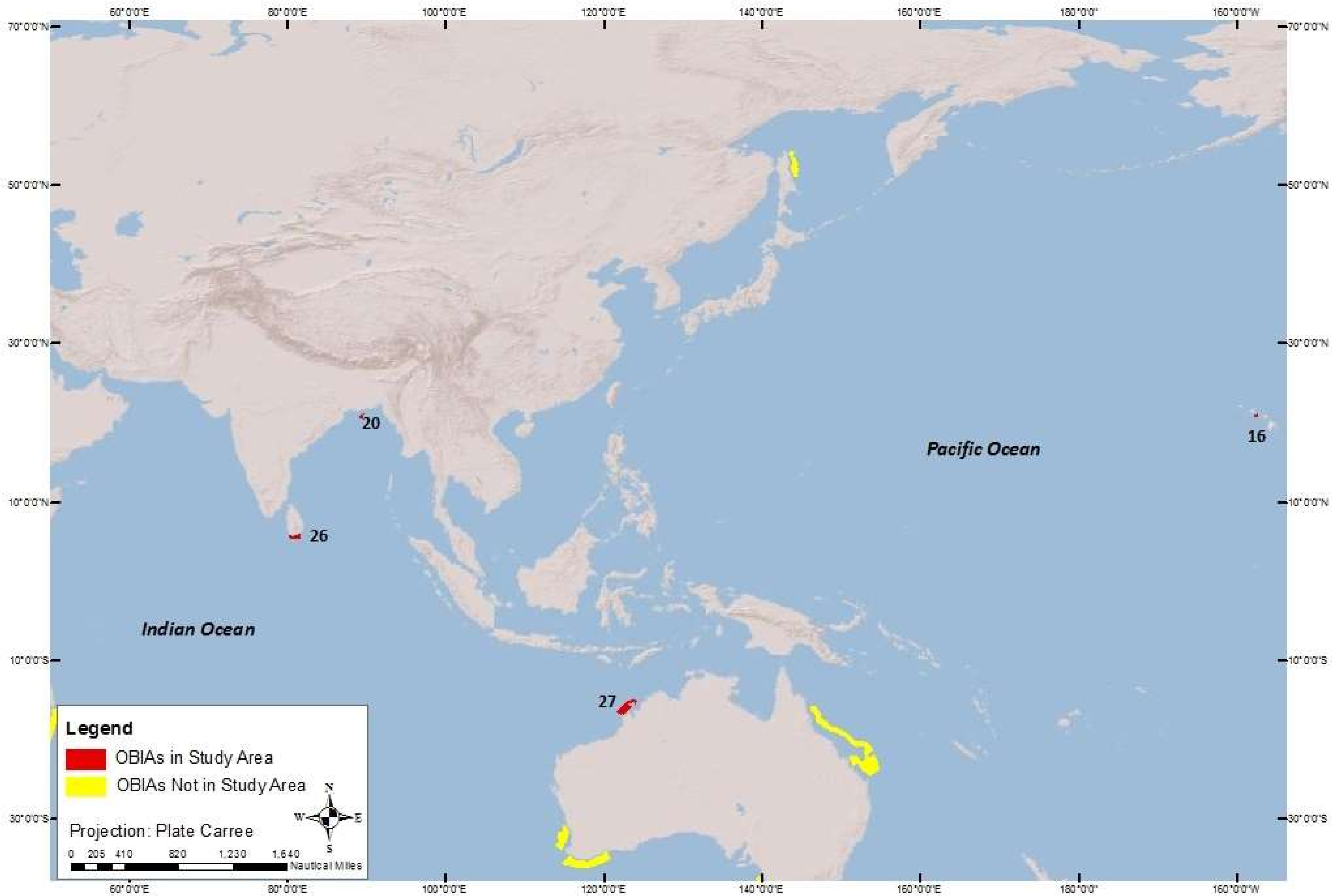

Figure 2-4. Locations of the Four OBIAs in the SURTASS LFA Sonar Study Area.

➢ <u>Potential Marine Mammal OBIAs for SURTASS LFA Sonar</u>

Since the 2017 SEIS/SOEIS and MMPA NDE for SURTASS LFA sonar, consideration and assessment of marine areas as potential OBIAs has continued. 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 SURTASS LFA sonar. As a continuation of the Navy and NMFS' ongoing effort to assess areas for potential OBIAs for SURTASS LFA sonar, the Navy and NMFS are conducting a comprehensive assessment of potential marine areas as part of the analysis and development of geographic mitigation.

2.4.4 Mitigation Monitoring Measures

The Navy would continue to conduct the following monitoring to prevent injury to marine animals when SURTASS LFA sonar is transmitting during training and testing activities:

- **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.

All detections are recorded in a log and are provided in the annual reports that demonstrate the Navy's monitoring for potential long-term environmental impacts.

2.4.4.1 Visual Monitoring

Visual monitoring would include daytime observations of the sea surface for the presence of marine mammals and sea turtles from the bridge of SURTASS LFA sonar vessels. Daytime is defined as the time beginning 30 minutes before sunrise and ending 30 minutes after sunset. Visual monitoring would begin 30 minutes before sunrise or 30 minutes before SURTASS LFA sonar begins to transmit and would continue until 30 minutes after sunset or until the SURTASS LFA sonar training and testing transmissions cease. Observations would be made by civilian ship 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 would be to ensure that no marine mammal or sea turtle approaches the ship or transmitting sonar array close enough to enter the LFA mitigation zone.

Visual observers would maintain a watch for marine mammals and sea turtles at the sea surface and log all detections of marine animals during SURTASS LFA sonar training and testing transmissions. The number, identification, bearing, and range of observed marine mammals or sea turtles, as well as any unusual behavior they may exhibit, would be recorded. A designated ship's officer would monitor the conduct of the visual watches and would periodically review the observation log. If a potentially affected marine mammal or sea turtle would be sighted anywhere within the LFA mitigation zone, the bridge officer would notify the senior military member-in-charge of the military crew (MILCREW) onboard the SURTASS LFA sonar vessel who would 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 senior military member-in-charge of the estimated range and bearing of the observed marine mammal or sea turtle. The senior military member-in-charge would 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 determines that the marine mammal or sea turtle would pass into the LFA mitigation zone, the senior military member-in-charge would order the immediate delay or suspension of SURTASS LFA sonar transmissions when the marine animal enters the LFA mitigation zone. The visual observer would continue visual observations until the marine mammal or sea turtle is no longer observed. SURTASS LFA sonar transmissions would 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 of the detected animal would continue until the behavior returns to normal or conditions did not allow monitoring to continue.

2.4.4.2 Passive Acoustic Monitoring

Passive acoustic monitoring would be conducted using the SURTASS towed HLA to listen for (detect) vocalizing marine mammals as an indicator of their presence whenever LFA sonar is transmitting during training and testing activities. If a detected sound were estimated to be from a vocalizing marine mammal, the sonar technician would notify the senior military member-in-charge, who would alert the HF/M3 sonar operator and visual observers (during daylight). Delay or suspension of SURTASS LFA sonar transmissions would be ordered when the HF/M3 sonar and/or visual observers verify the presence of a marine mammal to be within the LFA mitigation zone. Passive acoustic sonar technicians are trained to identify the detected vocalizations to marine mammal species whenever possible. Passive acoustic monitoring would begin 30 minutes prior to the first LFA sonar transmission, continue throughout all LFA sonar transmissions, and cease 15 minutes after LFA sonar transmissions have concluded.

2.4.4.3 Active Acoustic Monitoring

HF active acoustic monitoring uses the HF/M3 sonar whenever LFA sonar is transmitting during training and testing activities to detect, locate, and track marine mammals that could pass close enough to the SURTASS LFA sonar array to enter the LFA mitigation zone. Detection of sea turtles by the HF/M3 sonar system is possible due to the position of the HF/M3 sonar system above the LFA sonar array, since a sea turtle would have to swim from the surface through the HF/M3 sonar detection zone to enter the LFA mitigation zone, making an acoustic detection of a sea turtle highly likely.

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 of the HF/M3 sonar, the 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. This ramp-up procedure would ensure that sea turtles and marine mammals would not be inadvertently exposed to HF/M3 transmissions at RLs ≥180 dB re 1 µPa (rms).

If a marine mammal or sea turtle contact were detected during HF/M3 monitoring within the LFA mitigation zone, the sonar operator would notify the senior military member-in-charge, 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 senior military member-in-charge that a detected animal may move into the LFA mitigation zone. The senior military member-in-charge would notify the bridge and passive sonar operator of the potential presence of a marine animal projected to enter the mitigation zone. The senior military member-in-charge would order the delay or suspension of LFA sonar transmissions only when the marine mammal/sea turtle enters the LFA mitigation zone, as detected by any of the three monitoring methods. SURTASS LFA sonar transmissions would commence/resume 15 minutes after there are no further detections of the animal within the LFA mitigation zone were made by the HF/M3 sonar, visual, or passive acoustic monitoring.

The effectiveness of the HF/M3 sonar system to monitor and detect marine mammals has been described in the Navy's 2001 FOEIS/EIS (Chapters 2 and 4) for SURTASS LFA sonar (DoN, 2001) in addition to the technical report by Ellison and Stein (2001). 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 use of the HF/M3 system:

- Substantially increased the probability of detecting a marine mammal within the LFA mitigation zone;
- 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);
- Would result in several detections of a marine mammal before it even entered the LFA mitigation zone (DoN, 2001)—based on the scan rate of the HF/M3 sonar system, most animals would receive at least eight pings from the sonar (i.e., eight sonar returns or detections) before even entering the LFA mitigation zone;
    - based on this scan rate, the probability of any marine mammal being detected prior to even entering the LFA mitigation zone approaches 100 percent (Ellison and Stein, 2001);
    - the probability of the HF/M3 sonar system detecting a medium- to large-sized (~33 to 98 ft [10 to 30 m]) marine mammal (humpback to blue whale) swimming towards the system in the LFA mitigation zone with only one HF/M3 ping would be near 100 percent (Ellison and Stein, 2001);
    - for a small (~8 ft (2.5 m]) marine mammal such as a dolphin, the detection probability is 55 percent from one HF/M3 ping when the sonar is located at a distance of 2,625 to 3,051 ft (800 to 930 m) from the animal, while the detection probability increases to 90 percent for four HF/M3 pings; and
- May result in higher detection probabilities in a typical at-sea operating environment—during HF/M3 testing, analysts noted that in the expected at-sea conditions of reduced clutter interference in the open ocean and small marine mammals traveling in their typical group configurations (i.e., in pods), the detection rate would be higher (Ellison and Stein, 2001).

Qualitative and quantitative assessments of the HF/M3 system's ability to detect marine mammals of various sizes were verified by 170 hours of at-sea testing (Ellison and Stein, 2001). Since the information on the HF/M3 sonar system remains valid, it is thus incorporated herein by reference.

2.4.4.4 Visual and Passive Acoustic Observer Training

The lookouts aboard SURTASS LFA sonar vessels conduct visual monitoring for marine animals at the sea surface whenever LFA sonar is transmitting during training and testing activities. Per conditions of the 2017 NDE and ITS for SURTASS LFA sonar, a marine mammal biologist qualified in conducting at-sea visual monitoring of marine mammals from surface vessels would train and qualify designated personnel aboard the Navy's ocean surveillance vessels to conduct at-sea visual monitoring for marine mammals and sea turtles. Training of the civilian ship personnel would include 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 (DoD, 2017). The visual training may be accomplished either in-person or via video training. Until a video training module can be readied, currently the Navy sends a qualified marine mammal biologist to train as many of the civilian crew members that act as lookouts and visual monitors aboard the SURTASS LFA sonar vessels when the vessels are available in port.

Although not currently required by the NDE or ITS for SURTASS LFA sonar, the Navy routinely conducts training of military sonar operators stationed aboard SURTASS LFA sonar vessels to augment their sonar detection capabilities. Senior marine acousticians conduct passive acoustic training of the military sonar operators to increase their ability to distinguish biological sounds from mission-directed sounds. The Navy intends to continue conducting training on biological sound signatures for its passive sonar operators.

2.5 Reporting

The Navy currently reports quarterly and annually on SURTASS LFA sonar training and testing activities, including the locations in which LFA sonar transmissions occurred, the duration of LFA sonar transmissions, the species of marine mammals or sea turtles exposed to SURTASS LFA sonar transmissions, the associated taking of marine mammals from exposure to LFA sonar transmissions, and the potential population or stock level impacts to marine mammals that occurred in association with exposure to SURTASS LFA sonar. The Navy would continue to track the total number of SURTASS LFA sonar transmission hours during training and testing activities throughout each annual period to ensure that the maximum approved level of sonar transmissions is not exceeded.

2.5.1 Incident Reporting

The civilian crews of the SURTASS LFA sonar vessels systematically observe the sea surface during and after SURTASS LFA sonar training and testing transmissions for the presence of struck, injured, disabled, or stranded marine mammals or sea turtles. The Navy must notify NMFS immediately, or as soon as clearance procedures allow, if an injured, stranded, or dead marine mammal or sea turtle is found during, shortly after (within 24 hr), or in the vicinity of any SURTASS LFA sonar training and testing activities or anytime an injured, stranded, or dead marine mammal is observed at sea. In the event that an injured, stranded, or dead marine mammal is observed by the SURTASS LFA sonar vessel crew during transit or during normal ship activities not related to training or testing of SURTASS LFA sonar, the Navy would report the incident as soon as is operationally feasible and clearance procedures allow. In addition, the Navy would immediately, or as soon as clearance procedures allow, report any ship strikes of marine mammals or sea turtles by one of the SURTASS LFA sonar vessels, including all pertinent information on the strike and associated vessel. However, in the history of the Navy's use of SURTASS LFA sonar, no marine mammals or sea turtles have been struck by SURTASS LFA sonar vessels nor have any injured or disabled marine mammals or sea turtles been observed during or following SURTASS LFA sonar activities.

The Navy also routinely monitors the principal marine mammal stranding networks, the Internet, and social media to compile stranding data for the regions in which SURTASS LFA sonar training and testing activities were conducted. The Navy correlates the temporal and spatial locations of SURTASS LFA sonar transmissions with marine mammal strandings, particularly mass strandings. The Navy would report to

NMFS any marine mammal strandings that were correlated in time and space with the training or testing activities of any SURTASS LFA sonar vessels.

2.5.2 Annual and Comprehensive Reports

Annually, the Navy would submit a synthesis report of the training and testing activities using SURTASS LFA sonar to the NMFS Office of Protected Resources Director no later than 60 days after the anniversary of the date of the 2017 NDE and BO/ITS for SURTASS LFA sonar become effective. The annual report on SURTASS LFA sonar training and testing activities would contain summaries of the dates/times and locations of LFA sonar activity; marine mammal or sea turtle detections from visual, passive acoustic, and active acoustic monitoring; and delays or suspensions of LFA sonar transmissions due to mitigation monitoring protocol.

Marine mammal (or sea turtle) detections would include general type of marine mammals (i.e., whales, dolphins) and/or species identifications, number of marine mammals detected, time frame of detections, type of detection (visual, passive acoustic, HF/M3 sonar), bearing and range from the vessel, abnormal behavior (if any), and remarks/narrative (as necessary). The annual report would also include the Navy's estimates of the number of individual marine mammals affected by exposure to SURTASS LFA sonar transmissions using acoustic impact modeling based on locations, seasons, system characteristics, oceanographic environmental conditions, and marine mammal demographics; estimations of the total number of marine mammals affected by all SURTASS LFA sonar transmissions during the annual period; analysis of the effectiveness of mitigation measures; estimation of cumulative impacts; and long-term effects on marine mammals from SURTASS LFA sonar transmissions.

Each annual report would build on the previous annual report to provide a cumulative overview of the level of training and testing sonar transmission hours per year as well as estimates of the number of marine mammals affected by SURTASS LFA sonar transmissions during each annual period. At the end of the ITS effective period, the final annual report would be a cumulative, comprehensive report of all LFA sonar training and testing activities that occurred during the 7-year effective period as well as an overall assessment of the mitigation monitoring and its effectiveness in detecting and thus reducing risk to marine mammals and sea turtles.

2.6 Potential Stressors Associated with the Proposed Action

A proposed action may have individual, interactive, or additive indirect or direct effects on the environment, which are the environmental "stressors". The principal aspects or stressors of the Navy's Proposed Action that may affect protected biota and/or habitats 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;
- Transmission of LFA sonar.

Although these potential stressors that are related to use of the SURTASS LFA sonar have been described in detail in previous documentation for SURTASS LFA sonar documents (DoN, 2016a, 2017) and are incorporated by reference, a brief summary is provided herein, including how potential effects are reduced or eliminated by the operational characteristics of the SURTASS LFA sonar system and vessels in addition to the suite of mitigation measures implemented for SURTASS LFA sonar training and testing activities.

2.6.1 Presence and Movements of the T-AGOS Vessels

Potential adverse effects associated with the presence and movements in the marine environment of SURTASS LFA sonar vessels for training and testing activities are ship strikes, ship discharges, and noise generated by the vessel engines or propellers.

2.6.1.1 Ship Strike Potential

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 use, a ship strike associated with the operation of the SURTASS LFA sonar vessels has never occurred. The miniscule potential for ship strikes is due in part to the low speed at which the SURTASS LFA sonar vessels travel, which is 3 kt (5.6 kph) during sonar operations and up to 12 kt (22 kph) during transit, depending upon the vessel type[5]. 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. Additionally, 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.

The hull of the T-AGOS vessels is a catamaran-type split hull (SWATH) design, which along with an enclosed propeller system make the potential for striking and harming a marine mammal or sea turtle much less than for a conventionally designed ship. Additionally, since the lookouts that keep watch during routine vessel transit and maneuvering are also trained observers in the visual detection at sea of marine mammals and sea turtles, the likelihood of an animal in the vessel’s path during daylight hours being detected is significantly increased. The movements of SURTASS LFA sonar vessels are not unusual or extraordinary and are representative of routine operations of seagoing vessels.

2.6.1.2 Ship Discharge Potential

Federal jurisdiction regarding sediments and water quality extends from 3 (or 9 for some states/territories) to 200 nmi (5.6 to 370 km) from shore. These standards and guidelines are mainly the responsibility of the U.S. Environmental Protection Agency (EPA), specifically ocean discharge provisions of the Clean Water Act (CWA) (33 U.S.C. section 1343). Ocean discharges may not result in “unreasonable degradation of the marine environment.” Specifically, disposal may not result in: (1) unacceptable negative effects on human health; (2) unacceptable negative effects on the marine ecosystem; (3) unacceptable negative persistent or permanent effects due to the particular volumes or concentrations of the dumped materials; and (4) unacceptable negative effects on the ocean for other uses as a result of direct environmental impact (40 Code of Federal Regulations [CFR] section 125.122). Proposed training and testing activities using SURTASS LFA sonar also occur beyond 200 nmi (370 km) from any U.S. shores. Even though the CWA regulations may not apply to those waters, the pertinent CWA water quality standards are used as accepted scientific standards to assess potential effects on sediments and water quality associated with SURTASS LFA sonar training and testing activities.

The International Convention for the Prevention of Pollution from Ships (Convention) addresses pollution generated by normal vessel operations. The Convention is incorporated into U.S. law as 33 U.S.C. sections 1901–1915. The Convention includes six annexes: Annex I, oil discharge; Annex II, hazardous liquid control; Annex III, hazardous material transport; Annex IV, sewage discharge; Annex V, plastic and garbage disposal; and Annex VI, air pollution. The Navy is required to comply with the

5 The USNS ABLE, EFFECTIVE, and VICTORIOUS may travel at top speeds of 10 kt (18.5 kph) when not towing the SURTASS LFA sonar arrays, while the USNS IMPECCABLE has a top speed of 12 kt (22 kph) when underway.

Convention; however, the U.S. is not a party to Annex IV. The discharge of sewage by military vessels is regulated by Section 312(d) of the CWA. The Convention contains handling requirements and specifies where materials can be discharged at sea, but it does not contain standards related to sediments nor water quality.

The NDAA of 1996 amended section 312 of the CWA, directing the EPA and the DoD to jointly establish the Uniform National Discharge Standards (UNDS) for discharges (other than sewage) incidental to the normal operation of military vessels. The UNDS program establishes national discharge standards for military vessels in U.S. coastal and inland waters extending seaward to 12 nmi (22 km) from shore. Twenty-five types of discharges were identified as requiring some form of pollution control (e.g., a device or policy) to reduce or eliminate the potential for effects. The discharges addressed in the program include, ballast water, deck runoff, and seawater used for cooling equipment. A complete list of discharges may be found in 40 CFR part 1700.4. These national discharge standards reduce the environmental effects associated with vessel discharges, stimulate the development of improved pollution control devices aboard vessels, and advance the development of environmentally sound military vessels.

The U.S. Navy adheres to regulations outlined in the UNDS program. Accordingly, discharges addressed under the Convention or the UNDS program for the typical operations of military vessels are not addressed further in this BE. Only the impacts associated with discharges strictly related to training or testing activities would be addressed. However, because training and testing activities involving the use for SURTASS LFA sonar as proposed herein do not involve any specific discharges, including for example, military expended materials (i.e. chaff, flares, munitions, etc.), there is no further discussion of discharges in this BE.

2.6.1.3 Ship-generated Underwater Noise

The anthropogenic ambient noise environment in both the Pacific and Indian Oceans are dominated by noise from ships (Miksis-Olds and Nichols, 2016). Most of the underwater sound generated by ships is LF (<1,000 Hz), with most ship noise resulting from propeller cavitation that dominates the <200 Hz frequency range (Ross, 1976). The noise ships produce results not only from the type of engine and propeller systems used but also from the speeds at which the ships travel. Generally, larger (>328 ft [100 m]), faster moving vessels generate more intense LF underwater sound than smaller, slower moving vessels or boats (Frankel and Gabriele, 2017; Southall et al., 2018).

Most research on ship noise is from large vessels, fishing vessels, or small boats. Little to no research is available on the size class and hull design (catamaran hull) of the Navy's SURTASS LFA sonar vessels (Hildebrand, 2009; McKenna et al. 2012; Southall et al., 2018). SURTASS LFA sonar vessels range in size from 235 to 281 ft (72 to 86 m) in length and travel at speeds of 3 to 13 knots (kt) (5.6 to 47 kilometers per hour [kph]) (DoN, 2017d). Similarly-sized vessels are individual merchant ships (lengths of 276 to 400 ft [84 to 122 m]) that travel at speeds of 9.9 to 15 knots (kt) (18.4 to 27.7 kilometers per hour {kph}]) and smaller fishing vessels (49 to 151 ft [15 to 46 m]) capable of traveling at speeds from 7 to 10 kt (13 to 18.4 kph). Sounds from these two types of vessels range in frequency from 10 to 50 Hz with SLs from 161 to 165 dB re $\mu Pa^2/Hz$ @ 1 m and 139 to 143 dB re $\mu Pa^2/Hz$ @ 1 m, respectively (NRC, 2003).

Although no specific information is available on the noise generated by SURTASS LFA sonar vessels, since the purpose of these vessels is the detection of quiet, submersed vessels, it follows that the vessels themselves would operate as quietly as possible and generate as little detectable noise as technologically possible. For instance, the specialized catamaran (SWATH) hull design and encased propeller system of the T-AGOS vessels likely produce less noise than other seagoing vessel hull or propeller designs. Thus, while it is likely that the T-AGOS vessels produce some underwater noise, the lower speed at which the vessels typically operate, and their specialized function, likely result in the addition of far less noise to the ambient noise environment than the majority of other ocean-going vessels.

2.6.2 SURTASS Passive Sonar

The SURTASS or passive component of the SURTASS LFA sonar system 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 to 4 kt [5.6 to 7.4 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. 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, its horizontal orientation when towed, and the heavy tow cables that remain taut and rigid when the array is under tow, all of which reduce the potential of an marine animal inadvertently becoming entangled in the deployed equipment. For these reasons, operation of the SURTASS HLA is not reasonably likely to result in impacts to the environment.

2.6.3 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 effects 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 LFA mitigation and buffer zones under the most adverse oceanographic conditions (low echo return and high ambient noise). The maximum HF/M3 sonar pulse is 40 milliseconds (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 above the LFA sonar VLA (Figure 2-3). 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 sonar vessel.

The parameters at which the HF/M3 sonar operates and the high transmission loss of the sonar signals due to the high operating frequency together reduce the possibility for the sonar to affect marine mammals, sea turtles, or marine 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 some odontocetes. However, the required ramp-up period from a SL of 180 dB re 1 µPa @ 1 m (rms) 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 and thus not be affected by the HF/M3 transmissions. In total, these factors result in a predicted negligible impact on marine mammals, sea turtles, or marine fishes from exposure to HF/M3 sonar.

2.6.4 Transmission of LFA Sonar

The only remaining component of the Navy's proposed action that may affect the marine environment is the transmitted LFA sonar signals. The described characteristics of the signals transmitted by LFA sonar and its operational parameters must be considered in determining the potential for effects on the environment. In this BE, the Navy's effects analysis illustrates the estimated potential effects on ESA-listed marine species or their critical habitat from LFA sonar training and testing transmissions.

3 LISTED MARINE SPECIES AND CRITICAL HABITAT IN THE ACTION AREA

Although numerous marine or anadromous[6] animals and their designated critical habitats are protected under the ESA, not all these marine species and critical habitats are considered in this BE. To establish which of the ESA-listed marine species and critical habitats may potentially be affected by SURTASS LFA sonar operations and would thus be considered herein, three essential screening criteria were applied:

- Species or critical habitat had to occur (at least seasonally for marine species) in the study area of SURTASS LFA sonar, and
- Species had to possess sensory organs or tissues that allow the animals to perceive the LF sounds produced by LFA sonar, and/or
- 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 herein.

These criteria immediately limit the types of animals that could be affected by SURTASS LFA sonar activities. To be affected by LF sound, marine species must be able to hear LF sound and/or at least have some organ or tissue capable of changing sound energy into mechanical effects. For LF sound to affect an animal, the organ or tissue must have acoustic impedance different from water, where impedance is the product of density and sound speed. Since many marine organisms do not have an organ or tissue with acoustic impedance different from water, they would be unaffected, even if they were in areas ensonified by LF sound.

If marine animals possess no sound sensing organs or tissues, it is nearly impossible to gauge if LF sounds affect them or if they would respond to LF sounds. Thus, ESA-listed marine animals would be unaffected by exposure to LF sounds if those listed animals lack sound sensing organs or tissues or the animals or critical habitat does not occur in an area where SURTASS LFA sonar may be operated and would thus not even be exposed to LFA sonar.

Only those species of ESA-listed marine animals or ESA designated critical habitats meeting these criteria are considered further in this assessment (Tables 3-1 and 3-2). In cases where direct evidence of acoustic sensitivity to LF sound or any other frequency range is lacking for a species, reasonable indirect evidence was used to support the evaluation (e.g., there is no direct evidence that a species hears LF sound, but good evidence exists that the species produces LF sound). In cases where important biological information was not available or was insufficient for one species, but data were available for a related species, the comparable data were used.

3.1 ESA-Listed Marine Species Not Further Considered

For ESA-listed species to be considered or evaluated in this BE, the potential must exist for a species to be affected by SURTASS LFA sonar training and testing activities. If no potential reasonably is expected for effects to ESA-listed marine species, then those species are not further considered herein. Even

6 Anadromous species are born in freshwater but migrate as juveniles to the ocean, where they grow to adults before migrating back to freshwater to spawn. Examples of anadromous species are salmon, striped bass, and lamprey.

Table 3-1. ESA-Listed Marine or Anadromous Species and Distinct Population Segments (DPSs) that May Occur in the Study Area for SURTASS LFA Sonar and Whether They are Included for Consideration in This Biological Evaluation.

Marine ESA-listed Species	***ESA Status***		***Further Considered***	***Not Further Considered***
	Threatened	***Endangered***		
Marine Invertebrates[7]				
Acropora globiceps	Throughout Its Range			X
Acropora jacquelinae	Throughout Its Range			X
Acropora lokani	Throughout Its Range			X
Acropora pharaonis	Throughout Its Range			X
Acropora retusa	Throughout Its Range			X
Acropora rudis	Throughout Its Range			X
Acropora speciosa	Throughout Its Range			X
Acropora tenella	Throughout Its Range			X
Anacropora spinosa	Throughout Its Range			X
Cantharellus noumeae	Throughout Its Range			X
Chambered nautilus ((*Nautilus pompilius*)	Throughout Its Range			X
Euphyllia paradivisa	Throughout Its Range			X
Isopora crateriformis	Throughout Its Range			X
Montipora australiensis	Throughout Its Range			X
Pavona diffluens	Throughout Its Range			X
Porites napopora	Throughout Its Range			X
Seriatopora aculeata	Throughout Its Range			X
Siderastrea glynni	Throughout Its Range			X
Tubastraea floreana	Throughout Its Range			X
Marine Reptiles				
Dusky sea snake (*Aipysurus fuscus)*		Throughout Its Range		X
Green turtle (*Chelonia mydas)*	Central West Pacific DPS	Central North Pacific DPS	X	
		East Indian-West Pacific DPS	X	

7 All ESA-listed marine invertebrates potentially occurring in the SURTASS LFA study area are coral species with the exception of the chambered nautilus.

Table 3-1. ESA-Listed Marine or Anadromous Species and Distinct Population Segments (DPSs) that May Occur in the Study Area for SURTASS LFA Sonar and Whether They are Included for Consideration in This Biological Evaluation.

Marine ESA-listed Species	***ESA Status***		***Further Considered***	***Not Further Considered***
	Threatened	***Endangered***		
Green turtle (Continued)		North Indian DPS	X	
Hawksbill turtle (*Eretmochelys imbricata)*		Throughout Its Range	X	
Leatherback turtle (*Dermochelys coriacea)*		Throughout Its Range	X	
Loggerhead turtle (*Caretta caretta*)	Southeast Indo-Pacific Ocean DPS	North Indian Ocean DPS	X	
		North Pacific Ocean DPS	X	
Olive ridley turtle (*Lepidochelys olivacea)*	All Populations Except Mexico Pacific Coast[8]		X	
Marine and Anadromous Fishes				
Chinese sturgeon (*Acipenser sinensis*)		Throughout Its Range		X
Chinook salmon (*Oncorhynchus tshawytscha*)	Puget Sound ESU[9]	Upper Columbia River Spring-run ESU	X	
	California Coastal ESU	Sacramento River Winter-run ESU	X	
	Upper Willamette River ESU		X	
	Central Valley Spring-run ESU		X	
	Snake River Fall-run ESU		X	
	Lower Columbia River ESU		X	
	Snake River Spring/Summer-run ESU		X	
Chum salmon (*Oncorhynchus keta)*	Columbia River ESU		X	
	Hood Canal Summer-run ESU		X	
Coho salmon (*Oncorhynchus kisutch)*	Lower Columbia River ESU	Central California Coast Coho ESU	X	
	Oregon Coast ESU		X	
	Southern Oregon/Northern California Coasts ESU		X	
Dwarf sawfish *(Pristis clavata)*		Throughout Its Range		X

8 The Mexico Pacific coast breeding population of olive ridley turtle's is listed under the ESA as endangered.

9 ESU=evolutionary significant unit

Table 3-1. ESA-Listed Marine or Anadromous Species and Distinct Population Segments (DPSs) that May Occur in the Study Area for SURTASS LFA Sonar and Whether They are Included for Consideration in This Biological Evaluation.

Marine ESA-listed Species	***ESA Status***		***Further Considered***	***Not Further Considered***
	Threatened	***Endangered***		
Giant manta ray (*Manta birostris*)	Throughout Its Range		X	
Green sawfish (*Pristis zijsron*)		Throughout Its Range		X
Kaluga sturgeon *(Huso dauricus)*		Throughout Its Range		X
Largetooth sawfish (*Pristis pristis*)		Throughout Its Range		X
Narrow sawfish (*Anoxypristis cuspidata*)		Throughout Its Range		X
Oceanic whitetip shark *(Carcharhinus longimanus)*	Throughout Its Range		X	
Sakhalin sturgeon (*Acipenser mikadoi)*		Throughout Its Range	X	
Scalloped hammerhead shark (*Sphyrna lewini)*	Indo-West Pacific DPS		X	
Sockeye salmon (*Oncorhynchus nerka)*	Lake Ozette ESU	Snake River Sockeye ESU	X	
Steelhead trout (*Oncorhynchus mykiss)*	California Central Valley DPS	Southern California Coast DPS	X	
	Central California Coast DPS		X	
	Lower Columbia River DPS		X	
	Middle Columbia River DPS		X	
	Northern California-Coast DPS		X	
	Puget Sound DPS		X	
	Snake River Basin ESU		X	
	South Central California Coast DPS		X	
	Upper Columbia River ESU		X	
	Upper Willamette River DPS		X	
Marine Mammals				
Blue whale (*Balaenoptera musculus)*		Throughout Its Range	X	
Fin whale (*Balaenoptera physalus)*		Throughout Its Range	X	
Gray whale *(Eschrichtius robustus)*		Western North Pacific DPS	X	
Humpback whale (*Megaptera novaeangliae*)		Western North Pacific DPS Arabian Sea DPS	X	 X
North Pacific right whale (*Eubalaena japonica*)		Throughout Its Range	X	
Sei whale (*Balaenoptera borealis*)		Throughout Its Range	X	

Table 3-1. ESA-Listed Marine or Anadromous Species and Distinct Population Segments (DPSs) that May Occur in the Study Area for SURTASS LFA Sonar and Whether They are Included for Consideration in This Biological Evaluation.

Marine ESA-listed Species	***ESA Status***		***Further Considered***	***Not Further Considered***
	Threatened	***Endangered***		
Chinese river dolphin *(Lipotes vexillifer)*		Throughout Its Range		X
False killer whale (*Pseudorca crassidens*)		Main Hawaiian Islands Insular DPS	X	
Indus River dolphin (*Platanista gangetica minor*)		Throughout Its Range		X
Sperm whale (*Physeter macrocephalus*)		Throughout Its Range	X	
Taiwanese humpbacked dolphin (*Sousa chinensis taiwanensis)*		Endangered		X
Hawaiian monk seal (*Neomonachus schauinslandi*)		Throughout Its Range	X	
Spotted seal (*Phoca largha*)	Southern DPS		X	
Western Steller sea lion (*Eumetopias jubatus jubatus*)		Western DPS/stock	X	

Table 3-2. Designated Critical Habitat for ESA-listed Species Located within the Study Area for SURTASS LFA Sonar that is Further Considered in this Biological Evaluation, Including the Type and Location of the Critical Habitat.

ESA-listed Marine Species	***ESA-listed DPS***	***Critical Habitat Location***	***Further Considered***	***Not Further Considered***
Marine Mammals				
False killer whale (*Pseudorca crassidens*)	Main Hawaiian Islands Insular DPS	Waters from the 148- to 10,499-ft (45-to 3,200-m) depth contours around the Main Hawaiian Islands from Niihau east to Hawaii	X	
Hawaiian monk seal (*Monachus schauinslandi*)		Shallow (<263 ft [80 m]), sheltered marine neritic habitat adjacent to onshore pupping or haulout areas and marine benthic habitat of the Northwestern and Main Hawaiian Islands (seafloor plus waters 33 ft [10 m] above seafloor) from shore to 263 ft [80 m]) and onshore nesting beach habitat	X	

though 54 ESA-listed marine or anadromous species or at least one distinct population segment (DPS)[10] of an ESA-listed species occur in the study area for SURTASS LFA sonar (Table 3-1), some of the listed species occur in areas such as rivers, inland waters, or nearshore habitats where SURTASS LFA sonar training and testing activities would not occur. Other ESA-listed species occur in the study area but do not meet the other screening criteria of possessing tissue or organs capable of detecting LF underwater sound. Further details follow on aspects of the screening factors associated with the ESA-listed species or DPSs that are further considered in this BE.

3.1.1 Potentially Occurring ESA-Listed Marine Invertebrate Species

ESA-listed marine invertebrates that potentially occur in the study area for SURTASS LFA sonar training and testing activities include coral species and the chambered nautilus (Table 3-1). The species of threatened corals listed under the ESA that occur in the study area grow in the shallow waters of the Indo-Pacific, in waters no greater than 131 ft (40 m) in depth, and typically less than 100 ft (30 m) in depth. These potentially occurring ESA-listed coral species most likely all occur in the waters of the coastal standoff range, where LFA sonar would be transmitted at a level of 180 dB SPL (rms) or below.

Very little is known about the sound sensing capabilities of coral, but coral can at least sense water movement and apparently can detect reef sounds. Vermeij et al. (2010) suggested that some species of coral larvae can apparently detect and exhibit an attraction response to the sounds generated on coral reefs. This ability might be the means by which these larvae identify favorable sites for settlement and development to adult life stages. Kaplan and Mooney (2016) reported that average coral reef sound levels are so low that they are likely only discernible from very close to a coral reef, although individual transient sounds were louder and likely could be detected further from the reef, depending upon the sound sensing capabilities of the larvae. Lecchini et al. (2018) made similar observations to Vermeji's earlier work, noting that the larvae of two common Indo-Pacific coral species were attracted preferentially for settlement to the natural soundscape of coral reefs. Lecchini et al. (2018) further noted that these species of coral larvae apparently were able to distinguish between sound sources, with the presence of boat noise in the soundscape appearing to disrupt the settlement behavior of one of the species of coral larvae, preventing their preferential settlement on the reef. Adult coral's sensory capabilities appear to be largely limited to detecting water movement using receptors on their tentacles (Gochfeld, 2004).

Although some mollusks are capable of sensing water movement (particle motion), and some few cephalopods have been shown to be capable of perceiving LF sound, little is known about how underwater sound may affect mollusks. Cephalopods, such as octopus and squid, are known to be capable of sensing LF sound (Budelmann, 1994; Mooney et al., 2010; Packard et al., 1990) but nothing is known about the hearing or sound sensing capabilities of the ESA-listed chambered nautilus. Audiometric studies on adult invertebrates tested (e.g., cephalopods and crustaceans) show lowest (i.e., most sensitive) thresholds below 1,000 Hz. 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} meters per second squared (msec-^{2}) at 1 to 2 Hz. This type of sound sensing mechanism was confirmed by Mooney et al. (2010), who demonstrated that the statocyst of squid enables the animal to detect sound particle motion, for which a pressure threshold of 110 dB re 1 µPa at 200 Hz was measured. Mooney et al. (2016) reported on the results of a behavioral study that showed one species of squid

10 DPS=distinct population segment; 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.

possessed optimal hearing in the range from 200 to 400 Hz, with responses to 80Hz. Additionally, behavioral responses to sound stimuli including escape and predator avoidance (inking, which occurred at the lowest sound frequencies and highest sound levels, body color changes, and jetting) (Mooney et al., 2016). Common cuttlefish respond behaviorally to sounds below 1,000 Hz (maximum sensitivities near 150 Hz), with escape responses (inking, jetting) observed between 80 and 300 Hz, sound levels above 140 dB re 1 µPa (rms), and particle acceleration of 0.01 $msec^{-2}$; body pattern changes and fin movements were observed at exposures from 80 to 1000 Hz, SPLs of 85 to 188 dB re 1 µPa (rms), and particle accelerations of 0 to 17.1 $msec^{-2}$ (Sampson et al., 2014). Thresholds at higher frequencies have been reported, with a frequency of 1,000 Hz and levels of 134.4 dB re 1 µPa and 139.0 dB re 1 µPa for the oval squid and the octopus, respectively (Hu et al., 2009).

McCauley et al. (2017) reported on the effects that exposure to seismic air gun sound had on species of zooplankton (not coral larval species but copepods, euphausiids, and other invertebrate larval species). The LF, impulsive seismic air gun signals caused decreases in zooplankton abundance and increases in adult and larval zooplankton mortality following exposure to the air gun signals at ranges up to 0.65 nmi (1.2 km) (McCauley et al., 2017). The RL of the airgun signals at ranges of 1,670 to 2,159 ft (509 to 658 m) and 0.59 to 0.65 nmi (1.1 to 1.2 km) was 156 decibels referenced to 1 microPascal squared per second (dB re 1 $µPa^2$-sec) SEL (183 dB re 1 µPa peak-to-peak) and 153 dB re 1 $µPa^2$-sec SEL (178 dB re 1 µPa peak-to-peak), respectively (McCauley et al., 2017). However, seismic airguns transmit impulsive signals characterized by a large frequency bandwidth, high energy, and short duration signals. As such, airgun signals cannot be directly compared with SURTASS LFA sonar signals, since the signal characteristics are very different and the likelihood of impacts on living tissue are dissimilar as well.

No metrics or exposure thresholds exist to enable quantification or assessment of noise impacts on marine invertebrates. Available information indicates that while some marine invertebrates may be able to detect underwater sound, little to no information is available on whether the ESA-listed coral and nautilus species are capable of sensing underwater LF sound or how exposure to underwater sound such as LFA sonar may affect these marine invertebrates. If species such as ESA-listed coral or chambered nautilus cannot perceive or detect LFA sonar signals, they cannot be affected by these signals. This combined information on the species of ESA-listed coral and the chambered nautilus that may occur in the study area for SURTASS LFA sonar results in the conclusion that SURTASS LFA sonar activities would not affect these species, which are thus not considered further herein.

3.1.2 Potentially Occurring ESA-Listed Sea Snake

The one sea snake species listed under the ESA, the dusky sea snake, (Table 3-1) 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). Much of the distributional range of the dusky sea snake is not located in the study area for SURTASS LFA sonar training and testing activities and any dusky sea snakes that do occur in the LFA sonar study area would be located in the coastal standoff range, in which LFA sonar would not be transmitted above 180 dB SPL (rms).

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). 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 Hz) but may be able 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. Additionally, any dusky sea snakes occurring in the study area for SURTASS LFA sonar training and testing activities would be found in the near shore environment of the coastal standoff range, where it would never be exposed to LFA sonar transmissions of more than 180 dB SPL (rms). As such, the Navy has concluded that the dusky sea snake would not be affected by SURTASS LFA sonar training and testing activities. For these reasons, sea snakes are eliminated from further consideration herein.

3.1.3 Potentially Occurring ESA-Listed Marine and Anadromous Fishes

Fifteen species of ESA-listed marine and anadromous fish potentially occur in the study area for SURTASS LFA sonar training and testing activities (Table 3-1). However, not all 15 of these fish species meet the screening criteria for consideration of effects associated with training and testing activities of SURTASS LFA sonar. Two sturgeon and four sawfish species do not co-occur in the study area for SURTASS LFA sonar since these species are distributed in inland, inshore, or very shallow[11] coastal waters where SURTASS LFA sonar activities would not occur or would be highly unlikely to occur. Excluded from further consideration on this basis are:

- Chinese sturgeon (*Acipenser sinensis*)—this anadromous, endangered sturgeon is listed for the Yangtze River basin, where it occurs only in the middle and lower Yangtze River and very close to shore in the East China and Yellow seas (NOAA, 2013).
- Dwarf Sawfish (Pristis clavata)—this endangered sawfish's range is restricted to shallow (< 33 ft [10 m]) tropical coastal, estuarine, and riverine waters of the western-central Pacific and Eastern Indian oceans, but the population is considered to now be limited to waters of northern and northwestern Australia and is likely extinct in the waters of Papua New Guinea and Indonesia; no records of occurrence in offshore waters have been substantiated (Kyne et al., 2013; NOAA, 2014b).
- Green sawfish (Pristis zijsron)—as a species, this sawfish is listed as endangered and is distributed in inshore estuarine and riverine habitats in waters typically no more than 16 ft (5 m) in the Indo-West Pacific, although the green sawfish is considered very rare in the Indian Ocean and may be extirpated from most of its historic range (NOAA, 2014b).

11 Generally, SURTASS LFA sonar activities are conducted in waters deeper than 656 ft (200 m) in which potential objects of surveillance would be most likely to occur. However, testing and training activities using the CLFA source array and TL-29A receive array could be conducted in shallower water, depending upon the circumstances.

- Kaluga sturgeon (Huso dauricus)—this endangered fish only now occurs in the lower reaches of the Amur River in Russia and China (NOAA, 2013).
- Largetooth sawfish (Pristis pristis)—is an endangered species that occurs in shallow (<33 ft [10 m]) coastal, inshore, and river habitats of the Indo-Pacific and western Atlantic oceans, although currently this sawfish occurs only in isolated and often remote, very small populations throughout its historic range (NOAA, 2014b).
- Narrow sawfish (Anoxypristis cuspidata)—listed as endangered throughout its range, the narrow sawfish's distribution is restricted to shallow (130 ft [40 m]), inshore habitats with salinities between 25 and 35 practical salinity units (psu) in the western Pacific and Indian oceans, with a preference for muddy estuarine benthic habitats (NOAA, 2014b).

Although little information is available on the hearing abilities of these sawfish and sturgeon species, these fish species are thought capable of sensing underwater sound, as most fish species for which hearing has been measured having greatest hearing sensitivity in the range from 100 to 200 Hz and up to 800 Hz (Popper, 2003). While these species likely could detect the transmissions of LFA sonar, they occur inshore or in the coastal standoff range, where they would never be exposed to SURTASS LFA sonar transmissions greater than 180 dB SPL (rms). Due to the riverine, and inshore, shallow waters in which these ESA-listed sturgeon and sawfish species occur, it is unlikely that they would be exposed to LFA sonar signals at all, much less at levels high enough to affect them adversely. The six species of sawfish and sturgeon occurring in the western North Pacific and eastern Indian oceans are thus removed from further consideration in this BE.

3.1.4 Potentially Occurring ESA-Listed Marine Mammals

Of the 14 ESA-listed species of marine mammals that potentially occur in the study area for SURTASS LFA sonar, three occur in the riverine, inshore, or very shallow (<82 ft [25 m]) coastal waters where SURTASS LFA sonar training and testing activities would not occur, and the fourth occurs in waters adjacent to the western boundary of the study area for SURTASS LFA sonar. Thus, these four ESA-listed marine mammal species do not meet the screening criteria of co-occurrence with SURTASS LFA sonar training and testing activities. Excluded from further consideration on this basis are the following marine mammals:

- Baiji or Chinese river dolphin (*Lipotes vexillifer)*—this freshwater dolphin is highly endangered throughout its range in the Yangtze River of China (approximately an 870-mile [161 km] extent of the river), and may already be extinct (Turvey et al*.,* 2007).
- Indus River dolphin (*Platanista gangetica minor*)—this freshwater dolphin, also known as bhulan, is highly endangered throughout its range in the shallow waters of the Indus River system of Pakistan, where its range includes about 435 to 620 miles (700 to 1,000 km) of riverine habitat.
- Taiwanese humpbacked dolphin (*Sousa chinensis taiwanensis)*—this endangered coastal dolphin has only been reported occurring in shallow (<82 ft [25 m]) nearshore waters, no more than 1.6 nmi (3 km) from shore (Dares et al., 2014; Wang et al., 2016).
- Arabian Sea DPS of humpback whale (*Megaptera novaeangliae)*—the endangered DPS of humpback whales is geographically, genetically, and demographically isolated from all other populations of humpback whales (Minton et al., 2008). Research surveys over the past 30 years have confirmed the continuous presence of humpback whales in the shallow, nearshore waters of the Arabian Sea off Oman (Minton et al., 2011), which is not in the study area for SURTASS LFA

sonar. Only a limited and incidental number of humpback whale sightings and strandings have been reported from the eastern Arabian Sea off Pakistan and western India (Bettridge et al., 2015; Minton et al., 2008), with only the waters off western India being located within the study area for SURTASS LFA sonar. Given the well-documented concentration of this DPS in the western Arabian Sea, the Navy concluded that the likelihood of humpback whales from the Arabian Sea DPS being located in the waters of the northwestern most part of the study area was vanishingly small. For this reason, the Arabian Sea DPS of humpback whales is not further considered in this BE.

These species of marine mammals all typically occur in the shallow waters inshore or within the coastal standoff range for SURTASS LFA sonar where they would not be exposed to sonar sound levels above 180 dB SPL (rms). Since these species of marine mammals do not co-occur with the proposed SURTASS LFA sonar training and testing activities, they are thus not considered further in this BE.

3.2 ESA-Listed Marine Species and Critical Habitat Further Considered

3.2.1 ESA Critical Habitat Considered Further

Critical habitat (CH) 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)). Areas occupied by a species may include areas utilized throughout the entire life or only certain lifestages, even if not used on a regular basis (DoC and DoI, 2016). Additionally, CH can also be designated outside a species' geographical range if NMFS and/or USFWS, which share jurisdiction over ESA species and CH, determine that the area itself is essential for conservation. Critical habitat is not designated in foreign countries or other areas outside U.S. jurisdiction. 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, destroy, or adversely modify its designated critical habitat.

The physical or biological features or primary constituent elements (PCEs) of CH are those supporting the life-history needs of a species, including but not limited to, water characteristics, soil type, geological features, sites, prey, vegetation, symbiotic species, or others. A feature may be a single habitat characteristic or a more complex combination of habitat characteristics. The physical or biological features may include habitat characteristics that support ephemeral or dynamic habitat conditions and may be expressed in terms relating to principles of conservation biology, such as patch size, distribution distances, and connectivity (DoC and DoI, 2016). The life history parameters that these physical or biological habitat features support may include, but are not limited to:

- Space for individual and/or population growth and normal behavior
- Food (prey), water, air, light, minerals, or other nutritional or physiological requirements
- Cover or shelter
- Sites for breeding, reproduction, rearing of offspring
- Habitats protected from disturbance or that are representative of the historic geographical and ecological distributions of a species (50 CFR 424.12[b]).

Of the potentially occurring marine species that have been listed as threatened or endangered under the ESA, CH has been designated within the study area for SURTASS LFA sonar training and testing activities for only two marine mammal species, the Hawaiian monk seal and the Main Hawaiian Island (MHI) Insular DPS of the false killer whale (Table 3-2). Critical habitat for these two species/DPSs is considered in this BE. The following provides a description of the physical or biological features or PCEs of the designated CH for the Hawaiian monk seal and MHI Insular DPS of the false killer whale.

3.2.1.1 Critical Habitat for the Hawaiian Monk Seal

Critical habitat for the Hawaiian monk seal was first designated in 1988 for 10 nearshore areas in the Northwest Hawaiian Islands (NWHI) (NOAA, 1988), but in 2015, the CH was revised to extend the NWHI CH and to add CH in the MHI. As revised, CH for the Hawaiian monk seal includes seafloor and marine neritic and pelagic waters within 33 ft (10 m) of the seafloor from the shoreline seaward to the 628-ft (200-m) depth contour at 10 areas in the NWHI, including 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 and six areas in the MHI including Kaula, Niihau, Kauai, Oahu, Maui Nui (i.e., Kahoolawe, Lanai, Maui, and Molokai), and Hawaii (excluding National Security Exclusion zones off Kauai, Oahu, and Kahoolawe) (Figure 3-1) (NOAA, 2015c). The MHI CH also includes specific terrestrial areas from the shoreline inland 16 ft (5 m). Only the portions of the Hawaiian monk seal's marine benthic (seafloor plus waters 33 ft [10 m] above seafloor) and pelagic CH in the MHI and NWHI from 263 to 656 ft (80 to 200 m) of depth are considered further in this BE.

Certain areas have been excluded from the Hawaiian monk seal's CH because they are managed under and military Integrated Natural Resources Plans. These areas in the Hawaiian Islands include: 1) Marine Corps Base Hawaii, Oahu—a 500-yd (91 m) buffer zone in the waters surrounding the base and the Puuloa Training Facility on the Ewa coastal plain, Oahu; 2) Joint Base Pearl Harbor-Hickam, Oahu inclusive of Nimitz Beach, White Plains Beach, Naval Defensive Sea Area, Barbers Point Underwater Range, and Ewa Training Minefield; 3) Pacific Missile Range Facility, Kauai, Offshore Areas plus Kaula Island and the coastal and marine areas to the 33 ft (10-m) isobath surrounding the Island of Niihau; 4) Kingfisher Underwater Training area, off the northeast coast of Niihau; 5) Puuloa Underwater Training Range off Pearl Harbor, Oahu; and 6) Shallow Water Minefield Sonar Training Range, off the western coast of Kahoolawe in the Maui Nui area (NOAA, 2015c).

The physical or biological features of the Hawaiian monk seal CH that support the species' life history needs include 1) areas with characteristics preferred by monk seals for pupping and nursing; 2) shallow, sheltered nearshore marine areas preferred by monk seals for pupping and nursing; 3) marine areas up to 1,640 ft (500 m) in depth preferred by juvenile and adult monk seals for foraging; 4) areas with low levels of human disturbance; 5) marine areas with adequate prey quantity and quality; and 6) significant shore areas used by monk seals for hauling out, resting, or molting (NOAA 2015c).

Hawaiian monk seals focus foraging in bottom habitats on bottom-associated prey species, with most foraging occurring in waters between 0 and 656 ft (0 to 200 m) in depth. Habitat types that are regularly used for foraging include the sand terraces, talus slopes, submerged reefs and banks, nearby seamounts, barrier reefs, and slopes of reefs and islands. Habitat conditions, such as water quality, substrate type, and available habitat should support growth and recruitment of bottom-associated prey species to the extent that monk seal populations are able to forage successfully. Pupping areas are those locations where two, or more females have given birth, or where a single female chooses to return to the same

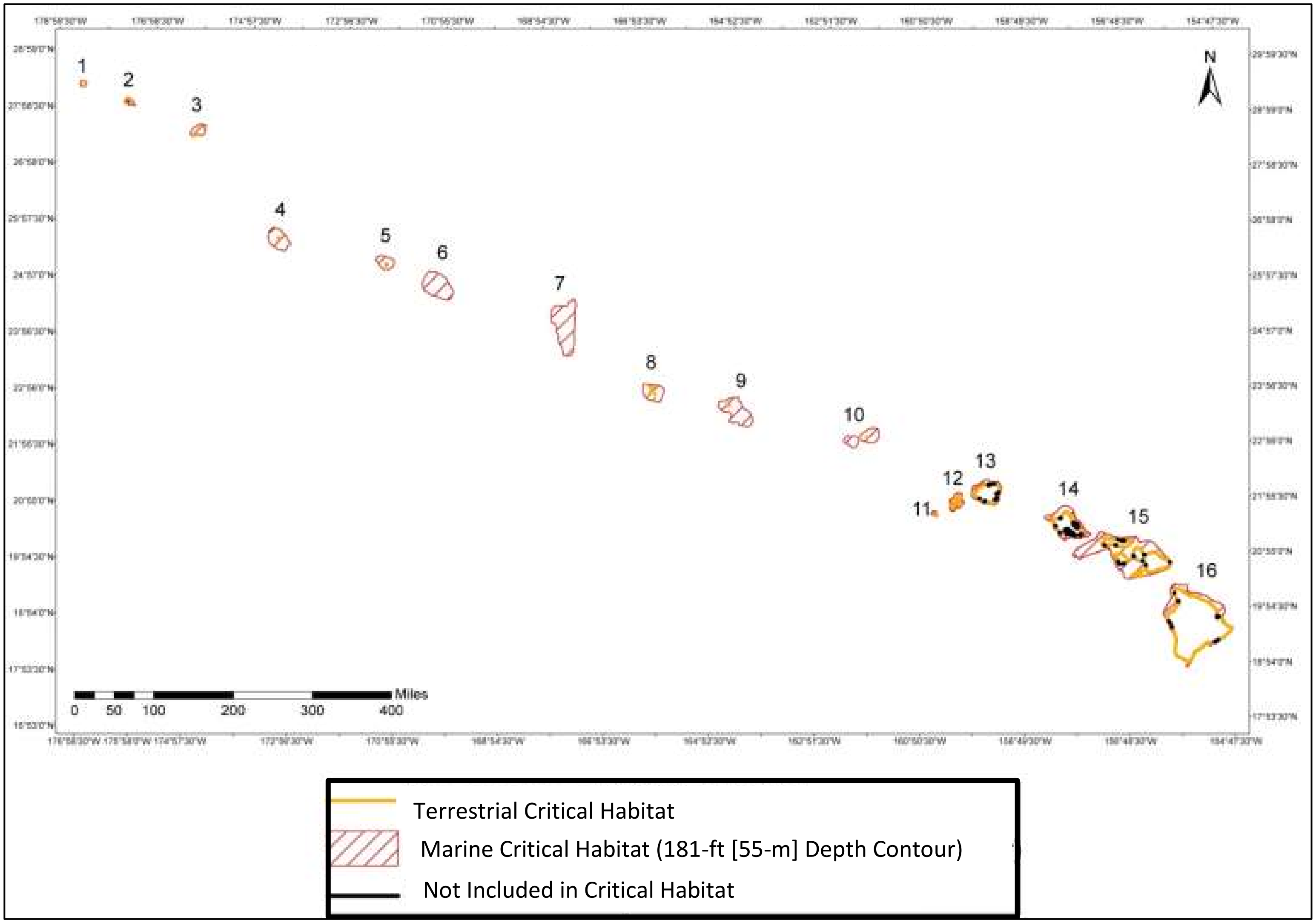

Figure 3-1. Critical Habitat for the Hawaiian Monk Seal in the Northwestern and Main Hawaiian Islands (NMFS, 2016b).

site more than one year. Preferred pupping areas generally include sandy, protected beaches located adjacent to shallow sheltered aquatic areas, where the mother and pup may nurse, rest, swim, thermoregulate, and shelter from extreme weather. Additionally, this habitat area provides relatively protected space for the newly weaned pup to acclimate to life on its own.

Nearly all the CH for the Hawaiian monk seal lies within the coastal standoff distance for SURTASS LFA sonar, wherein the sound field generated by LFA sonar cannot exceed 180 dB re 1 µPa (rms) (SPL) within 12 nmi (22 km) of any emergent land, including islands (Figure 3-2). A small area of the monk seal's critical habitat at Penguin Bank extends beyond the 12-nmi (22-km) coastal standoff distance. Though Penguin Bank extends beyond the protection of the coastal standoff distance, Penguin Bank is not only an OBIA for SURTASS LFA sonar, but no SURTASS LFA sonar training and testing activities would be conducted in the waters of Penguin Bank to the extent of the 600 ft (183 m) depth contour, which is also the boundary of the OBIA, per agreement with the State of Hawaii CZMA Program. Thus, no part of the CH for the Hawaiian monk seal would be exposed to LFA sonar RLs above 180 dB SPL (rms).

3.2.1.2 Critical Habitat for the Main Hawaiian Islands Insular Distinct Population Segment of the False Killer whale

Critical habitat has been designated for the MHI Insular DPS of the false killer whale (NOAA, 2018b). The critical habitat for the MHI DPS of false killer whales includes waters from the 148- to 10,499-ft (45-to 3,200-m) depth contours around the Main Hawaiian Islands from Niihau east to Hawaii (Figure 3-3). Critical habitat would not include most bays, harbors, or coastal in-water structures. The total CH area is approximately 19,184 mi² (49,701 km²) of marine habitat (NOAA, 2017).

More than 14 Navy and Bureau of Ocean Energy Management areas are excluded from the critical habitat designation because they are managed under a military Integrated Natural Resources Plan or would have economic, military readiness, or national security impacts (NOAA, 2018b). These areas include the 1) Bureau of Ocean Energy Management's Call Area, offshore Oahu; 2) Navy Pacific Missile Range Facilities Offshore Ranges, Kauai, inclusive of the Shallow Water Training Range, Barking Sands Tactical Underwater Range, and Barking Sands Underwater Range Extension; 3) Navy Kingfisher Range off the northeast coast of Niihau; 4) Navy Warning Area 188; 5) Kaula and Warning Area 187; 6) Navy Fleet Operational Readiness Accuracy Check Site Range; 7) Navy Shipboard Electronic Systems Evaluation Facility; 8) Warning Areas 191 and 196; 9) Warning Areas 193 and 194; 10) Kaulakahi Channel Portion of Warning Area 186; 11) the area north of Molokai; 12) part of the Alenuihaha Channel; 13) Hawaii Area Tracking System; 14) Kahoolawe Training Minefield; 15) Ewa Training Minefield, Joint Base Pearl Harbor-Hickam, Oahu; and 16) Naval Defensive Sea Area, Joint Base Pearl Harbor-Hickam, Oahu; (NOAA, 2018b).

One physical or biological feature of the designated CH has been defined as being essential for the conservation of the MHI Insular DPS of false killer whales: island-associated marine habitat (NOAA, 2018b). Four characteristics support the physical/biological feature of island-associated marine habitat and the false killer whale's ability to travel, forage, communicate, and move freely around and among the MHI:

- adequate space for movement and use within the continental shelf and slope habitat;
- prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth;

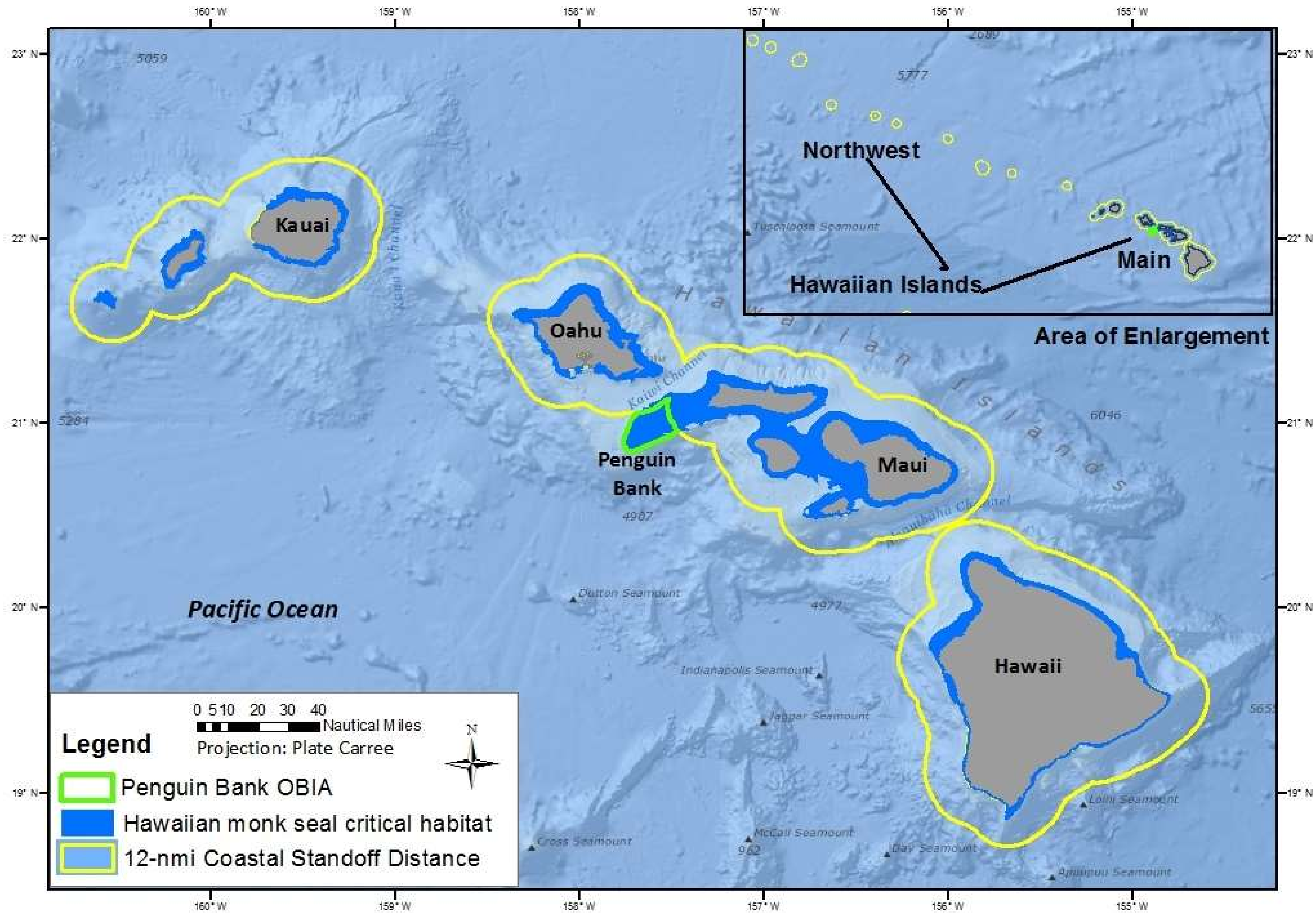

Figure 3-2. Location of the Hawaiian Monk Seal Critical Habitat in Association with the Coastal Standoff Range for SURTASS LFA Sonar in the Main Hawaiian Islands and the Location of the Penguin Bank.

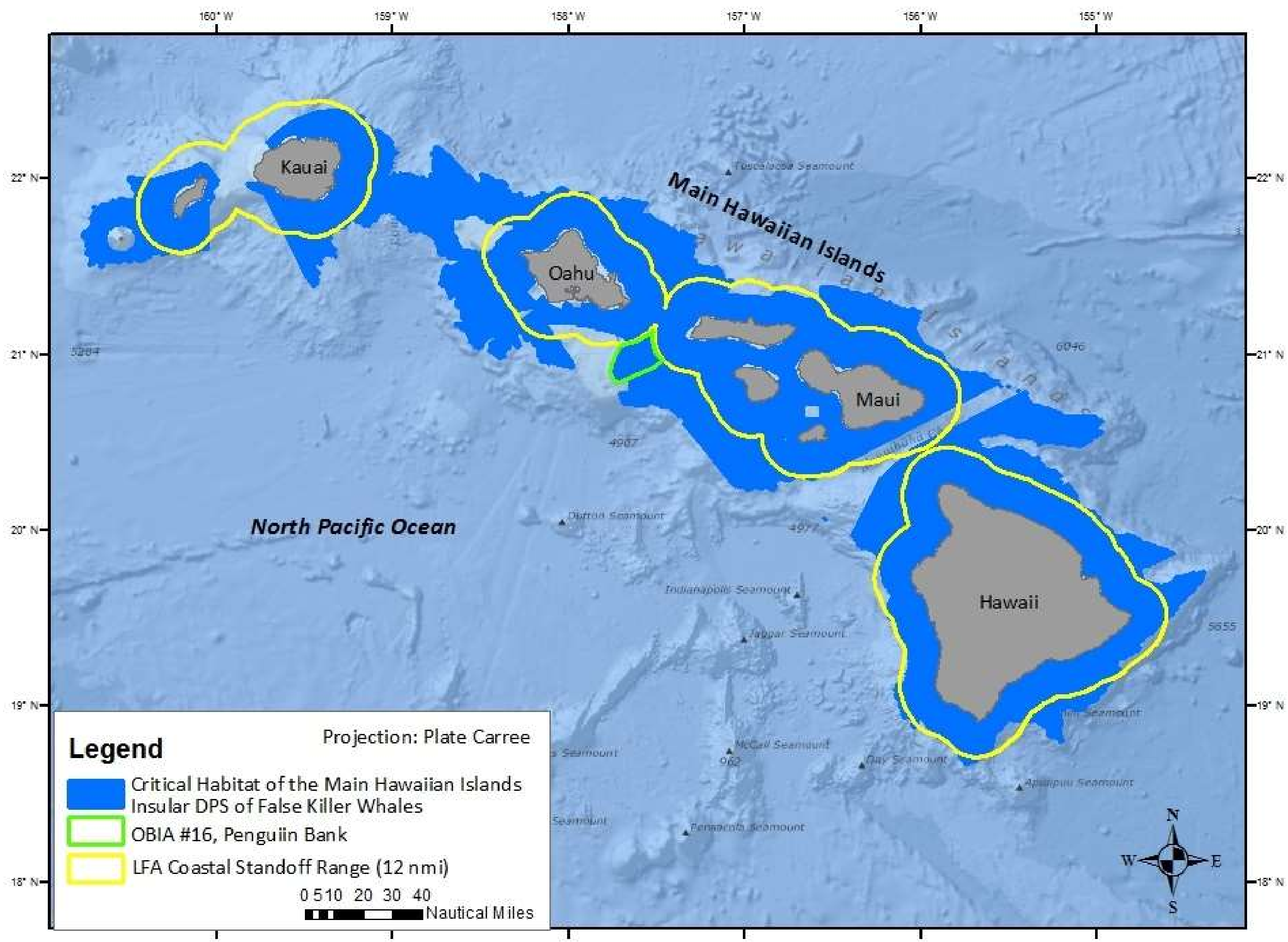

Figure 3-3. Location of Critical Habitat of the Main Hawaiian Islands Insular Distinct Population Segment of the False Killer Whale (NOAA, 2018c) in Conjunction with the Coastal Standoff Range for SURTASS LFA Sonar and Penguin Bank.

- waters free of pollutants of a type and amount harmful to MHI Insular false killer whales; and
- underwater sound levels that would not significantly impair false killer whales' use or occupancy (NOAA, 2018b).

The MHI Insular DPS of false killer whales are described as an island-associated population of whales that rely entirely on the productive, submerged marine habitat of the MHI to support all their life-history stages. (NOAA, 2018b). False killer whales do not uniformly utilize the marine habitat surrounding the MHI but instead use specific high-use or high-density areas that likely provide greater foraging success or that are relevant to certain social groups of whales. Although prey preference or the relative importance of various prey of the MHI false killer whale population is not fully understood, the MHI false killer whales feed on large pelagic game fish and squid. NMFS clarified in the Final Rule that the underwater sound levels referenced in the fourth characteristic of the island-associated habitat referred to chronic exposure to noise as well as the presence of persistent noise in the soundscape that may impede the ability of the MHI Insular DPS of false killer whales to use the island-associated marine habitat for foraging, navigating, and communicating, and may deter these false killer whales from using the habitat entirely (NOAA, 2018b).

In most areas of the waters surrounding the MHI, the coastal standoff range for SURTASS LFA sonar (12 nmi [22 km] from the emergent land of the MHI) is located closer to shore than the outer boundary of the CH for the MHI Insular DPS of the false killer whale, which is the 10,499-ft (3,200 m) isobath (Figure 3-3). SURTASS LFA sonar RLs would not exceed 180 dB SPL (rms) in these waters of the coastal standoff range. However, nearly 40 percent of the CH is located outside the coastal standoff range for SURTASS LFA sonar, including Penguin Bank. As noted previously, not only is Penguin Bank an OBIA for SURTASS LFA sonar, but SURTASS LFA sonar training and testing activities would not be conducted in the waters over Penguin Bank to the extent of the 600 ft (183 m) depth contour.

3.2.2 ESA-Listed Marine Species Considered Further

Twenty-four ESA-listed marine species or potentially occurring DPSs are considered herein. The marine species considered in this BE include five species of sea turtles, eight marine and anadromous fish species, and 11 species of marine mammals (Table 3-1) that may potentially be affected by SURTASS LFA sonar training and testing activities in the western and central North Pacific and eastern Indian oceans. Following is pertinent baseline information from which effects to these species can be assessed.

3.2.3 Potentially Occurring ESA-Listed Sea Turtles

Five of the seven species of living sea turtles potentially occur in the study area for SURTASS LFA sonar training and testing activities, and all are listed as threatened or endangered under the ESA (Table 3-1). Although a sixth sea turtle species, the flatback turtle, occurs in the study area, it is not listed under the ESA. Hearing has been studied in four of the seven species of sea turtles, with the hearing sensitivity of the green, loggerhead, Kemp's ridley, and leatherback turtles reported to be <2 kHz, with greatest hearing sensitivity from 200 to 750 Hz (Bartol et al., 1999; Bartol and Ketten, 2006; Dow Piniak et al., 2012b; Lavender et al., 2012; Lenhardt 1994; Lenhardt et al., 1983; Martin et al., 2012; Mrosovsky, 1972; O'Hara and Wilcox, 1990; Ridgway et al., 1969). Since it is likely that all the potentially occurring species of sea turtles hear LF sound, at least as adults (O'Hara and Wilcox, 1990; Ridgway et al., 1969), the five species of potentially occurring sea turtles, namely the green, hawksbill, leatherback, loggerhead, and olive ridley turtles are considered in this BE.

The global populations of the ESA-listed green and loggerhead turtles have been divided into DPSs. Only the DPSs that potentially occur within the study area for SURTASS LFA sonar area are considered herein. Overview information on the hearing and sound production capabilities of sea turtles is presented herein in addition to species-specific overviews that include the ESA status, critical habitat, abundances, distribution, diving, and threats to species' or DPS's recovery. The information presented herein is the best information available on these species and is presented in alphabetical order by species.

3.2.3.1 Hearing Capabilities and Sound Production in Sea Turtles

Despite the small number of sea turtle species, only limited data and information on sea turtle hearing and sound production exist. Sea turtles have no ear pinnae (external ear openings), as their middle ears are covered by a layer of fat that is overlain by a thick layer of skin on their external head surface called the tympanum; this layer of fat over the middle ear appears to be a distinguishing feature of sea turtle ear morphology. Sea turtle ears are adapted to hear both underwater and in air, with sound being received either by bone conduction (Lenhardt et al., 1985), resonance of the middle ear cavity (Willis et al., 2013), or standard tympanic middle ear path (Christensen-Dalsgaard et al., 2012).

Research conducted on green, loggerhead, Kemp's ridley[12], and leatherback turtles indicates that sea turtles hear LF sounds both in-water and in-air. Electrophysiological, behavioral, and morphological studies on hearing have been conducted on hatchling leatherback turtles (Dow Piniak et al., 2012a); juvenile green turtles (Bartol and Ketten, 2006; Dow Piniak et al., 2012b; Ridgway et al., 1969; Piniak et al., 2016); juvenile Kemp's ridley turtles (Bartol and Ketten, 2006); as well as post-hatchling, juvenile, and adult loggerhead turtles (Bartol et al., 1999; Ketten and Bartol, 2005/2006; Lavender et al., 2011, 2012; Martin et al., 2012). Additional investigations have examined adult green, loggerhead, and Kemp's ridley sea turtles (Mrosovsky, 1972; O'Hara and Wilcox., 1990). No published studies to date have reported audiograms of olive ridley or hawksbill sea turtles (Ridgway et al., 1969; O'Hara and Wilcox, 1990; Bartol et al., 1999).

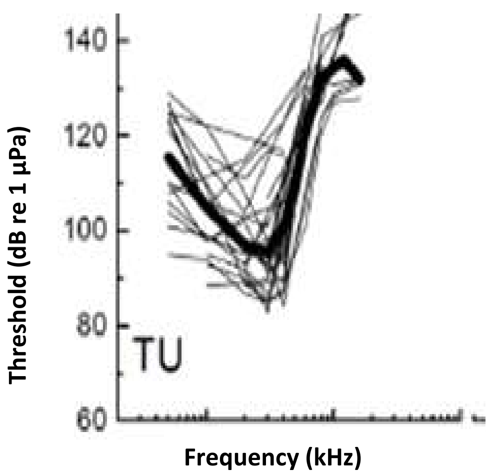

Figure 3-4. Composite Underwater Audiograms for Sea Turtles with Composite of All Audiograms Shown as Heavy Black Line (DoN, 2017b).

The available scientific research on sea turtle hearing capabilities indicates that overall, sea turtle's best hearing ranges is in the LF range between 200 and 700 Hz (Figure 3-4). To better illustrate the underwater hearing capabilities of sea turtles, the Navy compiled known data on sea turtle hearing and developed a composite audiogram (Figure 3-5) (DoN, 2017b). In-water, sea turtles are capable of detecting sound between 50 and 1,600 Hz, with best hearing from 100 and 400 Hz and hearing sensitivity dropping off at higher frequencies (Bartol and Ketten, 2006; Ketten and Bartol, 2005/2006; Piniak et al., 2016). In-air, juvenile sea turtles appear capable of hearing sounds between 50 to 800 Hz, with a maximum hearing sensitivity around 300 to 400 Hz (Piniak et al., 2016; Ridgway et al., 1969).

12 Even though the Kemp's ridley turtle does not occur in the study area for SURTASS LFA sonar, information about this sea turtle's hearing is included to provide a complete overview of what informs our understanding of sea turtle hearing capabilities.

Very little is known about sound production or how sound is used for communication or other purposes by sea turtles. Some sea turtle species, such as the leatherback turtle, produce sounds when ashore nesting (Mrosovsky, 1972), but no underwater sound production by sea turtles has ever been documented. Cook et al. (2005) noted that the broadband sounds female leatherbacks made during nesting, breath noises (inhalations/exhalations), grunts, and gular pumps[13], ranged in frequency from 300 to 500 Hz (which is in the hearing range of leatherbacks), and appeared to be associated with respiration, although their possible role in communication could not be excluded. Species of freshwater turtles produce sounds, up to 17 distinct sounds in one species (Giles, 2009), but the purpose for these vocalizations is not fully understood.

3.2.3.2 Sea Turtle Population Estimates

Sea turtles are difficult to observe and enumerate at-sea, especially in the open ocean environment, due to their small size, surface coloration, low percentage of time spent at the sea surface, low and greatly dispersed numbers, and small proportion of body visible at the sea surface. Population estimates or abundances of sea turtles are generally derived worldwide from counts of breeding females when they return to shore to nest or by counting the nests in which females have laid their eggs. This later method further complicates population estimation, as female turtles typically nest more than once per nesting season. An additional complication in depending upon counts of nesting females is that not all females reproduce every year. Although sea turtle population estimates derived from nest counts are the best available data, they always underestimate the total population, as they only represent counts of nesting females, 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. Few density data are available for sea turtles, except for some densities estimated at nesting beaches and these are rarely representative of the density of sea turtles in a particular region of the ocean environment in any given season.

3.2.3.3 Green Turtle (*Chelonia mydas*)

Eleven worldwide DPSs for the green turtle have been designated as either threatened or endangered under the ESA (Table 3-3) (NOAA, 2016b). The green turtle is protected under CITES and is listed as endangered by the IUCN Red List of Threatened Species, with declining populations (Seminoff, 2004). Three ESA DPSs were listed as endangered (Central South Pacific, Central West Pacific, and Mediterranean DPSs) with eight DPSs listed as threatened (Figure 3-5[14]). The DPS boundaries were derived based on genetic analysis of tissue collected from female green turtles when they came ashore to nest. Thus, the DPS boundaries are indicative of the nesting populations of green turtles but are not indicative of the overall movements of green turtles. Green turtles often make long, oceanic migrations between nesting and feeding grounds, so green turtles from multiple DPSs may be found on foraging grounds or in the pelagic ocean environment. Of the 11 green turtle DPSs, only four DPSs (Central West Pacific, Central North Pacific, East Indian-West Pacific, and North Indian DPSs) are located in the study area for SURTASS LFA sonar (Figure 3-5).

ESA critical habitat 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

13 The gular organ in sea turtles is similar to the larynx and functions in respiration.

14 The DPS ranges depicted in Figure 3-6 correspond to the nesting beach ranges for each DPS.

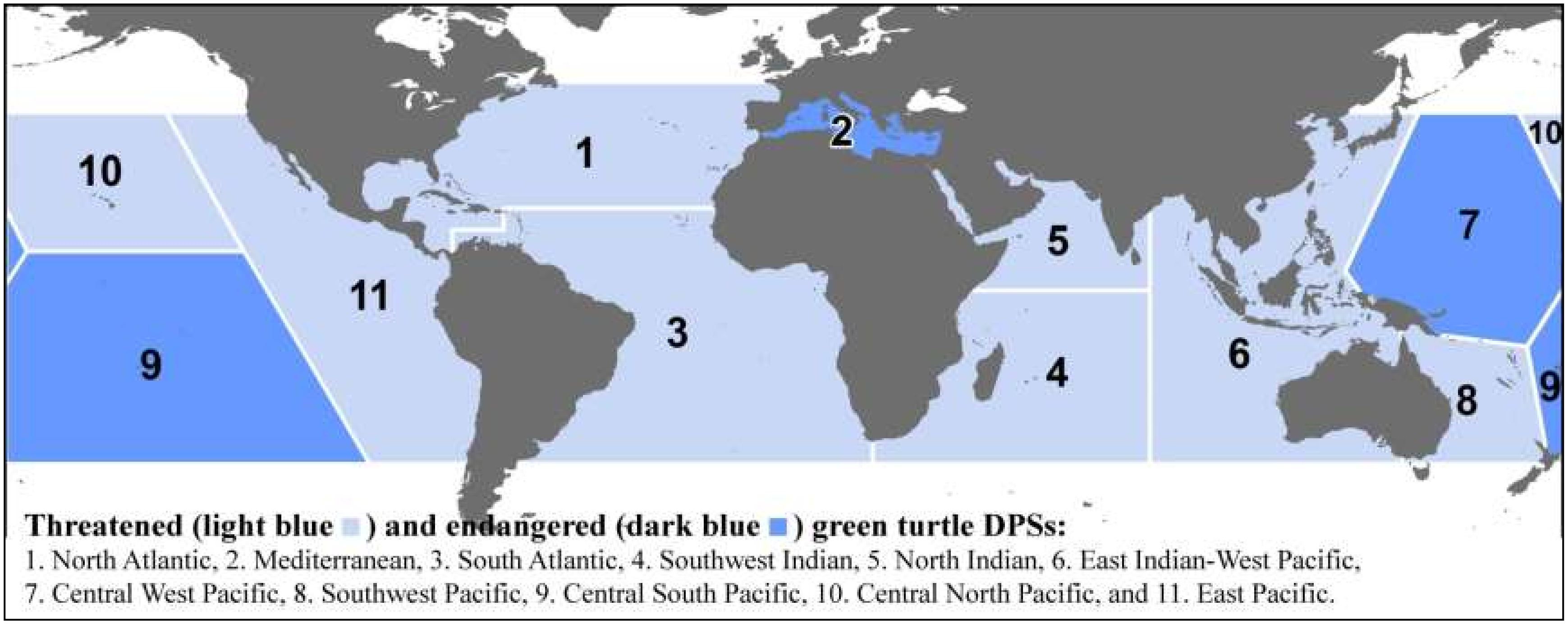

Figure 3-5. Global Distribution of the Threatened and Endangered Distinct Population Segments (DPSs) Listed Under the ESA for the Green Turtle (NOAA, 2016g).

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[15]
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

effect for the North Atlantic DPS. NMFS has determined that additional critical habitat is not determinable at this time (NOAA, 2016b).

No complete global population estimates exist for the green turtle. Seminoff (2004) compiled known population data and information but no overall abundance could be derived due to the disparate data (number of nesting females, nests, eggs, and hatchlings) reported for the major worldwide green turtle rookeries. However, more recently, estimates of the female nesting abundance for each green turtle DPS were derived, resulting in a best estimate of the global population of green turtles as 570,926 turtles (NOAA, 2016b; Table 3-4). The two largest worldwide nesting populations occur at Tortuguero, Costa Rica (Caribbean), where on average, 22,500 females' nest per season; and Raine Island, Australia (Great Barrier Reef), where 18,000 females' nest per season on average (Seminoff et al., 2015). The populations of green turtle in the waters of the CNMI were estimated as 795 to 1,107 turtles in Tinian waters and 297 turtles in Pagan waters; 97 percent of these populations are composed of juveniles and subadults (DoN, 2014). Although no abundance exists for the number of green turtles that occur in Hawaii, the Hawaiian green turtle population is increasing and has increased by 53 percent over the last 25 years NMFS, 2018a). The number of nesting female green turtles at one of the two largest nesting areas in the western North Pacific, the (Ogasawara Islands of Japan, has been increasing since the late 1970s, with a maximum number of 582 nesting females in 2008 (Kondo et al., 2017).

Green turtles are widespread throughout tropical, subtropical, and warm-temperate waters of the Atlantic, Pacific, and Indian oceans and Mediterranean Sea between 30° N and 30° S (Lazell, 1980). Except during the juvenile lifestage and adult migrations when green turtles are found in the oceanic environment, green turtles principally inhabit the neritic zone, typically occurring in nearshore and inshore waters where they forage primarily on sea grasses and algae (Mortimer, 1982). Green turtles make long pelagic migrations between foraging and nesting grounds, swimming thousands of miles

15 Median value

across the open ocean (Bjorndal, 1997; Pritchard, 1997). Nesting of green turtles occurs in over 80 countries worldwide (Hirth, 1997). Pike (2013) estimated that green turtles use 1,781 unique nesting beaches worldwide. Green turtles may nest more than once, remaining in the nesting vicinity between nesting periods. After hatching, juvenile green turtles begin an oceanic lifestage that spans several years, after which green turtles typically migrate to neritic developmental and foraging habitats (Seminoff, 2004). Researchers have suggested that late-stage juveniles migrate from the pelagic developmental habitat to neritic habitat that they select foraging areas proximal to their natal beaches (Naro-Maciel et al., 2007; Prosdocimi et al., 2011); this natal homing of late-stage juveniles has also been shown in loggerhead and hawksbill turtles.

In the central Pacific Ocean, green turtles occur around most tropical islands, including the Hawaiian Islands where green turtles are the most common turtle species. Foraging in the Main Hawaiian Islands, about 90 percent of the Hawaiian adult green population migrates to French Frigate Shoals in the Northwest Hawaiian Islands, where nesting and mating occurs; nesting rookeries in French Frigate Shoals are the largest in the central North Pacific (Seminoff et al., 2015). Green turtles occur year-round in Guam and in the CNMI, particularly in the waters of Tinian and Pagan (DoN, 2014). Nesting of green turtles occurs on Guam and on Tinian Island, CNMI, from February through August with highest nesting occurring at Unai Dankulo beaches (DoN, 2014; Seminoff et al., 2015), although nesting also occurred on Rota in the 2000s (Kolinski et al, 2006). Two larger nesting areas for green turtles in the western North Pacific are found in the Ogasawara Islands of Japan and in Micronesia. The waters of the main Japanese islands as well as other areas of the western North Pacific are foraging and developmental grounds for green turtles hatched in the Ogasawara Islands (Seminoff et al., 2015; Tachikawa et al., 1994). Green turtles now only nest on seven beaches in China, with post-hatchlings from Chinese beaches having been observed migrating in multiple directions either into the South China Sea or to Okinawan waters (Song et al., 2002); green turtles also nest on the shores of Vietnam, the Philippines, and Indonesia (NOAA, 2016b). Two primary nesting locations are found in the North Indian DPS, one in Oman and one in Yemen (NOAA, 2016b), but nesting also occurs along the shores of Pakistan, India, and Sri Lanka, with turtles migrating from the primary nesting areas in the northwest Indian Ocean to foraging habitat in the Arabian Sea, the Red Sea, Pakistan, and southward to the waters off Somalia (Khan et al., 2010; Rees et al., 2012; Al Saady et al., 2005). Widespread nesting of green turtles occurs throughout the eastern Indian Ocean, with nesting occurring at 58 sites, including large rookeries in Western Australia and Indonesia (Seminoff et al., 2015). Foraging grounds in the eastern Indian Ocean include the waters around the Andaman and Nicobar Islands and Indonesia (Andrews et al., 2006a; Suganthi, 2002).

Green turtles typically make shallow and short-duration dives to no more than 98 ft (30 m) for <23 min, but dives in excess of 453 ft (138 m) and for durations of 307 min have been recorded, with these deeper dives occurring more usually during winter (Blanco et al., 2013; Brill et al., 1995; Broderick et al., 2007; Hays et al., 2000; Hochscheid et al., 1999; Rice and Balazs, 2008). Migrating turtles in Hawaii showed a strong diurnal pattern, with maximum dive depths of 13 ft (4 m) occurring during the day, with deeper dives to more than 44.3 ft (13.5 m) occurring at night (Rice and Balazs, 2008). Hochscheid et al. (1999) reported that green turtles exhibit dives that are U, V, and S shaped. In their study of nesting green turtles in the Mediterranean Sea, Hochscheid et al. (1999) noted that the tagged turtles remained in coastal waters even during inter-nesting periods, and dove no 131 ft (25 m) but remained underwater for up to 40 min. Godley et al. (2002) reported travel speeds for three green turtles in nesting, open-ocean, and coastal habitats, with speeds ranging from 0.3 to 1.5 kt (0.6 to 2.8 kph), with crossing of deeper, open waters associated with faster swim speeds. Song et al. (2002) reported average swimming speeds ranging from 0.8 to 1.6 kt (1.4 to 3 kph) for migrating green turtles.

The recovery of green turtle populations around the world continues to be threatened by the ongoing harvest of not only eggs but also of adult green turtles from nesting beaches and of juvenile and adult turtles from foraging grounds. Entanglement in fishing gear and incidental fisheries bycatch are also a primary cause of green turtle mortality (Seminoff et al., 2015). In addition to threats such as oceanic pollution and marine debris, the green turtle is susceptible to the disease fibropapillomatosis, which causes internal and external tumorous growths. Large tumors can interfere with feeding and essential behaviors, and tumors on the eyes can cause permanent blindness.

3.2.3.4 Hawksbill Turtle (Eretmochelys imbricata)

The hawksbill turtle is listed as critically endangered under the IUCN Red List of Threatened Species (Mortimer and Donnelly, 2008), as endangered throughout its range under the ESA, and protected by CITES (Appendix I). 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).

In contrast to all other sea turtle species, hawksbill turtles' nest in low densities on dispersed, small beaches, making population estimation even more challenging. Hawksbill nesting occurs in at least 70 countries, although much of it now only occurs at extremely low numbers (Mortimer and Donnelly, 2008). Although population data are generally lacking for the hawksbill turtle, 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, 2013a), and overall, the population trend is of decreasing populations (Mortimer and Donnelly, 2008). The largest populations of hawksbill turtles occur in the Yucatan Peninsula, Mexico; the Republic of Seychelles; Oman; and Australia (NMFS and USFWS, 2013a). Only four regional populations in the Pacific remain with more than 1,000 females nesting annually (one in Indonesia and three in Australia). The largest nesting population of green turtles in the Pacific Ocean occurs in eastern Australia, with some 6,500 females nesting per year, while in the Indian Ocean, about 2,000 females' nest in Western Australia and 1,000 female's nest in Madagascar annually (Limpus, 2009; NMFS and USFWS, 2013a). The largest nesting aggregation in the northwest Indian Ocean is located in Oman, where 600 to 800 hawksbill's nest annually (NMFS and USFWS, 2013a). Fewer than 20 hawksbill turtles nest annually in the Hawaiian Islands, while the population in the CNMI's consisting primarily of juvenile and subadult hawksbill turtles was estimated as 151 turtles around Pagan Island, while 50 to 71 hawksbill turtles were reported from around Tinian Island, but no hawksbill nesting occurs (DoN, 2014; NMFS and USFWS, 2013a).

Hawksbill turtles typically occur in tropical and subtropical waters of the Atlantic, Pacific, and Indian oceans between about 30° N and 30° S latitudes (NMFS and USFWS, 2013a), and are especially often encountered in shallow lagoons and coral reefs. Hawksbill turtles even inhabit inshore waters of mangrove-lined bays and estuaries but are most typically associated with nearshore coral reefs environments. No hawksbills are reported from the Mediterranean Sea (Spotila, 2004). The largest populations live in the waters of the Caribbean Sea, the Seychelles, Indonesia, and Australia. Juvenile hawksbill turtles occur year-round in the waters of Pagan and Tinian, CNMI, although no nesting occurs on the beaches of these islands (DoN, 2014). In the U.S. Pacific, hawksbills occur in Hawaii, American Samoa, Guam, and the CNMIs. Through satellite tracking, the Hamakua Coast of Hawaii has been identified as an important foraging ground for Hawaiian hawksbills. In the northeastern Indian Ocean (Bay of Bengal), the hawksbill population found in the Andaman and Nicobar Islands is the largest in the Northern Indian Ocean (Andrews et al., 2006a). Hawksbill turtles are observed in Japanese waters but only nest in the Ryukyu Islands (Kamezaki and Matsui, 1997).

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 are highly migratory, migrating hundreds to thousands of miles between feeding and nesting grounds (Plotkin, 2003). While the migratory habits of hawksbills are still largely unknown, it appears that similarly to other hard-shelled turtles, hawksbill turtle hatchlings and juveniles exhibit a pelagic phase when they spend years in the open ocean, although specifics about their occurrences at sea during these early lifestages are not known. After several years spent in the pelagic environment, hawksbill turtles shift habitats to coastal, neritic developmental and foraging habitat. Juveniles remain in developmental habitats until they are reproductively mature, when females migrate back to their natal beaches to mate and nest. Gaos et al. (2017) recently reported that the neritic foraging grounds of juvenile hawksbill turtles in the eastern Pacific Ocean are located near their natal beaches, indicating that sea turtles have fidelity to specific nearshore areas not only for nesting and mating but also for foraging; this finding has also been suggested for loggerhead and green turtles.

Hawksbill turtles appear to exhibit a diurnal diving strategy, actively foraging during the day and resting at night (Blumenthal et al., 2009; Okuyama et al., 2010), although Gaos et al. (2012) observed foraging dives during both the day and night. Not known as deep divers, hawksbill turtles typically perform shallow dives to water depths between 33 and 164 ft (10 to 50 m), with mean dive depths between 16 to 26 ft (5 and 8 m) (Gaos et al., 2012; Van Dam and Diez, 1996). In the Seychelles, von Brandis et al. (2010) recorded the mean dive depths of juvenile hawksbill turtles as 27 ft (8.2 m) and 27.4 min, respectively. Hawksbill turtles are amongst the longest-duration divers, with routine dives ranging from 34 to 74 min (Starbird et al., 1999). The maximum dive depth recorded for hawksbill turtles is 299 ft (91 m) with a maximum dive duration of 138 min (Blumenthal et al., 2009; Hochscheid, 2014; Storch et al., 2005). Dive times have been shown to vary greatly during the inter-nesting intervals, with means of 30, 60, and 45 min (Walcott et al., 2013). Bell and Parmenter (2008) found that during the 14-day inter-nesting period of hawksbill turtles off eastern Australia, the mean dive time, dive depth, and surface intervals were 31.2 min, 19 ft (5.7 m), and 1.6 min, respectively, with the maximum water depth to which an inter-nesting female dove was 71 ft (21.5 m). Hawkes et al. (2012) reported that turtles outside Dominican Republic waters travelled an average of 19.4 nmi (36 km) per day, which resulted in a minimum speed estimate of 0.8 kt (1.5 kph), while turtles on the foraging areas moved 0.4 to 0.6 kt (0.67 to 1.17 kph). Storch et al. (2005) reported descending and ascending dive speeds of 0.7 and 0.6 kt (0.37 and 0.31 m/sec), respectively.

The recovery of hawksbill turtle populations is threatened by oceanic pollution, marine debris, entanglement in fishing gear, and incidental fisheries bycatch, but the greatest problem facing hawksbill turtle populations is the loss of habitat, specifically the loss of coral reef habitat globally. Global climate change with increasing sea temperatures and increased coastal development are degrading coral reefs around the world, resulting in loss of principal foraging habitat for hawksbills. In addition to loss of foraging habitat, nesting beach habitat is increasingly being impacted and lost due to coastal development and recreational use (NMFS and USFWS, 2013a). Historically, hawksbill turtles were commercially harvested for their shells, which is a practice that continues in some areas of the world, such as in many Caribbean countries. The harvest of adults and eggs at nesting beaches remains a widespread practice, especially in eastern Asia and India (NMFS and USFWS, 2013a).

3.2.3.5 Leatherback turtle (*Dermochelys coriacea*)

The leatherback turtle is the largest turtle in the world and one of the largest living reptiles. As a species, the leatherback is listed as vulnerable under the IUCN (Wallace et al., 2013), endangered throughout its

Table 3-4. Worldwide Subpopulations, Conservation Status, and Abundance Estimates of Leatherback Turtles as Identified by the International Union for Conservation of Nature and Natural Resources (IUCN) Red List Classification (Wallace et al., 2013).

Subpopulation	IUCN Red List Conservation Status	2010 IUCN Abundance Estimate/Nel (2012) (nests per year)
East Pacific Ocean	Critically Endangered	926
Northeast Indian Ocean	Data Deficient	ND
Northwest Atlantic Ocean	Least Concern	50,842
Southeast Atlantic Ocean	Data Deficient	ND
Southwest Atlantic Ocean	Critically Endangered	53
Southwest Indian Ocean	Critically Endangered	259
West Pacific Ocean	Critically Endangered	2,182/5,067-9,176
Total		54,262 / 57,147-61,256

ND= No data

range under the ESA, and protected under CITES. Seven subpopulations of leatherback turtles have been recognized by the IUCN (Wallace et al., 2013): East and West Pacific; Northeast and Southwest Indian Ocean; and the Northwest, Southwest, and Southeast Atlantic subpopulations (Table 3-4; Figure 3-6). The IUCN Red List classifies the East and West Pacific and Southwest Indian and Atlantic Ocean subpopulations as critically endangered (Wallace et al., 2013). ESA 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, 1979b, 2012a). 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).

Wallace et al. (2013) estimated that the worldwide population of leatherback turtles has decreased by 40 percent over the past three generations. The Turtle Expert Working Group (2007) and the recent analysis by Wallace et al. (2013) reported stable to slightly increasing population trends for Atlantic Ocean leatherbacks, while Pacific and Indian Ocean leatherback populations are decreasing, with Pacific nesting numbers having dramatically decreased over the last three generations (NMFS and USFWS, 2013b). Determining an exact worldwide population is complicated by lack of data and data reported in non-consistent population indicators (i.e., number nesting females vice number nests, which are not equivalent). Based on available published data on leatherback turtle nest abundances (average number of nests) through 2010, Wallace et al. (2013) estimated the current global population as 54,262 leatherback turtle nests per year. However, Nel (2012) reported the earlier documentation by Dutton et al. (2007) of 5,067 to 9,176 leatherback nests in the West Pacific Ocean population, which would increase the worldwide leatherback abundance to 57,147 to 61,256 nests annually (Table 3-4). The

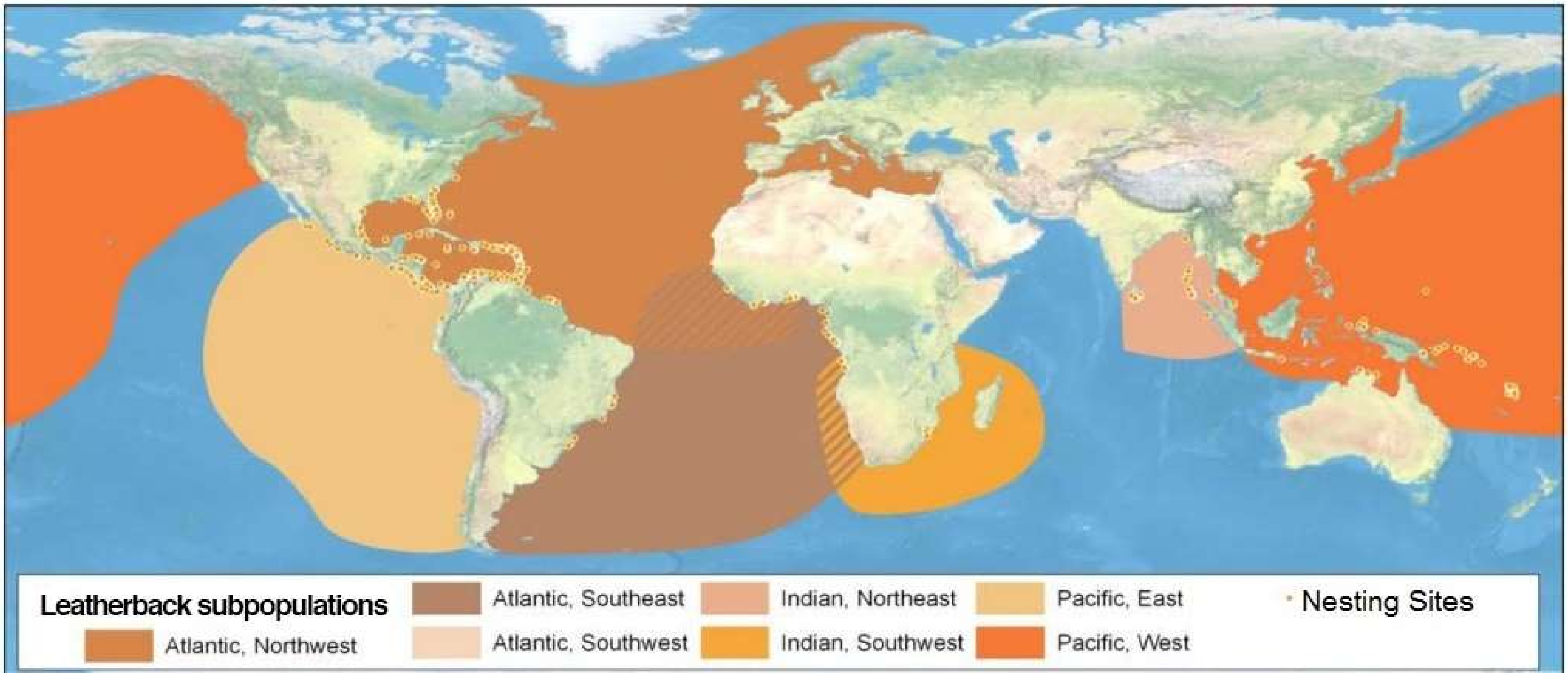

Figure 3-6. Location and Distribution of the Seven Worldwide Subpopulations of Leatherback Turtles and their Nesting Sites (Wallace et al., 2013).

Northwest Atlantic Ocean subpopulation is the largest in the world, with an estimated 34,000 to 94,000 individuals (The Turtle Expert Working Group, 2007) and 50,842 nests per year (Wallace et al., 2013).

The largest worldwide nesting location of leatherback turtles is in Gabon, Africa, where Witt et al. (2009) reported 5,865 to 20,499 nesting females annually, for an estimated total 15,730 to 41,373 breeding females. Leatherbacks are now essentially extinct in Malaysia, as only two nests were documented in the early 2000s, and numbers of Western Pacific leatherbacks have declined more than 80% over the last three generations, while the population of Eastern Pacific leatherbacks has declined by more than 97 percent over the last three generations (NMFS, 2018c). The Mexico nesting subpopulation of Eastern Pacific leatherback stock, which was once considered the world's largest, representing 65 percent of the worldwide population, is now less than one percent of its estimated 1980 size (NMFS, 2018c). In the Indian Ocean, the number of leatherback turtles is low, with the best available data indicating that 400 to 600 nesting females are estimated to occur annually in the Nicobar and Andaman islands area of the Bay of Bengal/Andaman Sea, while only 100 to 200 leatherbacks are estimated to nest in Sri Lanka, and very low numbers (20 to 40 and <10 nesting females annually) are estimated for the southwestern and southeastern Indian Ocean, respectively (Andrews et al. 2006b; Nel, 2012).

Leatherbacks are the most pelagic and most widely distributed of any sea turtle and can be found circumglobally in temperate and tropical waters between 71°N and 47°S, including the Mediterranean Sea (Eckert et al., 2012; NMFS and USFWS, 2013b; Wallace et al., 2013). Leatherback turtles nest in all oceans around the world except in the Mediterranean Sea (Eckert et al., 2012). The largest Atlantic nesting sites are located in Gabon, Africa and Trinidad, Caribbean Sea, but other significant nesting colonies are found in French Guiana; Suriname; Panama; Equatorial Guinea; Florida, U.S.; and St. Croix, U.S. Virgin Islands (Wallace et al., 2013). The largest nesting grounds in the Pacific is located in Indonesia, but other important Pacific nesting sites are found in Costa Rica, Solomon Islands, and Papua New Guinea, with sparse nesting occurring in the Indian Ocean (Wallace et al., 2013). Leatherbacks are not resident to the waters Marianas Islands, CNMI, or Hawaiian Islands nor do they nest on these islands but are observed in offshore, pelagic waters surrounding the islands (DoN, 2017b; Hadpei, 2013).

Highly migratory, leatherback turtles make annual long-distance excursions between their nesting and feeding grounds. Although the most oceanic of all sea turtles, leatherback turtles also may be found seasonally in highly productive continental shelf and slope waters, where they may spend months foraging (Benson et al., 2011; Dodge et al., 2014). Benson et al. (2011) also found that the time of year when leatherback turtles nested in the western Pacific made a difference in the habitat used following nesting, with those turtles nesting in summer migrating into temperate waters of the North Pacific or the tropical waters of the South China Sea, but winter nesters migrated into temperate and tropical waters of the southern hemisphere. 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). 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. Continuing northward, arriving in waters corresponding to the continental slope by April, leatherbacks finally arrive in continental shelf and coastal waters off New England and Atlantic Canada where they remain through October. In the fall, some leatherbacks move southward, essentially retracing their northward migration route offshore, 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, with turtles from the largest rookery in Gabon, West Africa migrating post-nesting to three foraging regions of the

Atlantic: tropical waters of the equatorial Atlantic, temperate waters off South America, and temperate waters off southern Africa in the Benguela and Agulhas Currents (Witt et al., 2011).

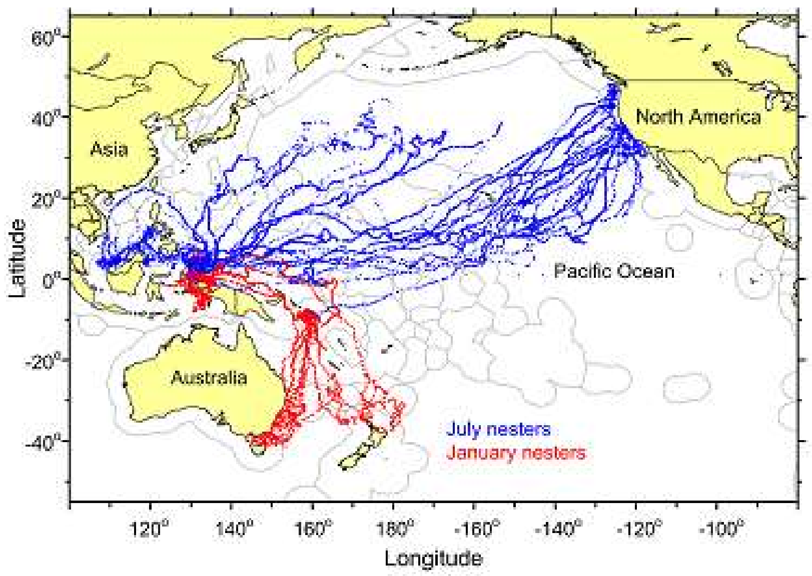

Figure 3-7. Trans-Pacific Seasonal Movements of Tagged Leatherback Turtles Showing Their 6,083 nmi (11,265 km) Journey from Nesting to Foraging Grounds (NMFS, 2016d).

Western Pacific Ocean leatherbacks engage in one of the greatest migrations of any air-breathing marine vertebrate, swimming from nesting beaches in the tropical western Pacific (primarily in Indonesia, Papua New Guinea, and the Solomon Islands) to foraging grounds in the eastern North Pacific Ocean off the Americas (Figure 3-7). This 6,083-nmi (11,265-km) trans-Pacific journey requires 10 to 12 months to complete (NMFS, 2016d). Eastern Pacific leatherbacks nest primarily in Mexico and Costa Rica (with isolated nesting sites in Panama and Nicaragua) and foraging grounds off Mexico, Central America, Chile, and Peru (NMFS, 2018c). Studies of leatherback turtle movements in the Pacific Ocean indicate that that there may be important migratory corridors and habitats used specifically by leatherbacks (Eckert, 1998; Eckert, 1999; Morreale et al., 1996). Shillinger et al. (2008) confirmed the existence of a persistent migration corridor for leatherbacks spanning the Pacific basin from the coast of Central America along the equator into the South Pacific.

Leatherback turtles make the deepest dives of any sea turtle, with the deepest dive recorded at 4,198 ft (1,280 m) (Doyle et al., 2008). Their longest duration dive was 86.5 min, but most dives are no more than 40 min (Byrne et al., 2009; López-Mendilaharsua et al., 2009; Sale et al., 2006). In their examination of nearly 10 years of satellite tag data on leatherback turtles in the North Atlantic Ocean, Hougthon et al. (2008) found that 99.6 percent of leatherback dives were to water depths less than 984 ft (300 m) while only a miniscule 0.4 percent were to deeper water depths, with the dives to waters >984 ft (300 m) occurring principally during the day and during migrational transit. Dives of 13 to 256 ft (4 to 78 m) and 256 to 827 ft (78 to 252 m) and of longer duration (28 to 48 min) characterize the migratory phases of the leatherback, while shallower dives (<164 ft (50 m]) and of shorter duration (<12 min) are more typical of foraging dives (James et al., 2005). Bradshaw et al. (2007) reported median dive depths and durations of over 17,618 dives of adult female leatherbacks as 174 ft (53 m) and 22 min, respectively. 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). Wallace et al. (2015) noted that leatherback turtles in Nova Scotian (North Atlantic) waters dove and foraged almost continuously during the day, spending 61.5 percent of the time diving and making short (4.5 min), shallow (<98 ft [30 m]) dives and capturing prey at the bottom of their dives or on their ascent, and diving to forage in areas where prey were most abundant and dense. Eckert et al. (1996) also noted that interesting leatherbacks dove nearly continuously during the day and that daytime dives were longer and to deeper water depths than night dives. Salmon et al. (2004) noted that in their study of juvenile leatherback turtles that the majority of their dives were V-shaped with a minority of W-shaped dives, and that not surprisingly, older turtles dove deeper (up to 59 ft [18 m]) than younger turtles but diving frequency did not differ with age, indicating that as leatherbacks rapidly grow during the beginning of the pelagic lifestage, their diving ability also rapidly progresses. The modal speeds of swimming leatherback 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). Inter-nesting leatherback turtles swam at speeds ranging from 0.7 to 1.4 kt (1.25 to 2.5 kph) (Byrne et al., 2009).

The principal ongoing threats to leatherback turtle populations globally are from incidental fisheries bycatch and harvest of nearly all lifestages of leatherback turtles. Egg collection continues to occur in some countries, resulting in major declines in the associated populations, while adults are still harvested from their feeding grounds by artisanal and commercial fisheries (NMFS and USFWS, 2013b). Ocean marine debris, specifically plastic debris such as plastic bags and balloons, present a significant threat to leatherbacks, who mistake the clear plastic for prey, due to the resemblance of clear plastic to leatherback's favored prey, jellyfish.

3.2.3.6 Loggerhead Turtle (*Caretta caretta*)

Under the ESA, nine loggerhead turtle subpopulations or DPSs have been identified and designated worldwide as endangered or threatened (Table 3-5; Figure 3-9). As a species, the loggerhead turtle is classified as vulnerable by the IUCN Red List of Threatened Species, with 10 global subpopulations identified, whose IUCN status ranges from least concern to critically endangered (Table 3-5) (Casale and Tucker, 2017).

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) (Table 3-5; Figure 3-8), although only the North Pacific Ocean, North Indian Ocean, Southeast Indo-Pacific Ocean DPSs occur in the study area for SURTASS LFA sonar (Table 3-5).

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, 2014d). 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. Also, in 2014, the 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).

No complete population estimates for each loggerhead DPS exist, but Casale and Tucker (2017) estimated the size of each IUCN subpopulation by combining the nesting counts, for a minimum estimate of 200,246 loggerhead turtles (Casale and Tucker, 2017). One of the two major global populations of loggerhead turtles occur in the waters of the western Atlantic Ocean and northern Gulf of Mexico (Northwest Atlantic DPS), where the total nesting population in the U.S. has been estimated at approximately 68,000 to 90,000 nests per year (i.e., nesting females). The most recent count of 65,807

Table 3-5. International Union for Conservation of Nature and Natural Resources (IUCN) Red List Classification of the Conservation Status of Loggerhead Global Populations (Casale and Tucker, 2017).

Global Subpopulation/DPS	IUCN Red List Conservation Status	ESA Status	Current IUCN Estimated Abundance (nests per year)
Mediterranean Sea	Least Concern	Endangered	7,200
North Indian DPS		Endangered	
Northeast Atlantic Ocean	Endangered	Endangered	15,000
Northeast Indian Ocean	Critically Endangered		25
North Pacific Ocean	Least Concern	Endangered	9,053
Northwest Atlantic Ocean	Least Concern	Threatened	83,717
Northwest Indian Ocean	Critically Endangered		70,000
South Atlantic DPS		Threatened	
Southeast Indian Ocean	Near Threatened		2,955
Southeast Indo-Pacific Ocean DPS		Threatened	
South Pacific Ocean	Critically Endangered	Endangered	NA
Southwest Atlantic Ocean	Least Concern		7,696
Southwest Indian Ocean	Near Threatened	Threatened	4,600
Total for all IUCN Subpopulations			200,246

Note: NA=not available

nesting females was reported for Florida in 2016, where the largest concentration of loggerhead nesting occurs in the Northwest Atlantic DPS (Florida Fish and Wildlife Conservation Commission [FFWCC], 2018). The nesting population in Florida had declined sharply, but since 2007, the nesting population of female loggerheads has increased by 65 percent, with an increase of 19 percent in the number of nesting females from 1989 through 2017 (FFWCC, 2018). The second largest nesting aggregation of loggerhead turtles occurs in the northwestern Indian Ocean in Masirah, Oman, where 20,000 to 40,000 females nest annually (Baldwin et al., 2003), but more recent estimates note a decline in the number of nesting females, with the most current estimate of 11,000 nests annually at Masirah (Environment Society of Oman, 2016). The abundance of the entire Northwest Indian Ocean subpopulation was estimated as 70,000 nests per year (Casale and Tucker, 2017). These two most abundant global populations represent 75 percent of the world's nesting female loggerheads (Casale and Tucker, 2017). The largest nesting aggregation in the southeastern Indian Ocean is located on the coast of northwestern Australia where as many as 1,000 to 3,000 loggerheads nest (Hamman et al., 2013). All loggerhead nesting in the North Pacific Ocean occurs only in Japan, where more than 4,000 females historically nested, but the number of nesting females in Japan has declined, with fewer than 1,000 females now nesting in Japan annually (Conant et al., 2009; Hamann et al., 2013; Kamezaki et al., 2003). Casale and Tucker (2017) estimated the number of annual nests in the North Pacific as 9,053.

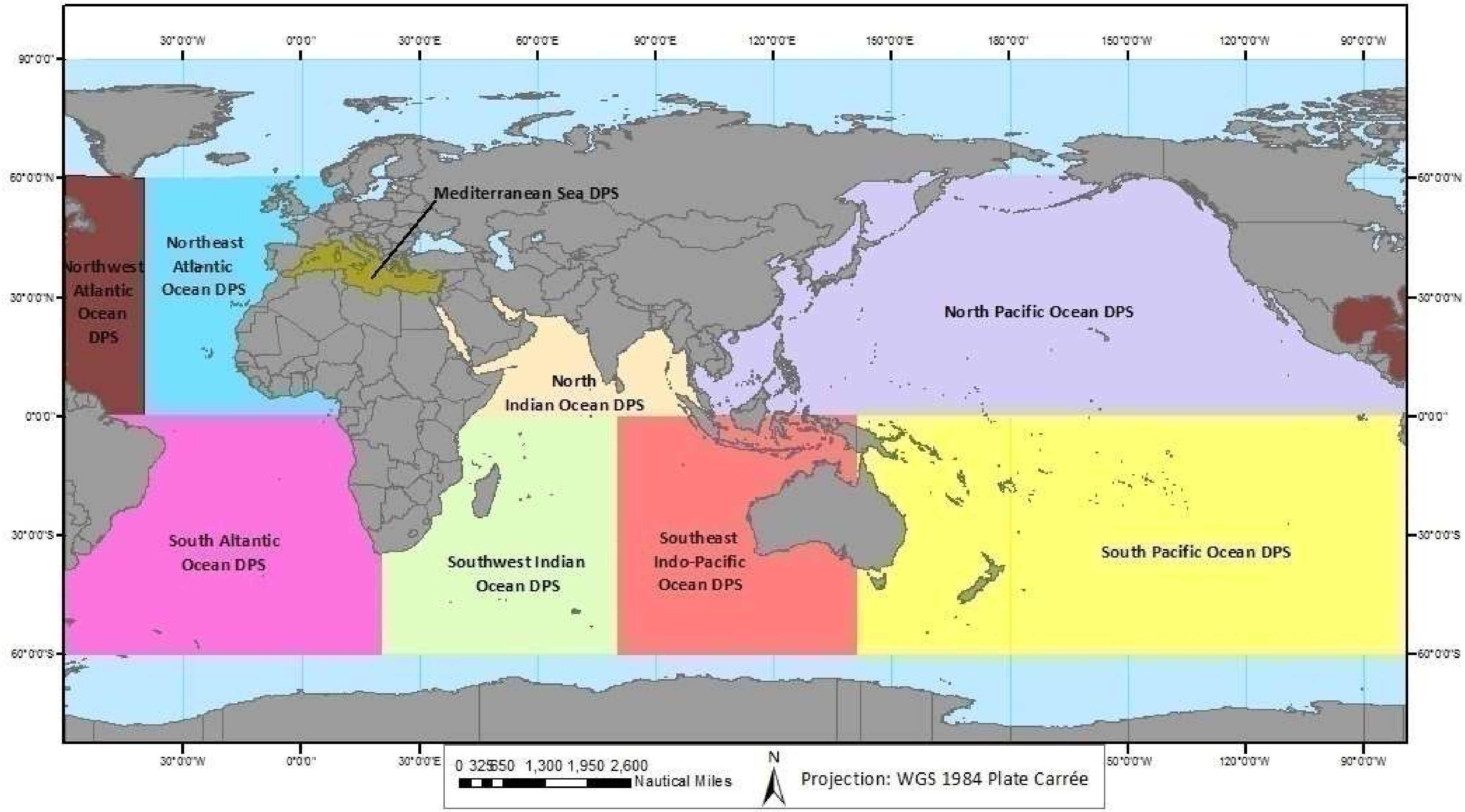

Figure 3-8. Global Distribution of the Threatened and Endangered Distinct Population Segments (DPSs) of the Loggerhead Turtle (NOAA and USFWS, 2011); Only the North Pacific Ocean, North Indian Ocean, and Southeast Indo-Pacific Ocean DPSs are Situated in the Study Area for SURTASS LFA Sonar.

Loggerhead turtles are found in coastal to oceanic temperate, tropical, and subtropical waters of the Atlantic, Pacific, and Indian Oceans and the Mediterranean Sea (Dodd, 1988). No migrational movements north/south across the equator are known. Habitat usage varies with lifestage. Loggerheads are highly migratory, capable of traveling hundreds to thousands of miles between feeding and nesting grounds. In the Pacific Ocean, 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). North Pacific loggerhead turtles make two transoceanic migrations, with hatchling and juvenile turtles making a 5,400 nmi (10,000 km) migration eastward across the North Pacific Ocean from nesting beaches in Japan (including the Ryukyu Archipelago) to developmental and foraging habitat off western North and Central America. Hatchlings use the Kuroshio and North Pacific currents as transport (Bowen et al., 1995).

As late juveniles or adults, loggerhead turtles make a return westward migration across the North Pacific to return to Japanese waters to mate and nest. Thus, juvenile loggerheads are distributed in the pelagic waters of the North Pacific Gyre, with juvenile loggerheads originating from Japanese nesting beaches exhibiting high site fidelity to the Kuroshio Extension Bifurcation region, an area dominated by extensive meanders and mesoscale eddies (Polovina et al., 2006). Kobayashi et al. (2008) and Polovina et al. (2006) observed that pelagic foraging habitat of loggerhead turtles is characterized by elevated primary productivity (i.e., higher chlorophyll *a* concentrations) and sea surface temperatures in the range of 58° to 68° F (14.5° to 20° C), which are characteristics of the North Pacific Transition Zone in the North Pacific Ocean, which is an important foraging habitat for loggerhead turtles. When the larger or older juvenile loggerhead turtles migrate from their developmental and juvenile foraging grounds, researchers have shown that they migrate specifically to foraging areas near their natal beaches. Bass et al. (2004) and Bowen et al. (2004) described the natal homing of juvenile loggerhead turtles to neritic foraging near their natal beaches; this finding has also been shown for juvenile hawksbill and has been suggested for green turtles.

Although loggerhead turtles occur in Hawaiian waters, principally juvenile loggerheads are observed in offshore waters migrating between the Japanese nesting grounds and foraging and developmental habitats in the eastern North Pacific. The highest densities of loggerheads in the central North Pacific Ocean occur north of the Hawaiian Islands in association with the North Pacific Transition Zone (Polovina et al., 2000). In the western Pacific Ocean, loggerheads have been reported to forage as far south as the Philippine Islands and the mouth of the Mekong River, Vietnam (Limpus, 2008; Sadoyama et al., 1996). Following nesting in Japan, satellite-tagged female loggerheads were observed to migrate to two different foraging grounds of the western North Pacific, the more neritic waters of the East China Sea and the oceanic waters along the perimeter of the Kuroshio Current (Hatase and Sakamoto, 2004; Hatase et al., 2002; Sakamoto et al., 1997). No loggerhead turtles' nest in the CNMI and during recent surveys, no loggerhead turtles were observed; oceanographic conditions north of the CNMI may function as a barrier to loggerhead occurrence in these islands (DoN, 2014).

Outside of the waters of the Arabian Sea in the northwestern Indian Ocean, loggerhead turtles are not common. In the northern Indian Ocean, nesting of loggerhead turtles primarily occurs in Oman and is rare elsewhere. In the eastern Indian Ocean, all nesting of loggerhead turtles occurs on beaches of Western Australia (Dodd, 1988). In the Indian Ocean, loggerhead turtles migrate, sometimes long distances, between their nesting grounds in Oman and foraging grounds off Oman, Yemen, southern Africa, Madagascar, Western Australia, and Indonesia. Tagging data have shown that nesting turtles from the dense nesting aggregations along the Oman coast use the waters of the Arabian Sea for foraging and seasonal migrational movements (Conant et al., 2009).

Polovina et al. (2003) observed 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 16 ft (5 m) in water depth. Arendt et al. (2012) reported time at the surface was 3 to 6 percent of the time spent diving. Similarly, Howell et al. (2010) found that more than 80 percent the time, loggerheads in the North Pacific Ocean dove to water depths <16 ft (5 m), but 90 percent of their time was spent diving to depths <49 ft (15 m). In their study of free-ranging loggerhead turtles, Hochscheid et al. (2010) noted that the loggerheads infrequently spent extended periods, lasting on average 90 min, at the sea surface during the day. This irregular behavior was suggestive of possible recovery from extensive anaerobic diving or as a means of re-warming their core body temperature after diving to depth (Hochscheid et al., 2010). Even as larger juveniles and adults, loggerheads' routine dives are only to 30 to 72 ft (9 to 22 m) (Lutcavage and Lutz, 1997). Migrating male loggerheads along the east coast of the U.S. dove to water depths of 66 to 131 ft (20 to 40 m) (Arendt et al., 2012). Tagged loggerheads in the open Pacific Ocean dove as deep as 525 ft (160 m) (Polovina et al., 2003), but an adult loggerhead made the deepest recorded dive to 764 ft (233 m), staying submerged for 8 min (Sakamoto et al., 1990). Five different dive types of loggerhead turtle dives 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. The longest duration dive by a loggerhead turtle was 614 min during deep-bottom resting dives (Broderick et al., 2007). 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 swam at minimum speeds of 0.7 to 0.9 kt (1.3 to 1.7 kph) (Godley et al., 2003). Loggerheads in the Mediterranean Sea swam at a mean speed of 0.9 kt (1.6 kph), with a maximum speed near 1.6 kt (3 kph). Sakamoto et al. (1990) reported loggerhead diving swim speeds ranging from 0.4 to 1.89 kt (0.2 to 0.97 m/sec).

The loggerhead population decline is attributable principally to incidental fisheries bycatch, entanglement in fishing gear, directed harvest, coastal development, increased human use of nesting beaches, and ocean pollution. The greatest continuing threat to the recovery of loggerhead turtle populations is incidental fisheries bycatch (Conant et al., 2009). The second most significant threat to loggerhead turtles is the continued directed harvest in countries such as Mexico, Cuba, and the Bahamas.

3.2.3.7 Olive Ridley Turtle (*Lepidochelys olivacea*)

The global population of olive ridley turtles is protected by CITES, classified as vulnerable under the IUCN (Abreu-Grobois and Plotkin, 2008), and listed as threatened under the ESA everywhere except the breeding stocks of the Mexican Pacific coast, which are listed as endangered under the ESA. No critical habitat has been designated for the olive ridley turtle. Although the olive ridley turtle is the most abundant sea turtle worldwide, many of its populations have declined or disappeared from historic areas. While many populations of olive ridley turtles have dramatically declined, some populations are stable or even increasing. For example, the once depleted population in La Escobilla, Mexico, which is the only remaining arribada beach in Mexico, has significantly increased, with the number of olive ridley nests increasing from 50,000 nests in 1988 to over 1,000,000 nests by 2000 (uncorrected for nest frequency) (Márquez et al., 2002). However, globally, the increase in some populations has not offset the overall significant decreases in olive ridley populations. Abreu-Grobois and Plotkin (2008) estimated the worldwide population of olive ridley turtles as 841,309 to 851,590 nesting females, while NMFS and USFWS (2014) estimated 1.15 to 1.62 million olive ridley turtles worldwide. Although most olive ridley females' nest in mass aggregations of hundreds to thousands of turtles, called arribadas[16], some olive ridley females are solitary-nesters with widely dispersed nest sites. Solitary nesting occurs on the beaches of 43 countries (NMFS and USFWS, 2014). The most recent abundances of nesting females recorded at the worldwide major arribada nesting beaches include Ostional (134,400) and Nancite (8,320) on Costa Rica's Pacific coast; La Flor (27,906) in Pacific Nicaragua; La Escobilla (574,937) and Ixtapilla (3,261 to 11,429) in Pacific Mexico; and the Rushikulaya/Gahirmatha/Orissa region, India (150,000 to 200,000) (Abreu-Grobois and Plotkin, 2008). From data collected at sea, Eguchi et al. (2007) estimated the juvenile and adult olive ridley population in the eastern tropical Pacific (ETP) Ocean (area encompasses major arribada beaches in Mexico and Central America) as 1.39 million olive ridley turtles.

Olive ridley turtles occur in tropical to warm-temperate waters of the Pacific, Atlantic, and Indian oceans, but do not occur in the Gulf of Mexico or Mediterranean Sea (Spotila, 2004). Information from tagged olive ridley turtles indicates a preference for waters with the rather narrow temperature range of 77° to 82.4° F (25° to 28°C) (Polovina et al., 2004; Swimmer et al., 2009). To remain in waters of this optimal temperature range, Swimmer et al. (2006) noted that when oceanographic conditions changed, olive ridley turtles in the tropical Pacific altered their dive depths. Worldwide, olive ridley turtles have been recorded in coastal waters of over 80 countries, with nesting occurring in 60 countries (Abreu-Grobois and Plotkin, 2008). Although olive ridley turtles occur in the western and central Pacific Ocean, their distribution in these areas is more restricted to open ocean waters. Olive ridley turtles are not common in the Hawaiian Islands, CNMI, and Guam, and nesting on any of these islands or any U.S. Pacific Island territory is extremely rare (DoN, 2014; NMFS, 2018b; State of Hawaii, 2013). Genetic analysis of olive ridley turtles caught as bycatch in Hawaiian longline fisheries suggests that the Hawaiian Islands represent some type of convergence area for olive ridley's since two-thirds of the bycaught olive ridley turtles were hatched in the eastern Pacific rookeries while the other third of olive ridley turtles derived from rookeries in the western Pacific and Indian oceans (State of Hawaii, 2013). Olive ridley turtle's occurrence in Japanese waters is considered rare and no nesting is known (DuPree, 1995; Kamezaki and Matsui, 1997). Olive ridley turtles occur more commonly in oceanic and neritic environments of the Indian Ocean (Abreu-Grobois and Plotkin, 2008).

Olive ridley turtles exhibit a complex natural history, all of which is not well understood. These turtles utilize a variety of oceanic habitats, depending upon their lifestage and geography. Most olive ridley turtles are highly migratory and spend much of their non-breeding life cycle in the oceanic environment, although some olive ridley's have been observed to inhabit coastal areas, including bays and estuaries, with no migration to the open ocean, particularly those turtles occurring in the western Atlantic Ocean (Plotkin, 2010; Pritchard, 1976). While olive ridley turtles migrate vast distances, they do not make trans-oceanic migrations typical of some other sea turtle species. Using satellite telemetry tags, scientists have documented both male and female olive ridley's leaving the breeding and nesting grounds off the Costa Rica-Pacific coast and migrating to the deep waters of the central Pacific Ocean. Olive ridley hatchlings begin a pelagic stage, during which they are transported by major ocean currents far from their natal beaches. Information is generally lacking, however, on the dispersal of post-hatchling and juvenile olive ridley turtles (NMFS and USFWS, 2014). At sexual maturity, olive ridley turtles migrate and aggregate in shallow, coastal waters near nesting beaches. Some males, however, do not migrate to the neritic environment, but remain in the open ocean and mate with females as they

16 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).

move towards their natal beaches (Kopitsky et al., 2000). The post-breeding and nesting migrations of olive ridley turtles are complex and varied, with no apparent or interannually varying migrational pathways (Abreu-Grobois and Plotkin, 2008; NMFS and USFWS, 2014). In the eastern Pacific Ocean, olive ridley turtles are considered nomadic, moving thousands of miles over vast expanses of the 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). In the ETP, tagged olive ridley have been observed spending as much as 36 percent of time in the vicinity of the Costa Rica Dome, a nutrient-rich circulation feature that encompasses waters of increased productivity and is a known foraging area for fish and marine mammals (Swimmer et al., 2009). Although during their pelagic stage, juvenile olive ridley's are transported by prevailing ocean currents and circulation, it is not clear that adult olive ridley turtles always use ocean currents for transport, passively floating with the currents, as data from satellite-tagged olive ridley turtles in the ETP and North Pacific indicated that the turtles actively swam against or across the prevailing currents (Beavers and Cassano, 1996; Polovina et al., 2004).

Diving in olive ridley turtles is not as well studied as in other sea turtle species (Hochscheid, 2014). Olive ridley turtles are capable of deep dives, having been recorded diving to a maximum water depth of 1,339 ft (408 m) (Swimmer et al., 2006), although routine feeding dives to depths from 33 to 361 ft (10 to 110 m) are more common (Bjorndal, 1997; Lutcavage and Lutz, 1997; Polovina et al., 2003 and 2004). 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). Swimmer et al. (2006) noted that olive ridley's spent nearly 100 percent of their time in the top 199 ft (60 m) of the water column with very few dives exceeding 328 ft (100 m). Beavers and Cassano (1996) noted that in their satellite-tagging study of a male olive ridley turtle that the turtle dove longer at night than during the day. The maximum dive duration measured for tagged olive ridley turtles was 200 min in waters off northern Australia for post-nesting and foraging turtles, with the mean of the dives ranging from 24.5 to 48 min (McMahon et al., 2007). Inter-nesting females made routine dives of 54.3 min while breeding and post-breeding males apparently made shorter duration dives of 28.6 min and 20.5 min, respectively (Lutcavage and Lutz, 1997). Whiting et al. (2007) documented the movement and foraging behavior of inter-nesting olive ridley turtles and found that the turtles dove to maximum depths of 492 to 656 ft (150 to 200 m) during maximum dive durations of 120 to 150 min, and the olive ridley turtles traveled 89 to 567 nmi (165 to 1,050 km) to five foraging areas during the inter-nesting period. Migrating adults had a mean speed of 0.6 kt (1.1 kph) (Plotkin, 2010), which could have been an underestimate due to the minimum distance between satellite positions. Whiting et al. (2007), however, reported swim speeds of 1.7 to 3 kt (0.87 to 1.54 kph) during foraging excursions of inter-nesting adult olive ridley turtles.

Incidental fisheries bycatch of olive ridley turtles continues to be a significant global issue in the recovery of this species in addition to harvest by subsistence fisheries (NMFS and USFWS, 2014). Olive ridley's face the same threats of ocean pollution, marine debris, and factors associated with global climate change that all turtle species currently experience. As olive ridley eggs develop in nests, the sex of the embryonic turtles is determined by the temperature of the nest. Elevated temperatures result in more females developing. Increasing sea and atmospheric temperatures associated with climate change may cause the sex ratios in populations of olive ridley turtles to become skewed if an increasing number of female turtles are produced (NMFS and USFWS, 2014).

3.2.4 Potentially Occurring ESA-Listed Marine and Anadromous Fishes

Nine species of marine and anadromous fish listed under the ESA may potentially occur in the study area of the western and central North Pacific and eastern Indian oceans where SURTASS LFA sonar training and testing activities would occur (Table 3-1). Anadromous fish species, such as salmon, are born in fresh water streams or water bodies, migrate to the ocean where they grow into adults, and return to the fresh water streams or lakes of their birth to spawn, with most Pacific salmon species dying after spawning. For some fish species, populations have been delineated into evolutionary significant units (ESUs) or DPSs. Not all ESUs or DPSs are listed under the ESA. For example, six DPSs define the global populations of the scalloped hammerhead shark but only four DPSs are listed under the ESA. Only the ESUs or DPSs that may occur in the SURTASS LFA sonar study area are considered in this evaluation. Following the example of the scalloped hammerhead shark, only one of the ESA-listed DPSs occurs in the study area for SURTASS LFA sonar (Table 3-1). What follows is an overview of fish hearing and sound production capabilities as well as species-specific information on the ESA status, critical habitat, abundance, distribution, and threats to the relevant ESA-listed marine and anadromous fish species or DPSs.

3.2.4.1 Fish Physiology, Hearing, and Sound Production

All the 100 or more fish species for which hearing has been studied are able to detect sound underwater. This number of studied fish species, however, when compared to the entirety of the fish taxa, represents only a miniscule number of species that have been studied. It is apparent that many bony (teleost) fish, but not elasmobranchs (sharks and rays), are capable of producing vocalizations and using these sounds in various behaviors. Hearing and sound production are documented in well over 240 fish species, encompassing at least 58 families and 19 orders, although it is likely that with additional study, many more fish species will be found to produce sounds.

Fish have two sensory systems that together allow them to detect sound underwater: inner ears and a lateral line system (Higgs and Radford, 2013). A fundamental component of both sensory systems is the highly specialized sensory hair cell, which converts mechanical energy (sound and motion) to electrical signals. The ear and lateral line system send these electrical signals to the fish's brain along separate pathways, however.

All fish species have ears that can detect sound and convey information about gravity and particle motion (Popper et al., 2014). The fish's inner ear is located in the head just behind the eye, and unlike terrestrial vertebrates, the inner ear of fish is not connected to an external opening in the head. The principal ear structures that function in fish hearing are three semicircular canals and otolith organs (Ladich and Popper, 2004; Schellart and Popper, 1992). The sensory regions of the semicircular canals and otolith organs contain the sensory hair cells. It is the relative motion between the otolith and the sensory hair cells that ultimately results in responses to sound or body motion. The lateral line system of fish consists of a series of receptors along the length of a fish's body that are sensitive to external particle motion from sources within a few body lengths of the animal (Popper and Schilt, 2008). 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 150 to 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 Fay, 1993; Popper and Schilt, 2008; Popper et al., 2003). The specific frequency response characteristics of the ear and lateral line system varies amongst fish species.

Hearing in many fish is improved by their ability to detect sound pressure via a gas or swim bladder (or other gas-filled structures) that re-radiates energy in the form of particle motion to the auditory organs of the ears. Fish species without a swim bladder detect little of the pressure component of sound (Popper and Fay, 1993). Being able to detect sound pressure as well as particle motion not only increases hearing sensitivity but also broadens the frequency bandwidth of hearing (Fletcher and Crawford, 2001; Sand and Hawkins, 1973). Hearing sensitivity is further amplified by the proximity of the swim bladder or gas bubbles to the inner ear or connections between the swim bladder and inner ear, which appear to enable higher-frequency hearing and better detection of sound pressure.

Fishes can be categorized by possession of similar anatomical features that affect their hearing capabilities and sensitivity (Popper and Fay, 2011). The categories of fishes include (Popper et al., 2014):

- Fishes with no swim bladder or other gas chamber (e.g., some flatfish, some tuna, sculpins, and elasmobranchs)—hearing is limited to particle motion detection frequencies well below 1 kHz;
- Fishes with swim bladders that is not involved in hearing (e.g., salmonids, such as steelhead trout and Pacific salmon, and sturgeons)—these species lack the anatomical hearing specializations and principally detect particle motion below 1 kHz;
- Fishes with a swim bladder or gas chamber that is involved in hearing (e.g., catfish, carp, sardines, and anchovies)—these fishes detect frequencies below 1 kHz, possess anatomical specializations to enhance hearing, and can detect sound pressure up to a few kHz;
- Fishes with a swim bladder and high-frequency hearing (e.g., Atlantic cod)—species can detect frequencies below 1 kHz and possess anatomical specializations and are capable of sound pressure detection at frequencies from to 10 to over 100 kHz, and possibly as high as 180 kHz (DoN, 2017b; Ladich and Fay, 2013).

Sensitivity to sound in most fish species occurs from below 100 Hz to several hundred hertz or several thousand hertz in a few species (Mann et al., 1997 and 2001). For those fish species for which hearing has been measured, greatest hearing sensitivity generally occurs in the range from 100 to 200 Hz and up to 800 Hz (Popper, 2003). Some members of one type of marine fishes (clupeiforms) with a swim bladder involved in hearing can detect sounds to about 4 kHz (Colleye et al., 2016; Mann et al., 1997 and 2001), with one subfamily in this taxon apparently able to detect very HF sounds, although their best hearing is still <1 kHz. Evidence suggests that at least some fish species can detect infrasound, typically defined as sounds below ~30 Hz. Infrasound hearing has been demonstrated in Atlantic salmon, Atlantic cod, plaice, Atlantic eel, and a perch (Karlsen, 1992a and 1992b; Knudsen et al., 1992; Sand and Karlsen, 1986; Sand et al., 2000). In all cases studied so far, however, detection in this frequency range 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.

The ability of fish to process complex soundscapes is also being better defined. Fay (2009) reviewed the literature on directional hearing abilities in fish. Several 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 differentiate between two sound signals that are presented simultaneously has been demonstrated in goldfish (Fay, 2009). These demonstrated abilities suggest that fish are capable of analyzing acoustic soundscapes, as has been shown in mammals, birds, and insects. This directional hearing ability also offers at least some fish to mitigate masking effects. As reviewed in Sisneros and Rogers (2016), fish were able to lower their masking levels when sources were separated by 20° and 85°, with this directional hearing providing them the ability to filter sound spatially and increase their signal detection ability.

Many species of fish produce sounds, with Myrberg (1981) reporting more than 50 fish families produce some type 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 harmful stimuli (Bass and Ladich, 2008; Myrberg, 1981; Zelick et al., 1999), but few species of fish produce sounds for purely social communication (Parmentier and Fine, 2016). Some of the sounds fish produce 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 other moving body parts. The swim bladder drumming muscles are correspondingly specialized for rapid contractions (Bass and Ladich, 2008; Zelick et al., 1999). Sounds are used in reproductive behavior by several fish species, and the current data lead to the suggestion that males are the most active sound 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).

3.2.4.2 ESA-listed Fishes with No Swim Bladder or Gas Chamber

Since none of the three ESA-listed species of elasmobranchs potentially occurring in the study area for SURTASS LFA sonar, the oceanic whitetip shark, the scalloped hammerhead shark, and the giant manta ray possess swim bladders, their hearing sensitivity is limited to the detection of particle motion.

3.2.4.2.1 Giant Manta Ray (*Manta birostris*)

The giant manta ray has been listed as threatened under the ESA as of February 21, 2018 (NOAA, 2018b). Critical habitat will not be designated as NMFS has concluded that it presently undeterminable. The giant manta ray is listed as vulnerable on the IUCN Red List of Threatened Species (Marshall et al., 2011).

The giant manta ray is considered a rare species throughout most of its range except in limited aggregation areas. Overall population size for the giant manta ray is unknown, but subpopulations appear to be small (about 100 to 1,500 individuals, sparsely distributed, and highly fragmented (Marshall et al., 2011; Miller and Klimovich, 2016). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (2013) reported that 10 worldwide populations of the giant manta ray have been studied, with 25 other aggregation sites having been noted, but the species is considered rare in all other areas, indicating that global population of giant manta rays is likely small. The rate of population decline appears to be high in several regions, with as much as an 80 percent decline over the last three generations (approximately 75 years), and a global decline of about 30 percent is strongly suspected (Marshall et al., 2011). The largest global aggregation site of giant manta rays is located in Pacific Ocean waters off Ecuador, where 1,500 individuals have been estimated and as many as 600 individuals are estimated at the largest aggregation site in the Indian Ocean (Mozambique) (CITES, 2013; Miller and Klimovich, 2016).

The giant manta ray is the largest living ray and has a circumglobal distribution in tropical, subtropical, and temperate oceanic waters but has also been observed in nearshore, highly productive waters and in waters surrounding coastal and offshore islands. The largest aggregation site in the world is located within the Ecuadorian waters of the Machalilla National Park and the Galapagos Marine Reserve (Hearn et al., 2014). In the Northern Hemisphere, the giant manta ray has been documented to occur as far north as southern California and Mutsu Bay, Japan waters in the Pacific; New Jersey and the Azores Islands in the Atlantic; and the Sinai Peninsula, Egypt in the Indian Ocean, while in the Southern Hemisphere, these rays have been observed as far south Peru, French Polynesia, and New Zealand in the Pacific; and Uruguay and South Africa in the Atlantic and Indian oceans (Marshall et al., 2011).

Giant manta rays appear to exhibit a high level of flexibility in their habitat use, especially water depths. Tagging studies have shown that the giant manta rays dive to water depths of 837 to 1,476 ft (200 to 450 m) at night (Rubin et al., 2008; Stewart et al. 2016) but are capable of diving to depths exceeding 3,281 ft (1,000 m) (Marshall et al., 2011). Considered a migratory species capable of traveling relatively long distances, the maximum estimated distance travelled by a tagged giant manta ray is 138 nmi (1,500 km) from an island off the Ecuadorian coast to Darwin Island in the Galapagos Islands (Hearn et al., 2014). Clark (2010) suggested that giant manta rays might conduct seasonal migrations to follow prey. A more recent study, however, using tagging, stable isotope, and genetic analysis of giant manta rays in Mexican waters provided evidence that giant manta rays may occur in well-structured subpopulations that exhibit a high degree of residency, especially to specific sites such as cleaning stations and feeding sites (Marshall et al., 2011; Stewart et al., 2016).

Although the giant manta ray's conservation is threatened primarily by fishery overexploitation, conservation is also challenged by the species very low reproductive output (one pup per litter) and its occurrence in small, isolated and fragmented subpopulations, which contribute to the slow or non-recovery of the population reductions (Marshall et al., 2011; Miller and Klimovich, 2016). Giant manta rays are targeted by directed commercial (especially purse-seine fisheries) and artisanal fisheries in unsustainable numbers and are captured as incidental bycatch in other fisheries (Miller and Klimovich, 2016).

3.2.4.2.2 Oceanic Whitetip Shark (*Carcharhinus longimanus*)

Effective March 1, 2018, as a species, the oceanic whitetip shark has been listed as threatened under the ESA (NOAA, 2018a). No critical habitat for the species has been designated, as NMFS determined that it was not currently determinable (NOAA, 2018a). The oceanic whitetip shark is listed as vulnerable on the IUCN Red List (Baum et al., 2015).

The oceanic whitetip shark was historically considered to be the most globally abundant and common pelagic shark in tropical waters. Although no global abundance exists for this shark, the available data and information suggest that overall this species has undergone a population decline that varies in extent regionally. In areas of the central and western Pacific Ocean, the abundance of oceanic whitetip sharks has declined by 86 to more than 90 percent (Young et al., 2016). Rice and Harley (2012) and FAO (2012) estimated the 2010 population in the western and central Pacific Ocean to include roughly 200,000 individuals, with the population severely depleted (NOAA, 2016e). While the data on the oceanic whitetip shark for the Indian Ocean are uncertain and less reliable, the best available information indicate varying levels of population decline, with the species having become rare throughout the Indian Ocean during the last two decades (Young et al., 2016). In some regions of its global range, however, such as in northwestern Atlantic Ocean, the oceanic whitetip shark populations have stabilized since 2000 (Young et al., 2016).

The oceanic whitetip shark is one of the most widely distributed shark species, occurring worldwide in pelagic tropical and subtropical waters of the Atlantic, Pacific, and Indian oceans (Baum et al., 2015). This shark occurs most commonly in open ocean waters between 10° N and 10° S but occurs in lower numbers in outer continental shelf waters and around deep-water oceanic islands as well as oceanic waters between 30° N and 35° S (Baum et al., 2015; Compagno, 1984; Young et al., 2016). The occurrence of the oceanic whitetip shark is thought to be rare in the northeastern Atlantic Ocean and Mediterranean Sea, as these areas are near the northern extent of the species' range. Oceanic whitetip sharks occur in waters between 59° to 82° F (15° and 28° C) and exhibit a strong preference for the surface mixed layer when water temperatures are above 68° F (20° C). This shark typically is found in the upper 328 ft (100 m) of the water column but has been documented diving to water depths of 840 ft (256 m) and even as deep as 3,550 ft (1,082 m) for short periods (~13 minutes) (Carlson and Gulak, 2012; Young et al., 2016).

Although the oceanic whitetip shark is known as a highly migratory species capable of making long distance movements (Howey-Jordan et al., 2013), members of at least some regional populations in Brazil and the Bahamas (Cat Island) exhibit some degree of site fidelity (Tolotti et al., 2015). Tagged oceanic whitetip sharks in the western Indian Ocean and western North Atlantic Ocean traveled from 1,048 to 3,510 nmi (1940 to 6,500 km) from their tagging locations (Filmalter et al., 2012; Young et al., 2016). In the central North Pacific Ocean, tagged oceanic whitetip sharks have shown complex movement patterns that were generally limited to the tropical waters north of the North Equatorial Countercurrent (Musyl et al., 2011).

The single greatest threat to the conservation of the oceanic whitetip shark is fishery overexploitation throughout its range (NOAA, 2016a). This shark is not generally the target of any fishery but suffers high mortality as bycatch and is also harvested for the international shark-fin trade (Young et al., 2016). Oceanic whitetips are regularly caught as incidental bycatch by the pelagic longline, drift net, purse seine, handline, troll, and occasionally pelagic and bottom trawl fisheries (Compagno, 1984). NOAA (2016a) includes a thorough description of the fishery threats to the oceanic whitetip shark.

3.2.4.2.3 Scalloped Hammerhead Shark (*Sphyrna lewini*)

The scalloped hammerhead shark is listed under the ESA, with the 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, 2014f). NMFS has not yet designated critical habitat for the scalloped hammerhead shark (NOAA, 2014f). 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 observed, with declines in abundance of 50 to 90 percent over 32-year periods in some parts of the species' range (Baum et al., 2007). From Asian shark fin market data and statistical analysis, Clarke et al. (2006) estimated 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, likely there are multiple patterns of declining abundance within the DPS (NOAA, 2014f). 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, 2014f).

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, that may occur in waters as deep as 902 ft (275 m), with occasional dives to even deeper depths (1,680 ft [512 m]) (Compagno, 1984; Compagno et al., 2005; Jorgensen et al., 2009). In the western Pacific Ocean, the scalloped hammerhead shark occurs in the waters of Japan, China, Vietnam, Thailand, Indonesia, the Philippines, eastern Australia, and New Caledonia (Compagno et al., 2005; Miller et al., 2014a). In the Indian Ocean, populations of this shark occur in the waters from South Africa to the Red Sea and eastward to Pakistan, India, Myanmar, and Western Australia (Miller et al, 2014a).

Scalloped hammerheads are highly mobile and partially migratory (Maguire et al., 2006). 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, 2014f). For instance, adult scalloped hammerheads generally move distances <108 nmi (200 km) but have occasionally been reported traveling up to 1,080 nmi (2,000 km).

The greatest threat to the status of the Indo-West Pacific DPS of the scalloped hammerhead shark is from overfishing, especially for its fins (Miller et al., 2014a). Additional threats to the scalloped hammerhead shark is from illegal fishing; fisheries bycatch; habitat degradation; and inadequate protective regulations and weak enforcement in some parts of the DPS' range (Miller et al., 2014a).

3.2.4.3 ESA-listed Fishes with a Swim Bladder/Gas Chamber Not Involved in Hearing

Although the following ESA-listed marine fishes are bony (teleost) fishes that possess swim bladders, no evidence exists that the swim bladder is involved in hearing. Further, these fishes possess no known auditory structures or tissues that would function to enhance hearing.

3.2.4.3.1 Chinook Salmon (*Oncorhynchus tshawytscha*)

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, two are listed as endangered, and one ESU, the Upper Klamath-Trinity River ESU, is a candidate for listing under the ESA; fishes associated with all these ESA-listed ESUs may occur in the North Pacific part of the study area for SURTASS LFA sonar. Critical habitat has been established for all nine ESA-listed ESUs. Critical habitat for the Chinook ESUs includes freshwater spawning, rearing, and migration sites, as well as estuarine and marine juvenile and adult forage and migration areas in the inland waters of California, Oregon, and Washington states. After significantly declining throughout its U.S. range, most of the ESA-listed Chinook ESUs are considered to be stable or improving, but two ESUs, the Upper Willamette Spring-Run ESU and the Sacramento River Winer-Run ESU, are considered to be under stress and declining (NOAA, 2016i; Northwest Fisheries Science Center, 2015).

Chinook, or king, salmon range throughout the North Pacific Ocean from Hokkaido, Japan and the Anadyr River, Russia and Monterey Bay, California northward to the Bering Strait and Chukchi Sea, as well as in associated inland tributaries and estuaries. 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 often hundreds of miles seaward to estuaries and finally to the ocean, where they mature and remain from 1 to 6 years, but more commonly remain at sea between 2 and 4 years (USFWS, 2009a). As adults, Chinook salmon return to their natal (birth) river or streams to mate, spawn, and die.

The life history and ecology of Chinook salmon exhibit a level of complexity and variability not known in other Pacific salmon species. Populations of Chinook salmon exhibit a great deal of variation 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 to freshwater. At least one resident population of Chinook salmon in Lake Cushman, Washington never migrates to saltwater (Good et al., 2005). Additionally, not all Chinook salmon migrate to freshwater at the same time of year. Different seasonal (i.e., spring, summer, fall, or winter) migration "runs" or movements of Chinook salmon from the ocean to freshwater exist, even within an individual river system. These runs are identified based on the season when adult Chinook salmon enter freshwater to begin their spawning migration. Entry into freshwater systems may be mediated by water temperature and the water flow regime of the natal 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 North Pacific. Stream-type Chinooks, found most commonly in headwater streams of large river systems, perform extensive offshore migrations into the North Pacific Ocean 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) Chinook salmon are much larger than their ocean-type counterparts and can 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 as noted, spend their adult life stage in coastal ocean waters. Ocean-type Chinook salmon return to their natal streams or rivers in fall through summer, with summer and fall migrational runs predominating. In most rivers, migration in the late summer or autumn of the first year represents most 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.

The principal threats to Chinook salmon are the operation of hydropower systems, harvest, hatcheries, and habitat degradation. Natural variations in freshwater and marine environments have substantial effects on the abundance of salmon populations. Of the various natural phenomena that affect most populations of Pacific salmon, changes in ocean productivity are generally considered most important. Ocean predation also probably contributes to significant natural mortality, although the levels of predation are largely unknown and are considered insignificant as a causative factor in the declines of the Pacific salmon stocks (NMFS, 2014a).

3.2.4.3.2 Chum Salmon (*Oncorhynchus keta*)

Two of four chum salmon ESUs, the Columbia River and Hood Canal Summer-run ESUs, are listed as threatened under the ESA, with fishes from both ESUs potentially occurring in the North Pacific portion of the study area for SURTASS LFA sonar. Critical habitat for chum salmon has been designated in the transboundary inland waters of Washington and northwestern Oregon to protect freshwater spawning, rearing, and migrational sites as well as estuarine migrational and rearing areas (NOAA, 2005b). Once the most abundant of all Pacific salmon species, seven of the 16 historical spawning populations of chum salmon in the Hood Canal Summer-run ESU are now extinct, with the overall population of this

ESU estimated in the early 2000s at several thousand and declining by 6 percent per year (Good et al., 2005). Although productivity of the Hood Canal Summer-run ESU remains low, recent information indicates that population rates have slightly increased in the last five years (NOAA, 2016k). The population of the Columbia River ESU is even lower, with an estimated population in the early 2000s of only 500 fish, and 14 of 16 spawning populations in this ESU are now considered extinct (Good et al., 2005). Abundances of the populations of chum salmon in the Columbia River ESU remain very low, with only three populations considered stable or very slightly increasing, while the other populations are in danger of extinction/extirpation (NOAA, 2016l).

The chum salmon has the widest natural geographic and spawning distribution of any Pacific salmonid, primarily because its occurrence extends farther north into the polar waters of the Arctic Ocean. With spawning populations ranging from Korea and Japan as far north as Russia in the western North Pacific, major spawning populations of chum salmon occur only as far south as Tillamook Bay on the northern Oregon coast in the eastern North Pacific Ocean. Like other Pacific salmon species, the chum salmon is anadromous and migrates from freshwater tributaries to saltwater, returning to the freshwater river or stream of birth to spawn once and die. However, one resident population in Puget Sound never migrates from the waters of the sound (USFWS, 2009b). Chum salmon do not travel as far upstream to spawn as other salmon, generally spawning close to saltwater. Like Chinook salmon, chum salmon are semelparous, only spawning once before dying.

Most chum salmon mature and return to their natal river of 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, 2009b). Only one form, the sea-run, of chum salmon exists. Chum salmon spawn in the lowermost reaches of rivers and streams, typically within 62 mi (100 km) 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 (Pauly 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.

The majority of the threats to chum salmon are related in large part to loss of freshwater habitat due to damning for hydropower, agriculture, and water control that have reduced the amount of available habitat or eliminated it all together. Modifications to the natural flow of the freshwater tributaries has led to increased water temperatures, changed natural fish fauna, and depleted water flow and velocity necessary for migration, spawning, rearing, and flushing of sediments from spawning gravels and transport of large woody debris (NMFS, 2014a). Not only has damning of rivers caused dramatic changes in the freshwater habitat, but the physical structures of the dams have also resulted in death for both adult and juvenile lifestages. Land use practices including logging and urbanization and development have also led to loss or degradation of available habitat. Studies indicate that about 80 to 90 percent of the historic riparian habitat in most western states has been eliminated (NMFS, 2014a).

3.2.4.3.3 Coho Salmon (*Oncorhynchus kisutch*)

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 (Table 3-1). ESA-listed coho salmon may occur in the North Pacific part of the LFA study area. 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 all four listed ESUs. 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, 2008a). The abundance of coho salmon south of Alaska has declined despite the establishment of large hatchery programs. Hatchery programs for coho salmon have been so successful that most salmon runs now consist of more than twice the number of hatchery-raised versus naturally occurring coho salmon. The overall population trend for the ESA-listed ESUs in the early 2000s indicated declining abundances, particularly in the Central California Coast ESU, although abundances for some years show promising increases (Good et al., 2005). More recently, the abundance of the Oregon Coast ESU has shown long-term increases (NOAA, 2016m), while little change has been apparent in the population status of the Southern Oregon/Northern California ESU (NOAA, 2016o).

The distributional range of coho salmon extends from central California to Alaska and from Japan to Russia, principally in coastal marine waters, with these salmon not ranging as widely in open ocean waters as other species of Pacific salmon. The extent of coho migrations appears to extend westward along the Aleutian Island chain ending somewhere around Emperor Seamount (Pacific Fisheries Management Council [PFMC], 2000).

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, such as in Puget Sound/Strait of Georgia, where some coho salmon spend their entire lives (Emmett et al., 1991). Coho salmon exhibit a simple, 3-year life cycle, spending the first year or so of life in freshwater. Juvenile coho salmon spend about 15 months developing in freshwater, and then from spring through summer (April to August), peaking in May, migrate into the waters of the North Pacific Ocean. 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). Adult coho salmon spend two years in the ocean before returning to freshwater to complete their life cycle by spawning and dying (Emmett et al., 1991). Some males known as "jacks" return to freshwater sooner as two-year-old spawners. The adult spawning migrations begin in summer, are completed by fall, and all spawning has occurred by mid-winter. Spawning occurs earlier at the northern extent of the coho’s geographic range (PFMC, 2000).

While threats to coho salmon are numerous and largely related to habitat loss or degradation, no one single cause has led to the decline in coho salmon numbers and extirpation of some populations. Like other species of Pacific salmon, damning for hydropower, agriculture, water control, and other purposes reduced the amount of available habitat or eliminated vital spawning habitat all together. Modifications to the natural flow of the freshwater tributaries resulted in higher water temperatures, changed natural fish fauna, and depleted water flow and velocity necessary for migration, spawning, rearing, and flushing of sediments from spawning gravels and transport of large woody debris (NMFS, 2014a).

3.2.4.3.4 Sakhalin Sturgeon (*Acipenser mikadoi*)

Endangered throughout its range under the 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 the Sakhalin sturgeon since its geographical range is entirely outside U.S. jurisdiction. 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 none captured during fish surveys from 2010 and 2013 (Mugue, 2010). Introduced into the Amur River estuary, five to 10 Sakhalin sturgeons are caught annually (Meadows and Coll, 2013).

The Sakhalin sturgeon occurs only in the waters of the western North Pacific Ocean from the Sea of Japan (as far south as Hokkaido, Japan, and Wonsan, North Korea) north to the Bering Strait, including the Sea of Okhotsk, and associated rivers (Mugue, 2010; Shmigirilov et al., 2007). Sakhalin sturgeon migrate into freshwater rivers to spawn, principally now only in the Tumnin River, 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).

An anadromous fish, the Sakhalin sturgeon lives from 15 to 20 years (NOAA, 2013), and begins spawning migrations to freshwater rivers once it reaches a length of about 4.4 ft (1.35 m) (Koshelev et al., 2012). Spawning occurs from June through July in the Tumnin River, Russia, and from April to May in rivers of Hokkaido, Japan (Mugue, 2010; Paul, 2007). Juveniles remain in freshwater or estuaries until the fall of their birth year, when they migrate to the sea (Birstein, 1993).

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 population decline (Meadows and Coll, 2013; Mugue, 2010). Pollution and poor water quality are additional threats to the Sakhalin sturgeon's recovery.

3.2.4.3.5 Sockeye Salmon (*Oncorhynchus nerka*)

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; sockeye from both the ESA-listed ESUs potentially may occur in North Pacific portion of the study area for SURTASS LFA sonar. 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, 1993b). 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, 2005b). The sockeye salmon is listed as least concern on the IUCN Red List of Threatened Species (Rand, 2011).

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 population 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). The Ozette Lake ESU population is small, particularly when compared to historical levels, and the population status has only slightly improved, with the natural-origin spawning population estimated to include only 2,679 sockeye salmon (NOAA, 2016j). The abundance of the Snake River ESU, albeit still very low, shows an increasing trend in the population, with the introduction of hatchery stock thought to have prevented this ESU from becoming extinct (NOAA, 2015e).

Sockeye salmon range from about 44°N to 49°N and occur around the northern Pacific Rim of the Pacific Ocean, ranging from the Klamath River and its tributaries (Northern California and Oregon) to the

Kuskokwim River, Alaska in the east and from Hokkaido, Japan to the Anadyr River, Russia in the west (Gustafson et al., 1997). Sockeye salmon prefer cooler ocean conditions than most other species of Pacific salmon and require lake environments for the first half of their lives, spending the remainder of their life cycle foraging in estuarine and marine waters of the North Pacific Ocean. For instance, nearly 90 percent of Asian sockeye salmon are reared in Kuril Lake in the Ozernaya River Basin, Kamchatka Peninsula, Russia (Gustafson et al., 1997).

Sockeye salmon are primarily anadromous and only spawn once before dying, but like Chinook salmon, exhibit a more varied life history and ecology than other species of Pacific salmon. Distinct landlocked populations (kokanee) of sockeye salmon exist 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 majority of sockeye salmon spawn in or near lakes (lake-type), where the juveniles develop for 1 to 3 years prior to migrating into marine waters. For this reason, the major distribution and abundance of sockeye salmon stocks are closely related to the location of rivers with accessible lakes in their watersheds for juvenile development, so that their occurrence in riverine habitats is more intermittent than that of other Pacific salmon. Sockeye spend approximately the first half of their life cycle in lake environments, with the remainder of their four to six-year life cycle 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 lake developmental habitat, developing to juveniles during 1 to 2 years in the slow-velocity sections of rivers. In Washington and British Columbia, lake residence is typically closer to 1 to 2 years, whereas juvenile lake-residence is closer to 3 to 4 years in Alaska. "Sea-type" sockeye 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, young sockeye spend their 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 sockeye salmon in the Cedar River spawning into February (Gustafson et al., 1997).

Threats to sockeye salmon are the same as for other Pacific salmon species, largely from habitat loss and degradation, although no one cause is responsible for the decline in sockeye numbers and decimation of populations from some areas. Loss of freshwater habitat due to damning for hydropower, agriculture, water control, and other purposes have reduced or eliminated all together the amount of available freshwater habitat. Modifications to the natural flow of the freshwater tributaries has led to increased water temperatures, changed natural fish fauna, and depleted water flow and velocity necessary for migration, spawning, rearing, and flushing of sediments from spawning gravels and transport of large woody debris (NMFS, 2014a). Of the various natural phenomena that affect most populations of Pacific salmon, changes in ocean productivity are generally considered most important. Ocean predation also probably contributes to significant natural mortality, although the levels of predation are largely unknown and are considered insignificant as a causative factor in the declines of the Pacific salmon stocks (NMFS, 2014a).

3.2.4.3.6 Steelhead Trout (*Oncorhynchus mykiss*)

Steelhead and rainbow trout are the same species, with steelhead trout exhibiting an anadromous lifestyle while rainbow trout remain wholly in freshwater throughout their lives and do not migrate into the ocean. In the U.S., steelhead trout are divided into 15 DPSs, with 11 ESUs listed under the ESA. The Southern California DPS is listed as endangered while 10 other DPSs listed as threatened under the ESA (Table 3-1), and a twelfth DPS, the Oregon coast DPS, is listed as a Species of Concern (NOAA, 2006a, 2007a). Steelhead trout from all 11 ESA-listed ESUs may potentially occur in the North Pacific portion of the SURTASS LFA study area. Critical habitat has been designated for all ESA-listed DPSs and includes the inland, freshwater river and stream habitat as well as coastal estuarine and marine habitat of California, Oregon, Washington, and Idaho (including Puget Sound) (NOAA, 2005a, 2005b, and 2016p). The population status of steelhead trout in U.S. waters is variable, with some DPSs declining or increasing, and others remaining unchanged. Some populations of the Northern California DPS may already be extirpated or extinct, with the summer-run populations considered more at risk (NOAA, 2016n). No overall abundance is available for the entire steelhead population.

The current distribution of steelhead trout ranges from the freshwater inland and marine waters from southern California to the Bering Sea and Bristol Bay of Alaska and to the Kamchatka Peninsula in Russia. Steelhead trout do not range into the deep central oceanic gyre waters of the North Pacific Ocean as do other Pacific salmonid species and occur in most streams in the Puget Sound region and many Columbia and Snake River tributaries (Pauley et al., 1986).

Steelhead trout exhibit one of the most complex life histories of any salmonid species. In addition to having a wholly freshwater ecotype[17] (rainbow trout), steelhead trout in the Pacific Northwest region of Washington, Oregon, and British Columbia can be divided into two phylogenetic groups, inland and coastal steelhead trout, separated by the Columbia and Fraser tributary systems in the Cascade Mountains (Busby et al., 1996). Steelhead trout can also be divided into two biological or reproductive ecotypes, stream-maturing and ocean-maturing, which are differentiated by their state of sexual maturity at the time of return entry to freshwater 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. Like chinook, steelhead trout also exhibit have two adult migrational movement patterns, with summer- and winter-runs. Most summer runs occur east of the Cascades, with steelhead trout entering streams in summer to reach the spawning grounds by the following spring. A few rivers in western Washington also have established runs of summer steelhead. Steelhead trout that are part of winter-runs spawn closer to the ocean, requiring less travel time to spawn.

Steelhead trout are capable of spawning more than once but most die after spawning twice (NOAA, 1997). In waters north of Oregon, repeat spawning is uncommon, and more than two spawning migrations are rare. The frequency of two spawning migrations is higher in waters of Oregon and California, 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 (Busby et al., 1996).

Steelhead trout are the most long-lived of the salmon family, living 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. Steelhead trout

17 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.

typically remain in marine waters for two to three years prior to returning to their natal stream to spawn. Spawning migrations can occur throughout the year and adults typically spawn between December and June (Busby et al., 1996). Some populations of trout 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.

Most threats to all Pacific salmon, not only to the steelhead trout, are related in large part to loss of freshwater habitat due to damning for hydropower, agriculture, and water control that have reduced the amount of available habitat or eliminated it all together. Modifications to the natural flow of the freshwater tributaries has led to increased water temperatures, changed natural fish fauna, and depleted water flow and velocity necessary for migration, spawning, rearing, and flushing of sediments from spawning gravels and transport of large woody debris (NMFS, 2014a). Not only has damning of rivers caused dramatic changes in the freshwater habitat, but the physical structures of the dams have also resulted in death for both adult and juvenile lifestages. Land use practices including logging and urbanization and development have also led to loss or degradation of available habitat. Studies indicate that about 80 to 90 percent of the historic riparian habitat in most western states has been eliminated (NMFS, 2014a). In the marine environment, changes in ocean productivity are generally considered most important. Ocean predation also probably contributes to significant natural mortality, although the levels of predation are largely unknown and are considered insignificant as a causative factor in the declines of the Pacific salmon stocks (NMFS, 2014a).

3.2.5 Potentially Occurring ESA-Listed Marine Mammals

Eleven species or DPSs of marine mammals that potentially occur in the study area for SURTASS LFA sonar training and testing activities are listed under the ESA as threatened or endangered (Table 3-1), including six mysticete, two odontocete, and three pinniped species. Taxonomy for marine mammals herein follows that of the Society for Marine Mammalogy (SMM) (2017), with species presented alphabetically within each of the following three marine mammal groups: mysticetes, odontocetes, and pinnipeds. Information follows on the status, critical habitat, population, distribution, diving, swim speeds, as well as hearing and vocalization for each species. Since marine mammal species face similar threats, both to their continued existence and to recovery from population decimation, threat information is presented herein for all marine mammal species listed under the ESA to eliminate redundancy in repeating the information for each species.

3.2.5.1 Threats to Marine Mammals

The status of marine mammal populations is impacted by their biological characteristics, natural phenomenon, and interaction with anthropogenic activity. Many cetacean and pinniped populations have been reduced due to the exploitation of commercial whaling and harvesting, incidental fisheries bycatch, harmful algal blooms, and habitat destruction over the last centuries.

Although whaling of cetaceans and hunts of pinnipeds have historically been the principal cause of the demise in most global marine mammal populations, now that nearly all international countries have banned commercial whaling, and far fewer countries engage in pinniped hunting, neither whaling nor hunts are now threats to the ESA-listed cetacean species.

Currently, the principal threats facing most marine mammals is the danger of ship or boat strikes; and fishery interactions, primarily entanglement in fishing gear especially for coastal species although some species are also incidentally taken in fishery operations. Anthropogenic noise, habitat degradation, vessel/boat and human disturbance, and climate change are additional concerns. However, impacts of these threats on individual species are very often difficult to quantify because so little information and data are available on species-level effects. Oceanic habitat degradation caused by pollutants (especially of heavy metals, polychlorobiphenyls, chlorinated pesticides, or polycyclic aromatic hydrocarbons) and concentrations of marine debris not only pose immediate ingestion and entanglement risks to marine mammals but also pose long-term health risks. Coastal development and the increased recreational use of coastal waters result in conflicts between marine mammals and humans that may lead to displacement, at least temporarily, from biologically important habitat or cessation of important biological activities.

Habitat changes, such as loss of sea ice and sea level rise, due to global warming are threats for ice-dependent species such as the spotted seal. Other specific threats to ESA-listed pinnipeds species include loss of shore haulout habitat due to erosion as sea level changes and storms increase natural sediment movement patterns. Some species of pinnipeds are still killed as a means of reducing fishery interactions. Species of both cetaceans and pinnipeds are subsistence hunted in Arctic regions of North America and Asia.

3.2.5.1.1 Potentially Occurring Mysticetes

- *Blue Whale (Balaenoptera musculus)*

The blue whale is listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and as endangered by the IUCN Red List of Threatened Species (Reilly et al., 2008c). The global population of blue whales is estimated between 10,000 to 25,000 individuals (Reilly et al., 2008c). In the central North Pacific (CNP) stock of blue whales, 133 individuals (CV=1.09) are estimated to occur (Bradford et al., 2017), while 9,250 blue whales are estimated for the WNP stock (Tillman, 1977). The Northern Indian Ocean stock of blue whales has been estimated to include 3,432 whales (IWC, 2016), while 1,657 blue whales are estimated to occur in the Southern Indian Ocean stock (inclusive of both pygmy blue and blue whales) (Jenner et al., 2008; McCauley and Jenner, 2010).

Blue whales are distributed in oceanic subpolar to tropical waters of the world's oceans and some continental seas except the Mediterranean Sea and Gulf of Mexico (Jefferson et al., 2015). Occurring primarily in open ocean waters, they also may occur in neritic waters when foraging and possibly when breeding. Blue whales occur in lower numbers in the central and western North Pacific than in the eastern North Pacific Ocean, but blue whales are reported from Hawaiian waters and from Kamchatka and the Kuril Islands to offshore Japan (Sears and Perrin, 2018). Blue whales occur throughout the Indian Ocean, with at least some blue whales off Sri Lanka remaining at low-latitudes throughout the year, presumably, because oceanographic upwelling supports sufficient productivity and prey (de Vos et al., 2014). Not all blue whales are migratory, as some remain resident and do not seasonally move from lower latitude calving and breeding grounds and higher latitude foraging grounds (Jefferson et al., 2015; Sears and Perrin, 2018).

The swimming and diving behavior of blue whales has been relatively well characterized. General blue whale dive durations and dive depths range from 5 to 15 min and 591 to 656 ft (180 to 200 m), respectively (Croll et al., 1998 and 2001a). Dives of 20 to 30 min are not unusual and the longest dive recorded was 36 min long (Jefferson et al., 2015; Sears and Perrin, 2018). Calambokidis et al. (2008a) reported a maximum dive depth of 961 ft (293 m). Foraging blue whales appear to dive more shallowly, with average foraging dives reaching only 223 ft (67.6 m) (Croll et al., 2001a). Dive descent swim rates of 2.4 kt (4.5 kph) have been recorded (Williams et al., 2000). The common surface swim speed for blue whales is 1.6 to 3.2 kt (3 to 6 kph), but travel speeds of 3.8 to 10.8 kt (7 to 20 kph) are not uncommon, and the maximum swim speed reported for a blue whale 18.9 kt (35 kph) (Sears and Perrin, 2018).

No hearing sensitivity has been measured for blue whales (Ketten, 2000; Nummela, 2009). Blue whales produce a variety of LF vocalizations ranging from 10 to 200 Hz throughout the year but with peaks in midsummer and winter (Alling and Payne, 1990; Clark and Fristrup, 1997; Edds, 1982; Rivers, 1997; Stafford et al., 1998, 1999a, 1999b, and 2001; Thompson and Friedl, 1982; Sears and Perrin, 2018). The majority of blue whale vocalizations are infrasonic sounds from 17 to 20 Hz with a SL of 188 dB re 1 µPa @ 1 m (Sears and Perrin, 2018), which makes their vocalizations amongst the loudest made by any animal (Aroyan et al., 2000; Cummings and Thompson, 1971). However, calls produced during foraging have been measured at lower SLs, ranging from 158 to 169 dB re 1 µPa @ 1 m (Akamatsu et al., 2014). Short sequences of rapid frequency modulated (FM) calls below 90 Hz are associated with animals in social groups (Mellinger and Clark, 2003; Moore et al., 1999). Off Australia, at least five types of pygmy blue whale calls were detected that consisted of amplitude modulated (AM) and FM 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 FM downsweeps with a frequency range of 105 to 48 Hz and durations of 1to 2 sec (Akamatsu et al., 2014). 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). Blue whales also produce long, patterned hierarchically organized sequences 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.

The call characteristics of blue whales vary geographically and seasonally (Stafford et al., 2001). McDonald et al. (2006) have suggested that song characteristics could indicate population structure. 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, with a recent study recorded four calls during ~22 hours (Akamatsu 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 Red List of Threatened Species (Reilly et al., 2013). Although the SMM (2017) has differentiated Northern and Southern subspecies of fin whales, since these subspecies are not differentiated at sea or in available population data and information, hereafter all information about the fin whale will only be referenced as a single species. The global population is estimated as <100,000 whales (Reilly et al., 2013). The population of fin whales in the Hawaii stock is estimated as 154 fin whales (CV=1.05) (Bradford et al., 2017), while fin whales in the East China Sea stock are estimated to include 500 individuals (Mizroch et al., 2009; Tillman, 1977; Evans, 1987), and the abundance of the WNP stock has been estimated as 9,250 individuals (Mizroch et al., 2009; Tillman, 1977). The northern Indian Ocean population of fin whales has been estimated to include 1,716 individuals (IWC, 2016), while the Southern Indian Ocean stock of fin whales off western Australia is estimated as 38,185 whales (Branch and Butterworth, 2001; Mori and Butterworth, 2006).

Fin whales are widely distributed in all oceans of the world, from tropical to polar oceanic waters, but appear to be absent from equatorial waters (Aguilar and García-Vernet, 2018). Fin whales are sometimes observed in neritic waters, but typically when deep water approaches near to land (Jefferson et al., 2015). Although fin whales have traditionally been considered migratory, acoustic data suggest no seasonality in the annual distribution of fin whales (Watkins, et al., 2000). Although fin whale calls have been reported from the central Pacific waters of Hawaii in all months except June and July, sightings of fin whales in these waters are rare (Muto et al., 2018). Specific breeding areas are unknown.

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). The deepest dive recorded for a fin whale was to a depth of 1,542 ft (470 m) but dives to <328 ft (100 m) are more routine (Panigada et al., 1999). Fin whales forage at water depths between 328 to 656 ft (100 and 200 m), with foraging dives lasting from 3 to 10 min (Aguilar, 2009; Witteveen et al., 2015). When traveling, fin whales have been recorded diving only to an average of 194 ft (59 m) (Croll et al., 2001a). Swimming speeds average between 5 to 8 kt (9.2 and 14.8 kph) (Aguilar, 2009). The average speed of descent during dives in the Mediterranean has been measured as 6.2 kt (11.5 kph), while the swim speed of ascending dives was recorded as 4.1 kt (7.6 kph) (Panigada et al., 1999). Watkins (1981) reported bursts of speed in fin whales up to 10.8 kt (20 kph). Singing fin whales swam at average speeds of 2.9 to 4.8 kt (5.3 to 8.8 kph) (Varga et al., 2018).

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 et al., 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 or call”, which is a LF (18 to 35 Hz) loud and long (0.5 to 1.5 sec) patterned sequence signal centered at 20 Hz (Clark et al., 2002; Patterson and Hamilton, 1964; Watkins et al., 1987). The pulse patterns of the 20-Hz signal vary only slightly geographically and with season (McDonald et al., 1995, Oleson et al., 2014; Širovic´ et al., 2007, 2013; Varga et al., 2018). 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, 20-Hz signals are produced regularly throughout the year, with Atlantic fin whales also producing higher frequency downsweeps ranging from 100 to 30 Hz (Frankel, 2009). Fin whales produce the 20-Hz call in two forms: songs and call-counter calls (Buccowich, 2014; McDonald and Fox, 1999; McDonald et al., 1995; Oleson et al., 2014; Širovic´ et al., 2013; Varga et al., 2018; Watkins et al., 1987). 20-Hz songs are simply regular patterns of 20-Hz calls that are associated with reproductive behavior, and are only produced by males (Croll et al., 2002; Delarue et al., 2013; Širovic´ et al., 2013 and 2017; Thompson et al., 1992). 20-Hz call-counter calls are irregular patterns of 20-Hz signals that likely are used for communication function and are produced by either solitary or multiple fin whales in an area (McDonald and Fox, 1999; McDonald et al., 1995; Širovic´ et al., 2013). 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 et al., 1987; Weirathmueller et al., 2013). Varga et al. (2018) reported the SLs of the 20-Hz songs off Southern California as 194.8 dB re 1 µPa @ 1 m (peak to peak) and 180.9 dB re 1 µPa @ 1 m (rms). Fin whales also produce 40 Hz downsweeps (Širović et al., 2012; Watkins, 1981).

- *Gray Whale (Eschrichtius robustus)*

Two genetically distinct stocks and DPSs, the WNP and Eastern North Pacific (ENP), of gray whales exist in the North Pacific Ocean (LeDuc et al., 2002). The ENP stock and DPS of gray whales was delisted from the ESA. The WNP DPS of gray whales is extremely small and remains listed as endangered under the ESA, depleted under the MMPA, and is considered critically endangered under the IUCN Red List of Threatened Species (Reilly et al., 2008a). The WNP stock/DPS was thought to be extinct, but a small group of 140 gray whales remains (Carretta et al., 2015).

Gray whales occur in shallow (16 to 49 ft [5 to 15 m]) coastal waters of the North Pacific Ocean and adjacent seas, occurring as far south as southern China in the western North Pacific and Mexico in the eastern North Pacific Ocean (Jefferson et al., 2015). Gray whales annually migrate north-south from high latitude feeding grounds to low latitude breeding grounds. Information about the WNP gray whale stock/DPS is not nearly as complete as is information about the eastern stock, but WNP gray whales summer in the Sea of Okhotsk, primarily near Sakhalin Island, and in Pacific waters off Kamchatka and eastern Japan and migrate southward via the Sea of Japan, East China, and South China seas (Meier et al., 2007; Weller et al., 2002). Reilly et al. (2018a) note that recent sightings in Pacific waters off Japan during the migrational period may suggest that WNP gray whales are using those waters as an additional or new migrational route. The breeding and calving grounds for the WNP gray whale are unknown, but Hainan Island in the South China Sea has been suggested as a possible location (Brownell and Chun, 1977). WNP gray whales have been satellite tracked traveling from Russia to America and sighted off North America (Mate et al., 2015; Weller et al., 2012), which may suggest genetic interchange between the two populations of North Pacific gray whales and that at least some members of both populations may share a common winter ground (Swartz, 2018).

Gray whales generally are not deep or long-duration divers. Swartz (2018) noted the maximum dive depth known for gray whales as 557 ft (170 m), and Stewart et al. (2001) reported a maximum duration of 13.25 min for gray whales, although Swartz (2018) reported a longer maximum dive duration of 26 min. Typical dives are to water depths of < 98 ft (30 m), with dives to <33 ft (10 m) most common, and mean dive durations of 2.24 min (Stelle et al., 2008; Stewart et al., 2001). Würsig et al. (1986) noted that during summer, foraging gray whales exhibited dive times as long as 7 min with a mean of 4 min dive durations. Swim speeds during migration average 2.4 to 4.9 kt (4.5 to 9 kph), with pursued gray whaled reaching speeds of 8.64 kt (16 kph) (Jones and Swartz, 2009).

Sparse data exist on the hearing sensitivity of gray whales. Ridgway and Carder (2001) attempted to measure hearing thresholds in a stranded gray whale but were not successful. 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, but this response ceased when the source was moved out of their migration path even though the RLs 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 to 4 kHz (Swartz, 2018). The most common sounds recorded during foraging and breeding are knocks and pulses with 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 SLs for sounds produced by gray whales range between 167 and 188 dB (Frankel, 2009).

- *Humpback Whale (Megaptera novaeangliae)*

The humpback whale is protected under CITES and is considered least concern as a species by the IUCN Red List of Threatened Species (Childerhouse et al., 2008; Reilly et al., 2008f). The worldwide ESA status of the humpback whale has been revised, with 14 worldwide DPSs identified (Figure 3-9). Of the 14 DPSs, only five are now listed under the ESA as threatened or endangered: the Arabian Sea, Cape Verde/Northwest Africa, WNP, and Central America DPSs are listed as endangered while the Mexico DPS is listed as threatened (NOAA, 2016a). NMFS has determined that the remaining nine global DPSs do not currently warrant listing under the ESA and that the protections of the ESA no longer apply to these nine DPSs (NOAA, 2016a). No critical habitat has been established for the humpback whale. Although the SMM (2017) has differentiated Northern and Southern subspecies of humpback whales, since these subspecies are not differentiated at sea or in available population data and information, all information about the humpback whale that follows will be referenced at the species rather than subspecies level.

Only one ESA-listed DPS, the WNP, occurs within the study area for SURTASS LFA sonar (Table 3-1). Although located in close proximity to the western boundary of the study area for SURTASS LFA sonar, the geographically, genetically, and demographically isolated and non-migratory population of humpback whales in the Arabian Sea DPS is centered off the coast of Oman, especially in the Gulf of Masirah and Kuria Muria Islands regions of the western Arabian Sea, where it is known to breed and forage (Bettridge et al. 2015; Minton et al., 2008). This population was historically known to occur in the waters of Pakistan and India, but over 30 years of research surveys have confirmed the continuous, year-round presence of humpback whales in the shallow, nearshore waters of the western Arabian Sea off Oman (Minton et al., 2011), which is not in the study area for SURTASS LFA sonar. Only a very limited and incidental number of humpback whales have been sighted or stranded in the eastern Arabian Sea off Pakistan or western India (Bettridge et al., 2015; Minton et al., 2008); only the waters off western India in this area are located within the study area for SURTASS LFA sonar. Given the well-documented concentration of this DPS in the western Arabian Sea, the Navy concluded that the likelihood of humpback whales from the Arabian Sea DPS being located in the waters of the northwestern most part of the study area was vanishingly small, and thus this DPS has not been included in this BE.

The humpback whale DPSs are based, among other factors, on the locations of humpback whale breeding grounds (Figure 3-10). In the North Pacific Ocean, four breeding grounds have been identified: Central America (Costa Rica, Panama, Guatemala, El Salvador, Honduras and Nicaragua), Mexico (mainland Mexico and Revillagigedos Islands), Hawaii, and the Western North Pacific (Okinawa, Philippines, and a third unknown breeding location in the western North Pacific) (Bettridge et al., 2015; NOAA, 2015b and 2016a). Three breeding areas have been identified in the Indian Ocean: Arabian Sea (where the population is non-migratory), southeast Africa/Madagascar (including the Seychelles Islands), and west Australia (NOAA, 2015b and 2016a). Contrastingly, stocks of humpback whales are identified by geographic areas that include discrete or multiple feeding areas. For instance, in the North Pacific Ocean, stocks of humpbacks include the California-Oregon-Washington (humpbacks that feed in the California-Oregon and Washington-British Columbia feeding areas), Central North Pacific (CNP) (with feeding areas from southeast Alaska to the Alaskan Peninsula), Western North Pacific (feeding areas in

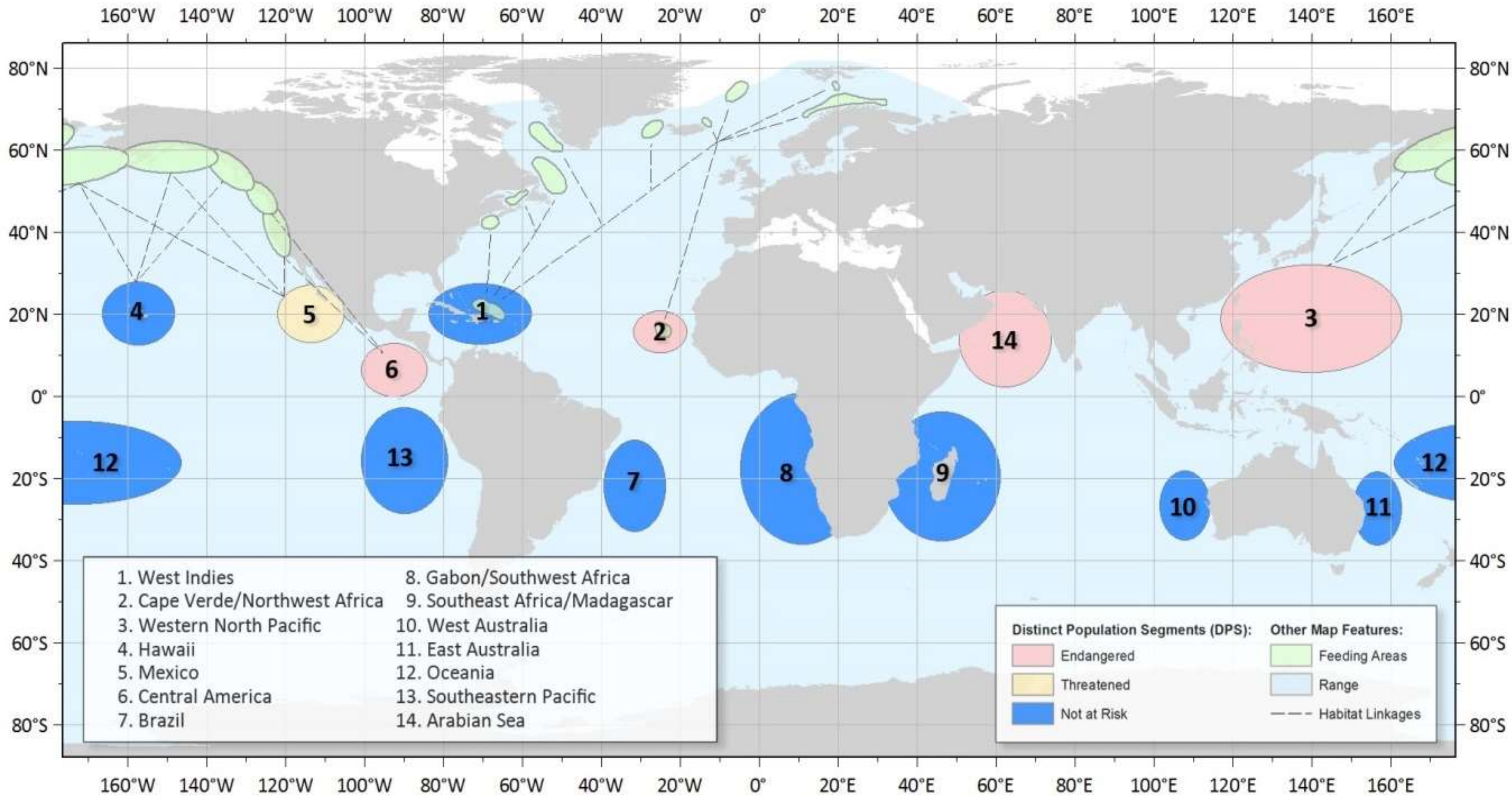

Figure 3-9. The Global Distinct Population Segments (DPSs) of the Humpback Whale Including those DPSs Listed Under the ESA (NOAA, 2016k). These Revisions Would Include Only Two Endangered DPSs, the Arabian Sea and Cape Verde/Northwest Africa, and Two Threatened DPSs, the Western North Pacific and Central America, with all Other DPSs not Proposed for Listing (NMFS, 2016a).

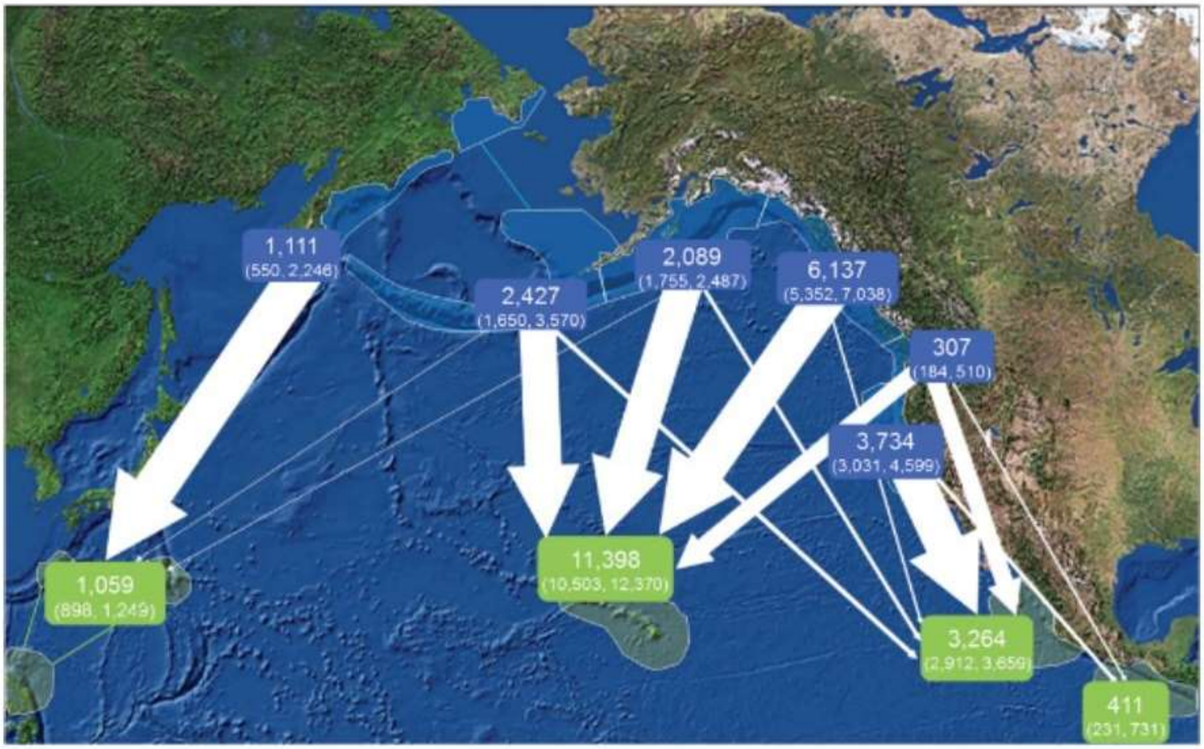

Figure 3-10. Seasonal Migrational Movements of Humpback Whales DPSs and Stocks in the North Pacific Ocean Between Summer Foraging Grounds (Blue) and Winter Breeding Grounds (Green). Estimated Humpback Whale Abundances are Presented by Area (95 Percent Log-Normal Confidence Intervals are given in Parentheses) (Wade et al., 2016).

the Aleutian Islands, the Bering Sea, and Russia), and America Samoa (which feeds in the Southern Ocean along the Antarctic Peninsula) (Carretta et al., 2016). Humpback whales from one DPS may migrate to feed in more than one feeding areas in varying numbers, meaning that animals from one DPS may occur in more than one stock. In the North Pacific Ocean, for example, whales in the Hawaii DPS and CNP stock forage in varying percentages of the DPS or stock in three feeding areas of Alaska during the summer (Figure 3-10).

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). The population of humpback whales in the entire North Pacific Ocean is estimated as 21,808 (CV=0.04) whales (Barlow et al., 2011; Bettridge et al., 2015). In the western and central North Pacific Ocean portion of the study area for SURTASS LFA sonar, the population of the WNP DPS and stock of humpback whales is estimated to include 1,328 individuals (Bettridge et al., 2015), while the abundance of the CNP stock and Hawaii DPS is estimated as 10,103 whales (Calambokidis et al., 2008; Muto et al., 2018). In the eastern Indian Ocean, the population of humpback whales off Western Australia (Western Australia DPS and stock) is estimated to include 13,640 individuals (Bannister and Hedley, 2001).

Humpback whales are distributed throughout the world's oceans and are only absent from high Arctic and some equatorial waters, although they occur only rarely in some parts of their former Pacific range, such as the coastal waters of Korea, and have shown no signs of a recovery in those locations (Gregr, 2000; Gregr et al., 2000). Humpbacks occur both in neritic and pelagic waters, with neritic occurrences particularly during summer on foraging grounds and during winter when they may be found in waters close to islands and reef systems (Clapham, 2018). Except for the humpbacks in the Arabian Sea DPS, humpback whales are considered a highly migratory species that have been documented traveling over 5,292 nmi (9,800 km) one way, which is the longest known migration of any mammal (Stevick et al., 2011). Humpback whales travel to high latitudes in the spring to begin feeding and to the warmer temperate and tropical waters in the winter to calve and breed. Despite this potential for long distance dispersal, there is considerable evidence that dispersal or interbreeding of individuals from different major ocean basins is extremely rare and that whales from the major ocean basins are differentiated by a number of characteristics. Data indicate that not all humpbacks migrate annually from summer feeding to winter breeding sites and that some whales remain in certain areas year-round (Barco et al., 2002; Christensen et al., 1992; Clapham et al., 1993; Murray et al., 2013; Straley, 1999). The small Arabian Sea population of humpback whales is non-migratory, breeding, and foraging in the same region (Bettridge et al., 2015; Pomilla et al., 2014).

Dive times of humpback whales have been recorded from 3 to 4 min in duration (Dolphin, 1987; Strong, 1990). Recently, Burrows et al. (2016) reported dive times that ranged from 7.5 to 9.6 min, with a mean of 6.0 min. Dive times on the wintering grounds can be much longer, with singing humpbacks typically diving between 10 and 25 min in duration (Chu, 1988). Humpback whales dove to depths from 131 to 512 ft (40 to 156 m) during foraging dives (Dolphin, 1988; Goldbogen et al., 2008). 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). During their long-distance migrations, humpback whales swim at speeds ranging from 0.7 to 7.7 kt (1.3 to 14.2 kph) (Cerchio et al., 2016; Chaudry, 2006; Chittleborough, 1953; Gabriele et al., 1996; Guzman and Félix, 2017; Horton et al., 2011; Kennedy et al., 2014). Swim speeds of humpbacks during dive descent range from 2.4 to 3.9 kt (4.5 to 7.2 kph) while speeds on ascending dives were 2.9 to 4.9 kt (5.4 to 9 kph) (Dolphin, 1987).

No direct measurements of humpback whale hearing sensitivity 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 of humpbacks by integrating the humpback basilar membrane position 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 (Houser et al., 2001).

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). Feeding calls were found to have SLs in excess of 175 dB re 1 μPa @ 1 m (Richardson et al., 1995; Thompson, et al., 1986). Humpback whales in the Northwest Atlantic Ocean produce "megaclicks", which are click trains and buzzes with most of their energy below 2 kHz, with relatively low SLs of 143 to 154 dB re 1 μPa @ 1 m (peak-peak) (Stimpert et al., 2007). "Whup" calls are composed of a short AM growl followed by a rapid upsweep from 56 to 187 Hz (Wild and Gabriele, 2014). Additional social sounds have been described that range from 70 Hz to 3.5 kHz, with a mean duration ranging from 0.8 to 16.7 sec (Fournet et al., 2015; 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). Calves produce short, LF sounds (Zoidis et al., 2008). Dunlop et al. (2007) reported 34 types of calls from migrating humpbacks ranging from 30 Hz to 2.4 kHz and between 0.2 and 2.5 sec in duration, with 21 of these call types being incorporated into songs; the median source level of social sounds is 158 dB re 1 µPa (Dunlop et al., 2013).

During the breeding season, males sing long, complex songs with frequencies between 25 Hz and 5 kHz, with mean SLs of ~165 dB re 1 µPa @ 1 m (broadband) (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 humpback whales sing more frequently in the late summer and early fall than previously observed.

- *North Pacific Right Whale (Eubalaena japonica)*

The North Pacific right whale is listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and is classified as endangered as a species under the IUCN Red List of Threatened Species, although the IUCN classifies the Eastern North Pacific (ENP) stock as critically endangered (Reilly et al., 2008). Two stocks or populations of North Pacific right whales have been identified, with the ENP stock encompassing right whales found in the Gulf of Alaska and the Bering Sea while the Western North Pacific (WNP) stock consists of right whales occurring in the Commander Islands, off the coast of Kamchatka, the Kuril Islands, and in the Sea of Okhotsk (Brownell et al., 2001; LeDuc et al., 2012). No overall population estimate for North Pacific right whales is available, but likely, less than 1,000 North Pacific right whales are currently living, as the population of ENP right whales is very small, with only 31 whales estimated (Wade et al, 2011; Muto et al., 2018). The WNP stock, which occurs within the study area for SURTASS LFA sonar, is estimated to include 922 individuals (Best et al., 2001). Critical habitat, comprising a total of 27,756 nmi^2 (95,200 km^2) in area for the North Pacific right whale has been designated in two areas of Alaska's marine waters: southeastern Bering Sea and the northwestern Gulf of Alaska where North Pacific right whales have been observed foraging (NOAA, 2008b).

Since so few North Pacific right whales exist, little information is available about the species. North Pacific right whales regularly occur only in the Sea of Okhotsk and the southeastern Bering Sea with very rare occurrences documented in the waters of the Gulf of Alaska, Sea of Japan (off South Korea), and North Pacific waters around the Ogasawara and Kuril islands and Hokkaido in Japan, as well as offshore Kamchatka (Jefferson et al., 2015; NMFS, 2018d; Sekiguchi et al., 2014). Since 2013, two North Pacific right whales have been reported off Hokkaido (one entangled) and one right whale was documented off South Korea, which was the first observation of this species in the Sea of Japan in 41 years (NMFS, 2018d). No swim speed or dive information is 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 and 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, while the down-up call swept down in frequency for 10 to 20 Hz before it became a typical up call, and the down and constant calls were typically interspersed with up calls (McDonald and Moore, 2002). 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). Munger et al. (2011) reported the SL of North Pacific right whale upcalls to be averaged from 176 to 178 dB re 1 μPa @ 1 m, with a frequency range of 90 to 170 Hz.

- *Sei Whale (Balaenoptera borealis)*

The sei whale is listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and as endangered by the IUCN Red List of Threatened Species (Reilly et al., 2008h). The SMM (2017) has differentiated Northern and Southern subspecies of sei whales. While the Navy recognizes this taxonomy, the subspecies are not differentiated at sea or in the available population data and information. Accordingly, all subsequent information presented herein about the sei whale is referenced only to the species level. The global population for the sei whale has been estimated by the IUCN to include 31,600 individuals (Reilly et al., 2008h) while Jefferson et al. (2015) reported a population as large as 80,000 whales. The population of the Hawaii stock of sei whales is estimated as 391 whales (CV=0.9) (Bradford et al., 2017), while the the North Pacific stock is estimated to include 7,000 whales (Mizroch et al., 2015; Tillman, 1977). The Indian Ocean stock of sei whales is estimated as 13,854 whales (IWC, 1981).

Sei whales occur in temperate, oceanic waters of all world oceans, occurring very uncommonly in neritic waters, the Mediterranean Sea, and in equatorial waters (Horwood, 2018; Jefferson et al., 2015). The sei whale is migratory, seasonally traveling between low latitude calving grounds to high latitude foraging grounds, although these migrations may not be as extensive as that of other mysticetes (Jefferson et al., 2015). Specific breeding grounds are not known for this species, although the waters off northwest Africa have been suggested for the North Atlantic sei whales (Prieto et al., 2014).

Ishii et al. (2017) documented U- and V-shaped dives of foraging sei whales and noted that they dove no deeper than 187 ft (57 m) during the day and to no more than 40 ft (12.2 m) at night, with maximum durations of 12 min. Dive times of sei whales range from 0.75 to 15 min, with a mean duration of 1.5 min (Schilling et al., 1992). When foraging, sei whales make shallow dives of 65 to 100 ft (20 to 30 m), followed by a deep dive up to 15 min in duration (Gambell, 1985). Sei whales are fast swimmers, surpassed only by blue whales (Sears and Perrin, 2018). Swim speeds have been recorded at 2.5 kt (4.6 kph), with a maximum speed of 14.8 kt (27.4 kph) (Brown, 1977; Olsen et al.; 2009). Prieto et al. (2014) reported that the mean swim speeds of satellite-tagged sei whales during migration were 3.3 to 4 kt (6.2 to 7.4 kph) and an “off-migration” speed was measured as 3.2 kt (6 kph). Ishii et al. (2017) measured mean swimming speeds of 1.9 to 2.7 kt (3.6 to 5 kph) for two sei whales.

No direct measurements of sei whale hearing sensitivity exist (Ketten, 2000; Thewissen, 2002). Sei whale vocalizations are the least studied of all the rorquals. Rankin and Barlow (2007) recorded sei whale vocalizations in Hawaii and reported that all vocalizations were downsweeps, ranging from on average from 100.3 to 446 Hz for “high frequency” calls and from 39.4 to 21.0 Hz for “low frequency” calls. In another study, McDonald et al., (2005) recorded sei whales in Antarctica with an average call frequency of 433 Hz. A series of sei whales FM calls have been recorded south of New Zealand with a frequency range of 34 to 87 Hz and a duration of 0.4 to 1.7 sec (Calderan et al., 2014).

3.2.5.1.2 Potentially Occurring Odontocetes

- *False Killer Whale (Pseudorca crassidens)*

False killer whales are classified as least concern (lower risk) by the IUCN. Three populations of false killer whales have been identified in Hawaiian waters, but only the MHI Insular DPS of false killer whales is listed under the ESA as endangered and depleted under the MMPA (NOAA, 2012b). The populations of false killer whales occurring in the insular waters of the Hawaiian Islands, the MHI and Northwestern Hawaiian Islands DPSs, have been shown to be genetically and behaviorally distinct from false killer whales found in oceanic or offshore waters (Chivers et al., 2010; Martien et al., 2011; NOAA, 2012b). The boundaries between the Hawaiian Island populations of false killer whales are complex and overlapping. The areal extent of the MHI Insular DPS of false killer whales is a 39-nmi (72-km) radius around the MHI, with the offshore extent of the DPS' outer boundary connected on the leeward sides of Hawaii Island and Niihau to encompass the offshore movements of MHI Insular DPS false killer whales within that region (Carretta et al., 2015). In comparison to other populations of false killer whales, the MHI Insular DPS is characterized by a very low abundance and very high density, suggesting that either the nearshore habitat used by these whales is highly productive or these whales employ an unique habitat-use strategy that supports a high density of false killer whales (Oleson et al., 2010; Wearmouth and Sims, 2008). Critical habitat has been designated for the MHI Insular DPS of the false killer whale (Figure 3-3) (NOAA, 2018b). The critical habitat for the MHI Insular DPS of false killer whales includes waters from the 148- to 10,499-ft (45-to 3,200-m) depth contours around the MHI from Niihau east to Hawaii; more than 14 Navy and Bureau of Ocean Energy Management areas, such as the Pacific Missile Range Facility offshore ranges and others, are excluded from the false killer whale critical habitat designation due to impacts on national security and eco (NOAA, 2018b).

The global population for the false killer whale is unknown. Estimates of 16,668 whales have been documented in the northwestern 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 whale populations have been estimated as 1,540 whales (CV=0.66) in the Hawaii pelagic population, 617 whales (CV=1.11) in the Northwestern Hawaiian Islands DPS, and 167 whales in the MHI Insular DPS (CV=0.14) (Bradford et al., 2014, 2015, 2018; Carretta et al., 2018). 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 worldwide in tropical to warm temperate zones in deep (> 3,300 ft (1,000 m) 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). In the North Pacific Ocean, false killer whales are well documented in the waters of southern Japan, Hawaii, ETP, and off the U.S. West Coast. In the waters of the Hawaiian Archipelago, false killer whales occur in nearshore (Baird et al. 2008, 2013) and pelagic waters, including waters surrounding Palmyra and Johnston Atolls (Barlow et al., 2008, Bradford and Forney, 2013). 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 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), while deep dives had a mean duration of 269 sec (SD = 189) and a mean maximum depth of 424 ft (129 m) (SD = 185) (Minamikawa et al., 2013), while 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 have an approximate swim speed of 1.6 kt (3 kph), although a maximum swim speed has been documented at 11.9 kt (28.8 kph) (Brown et al., 1966; Rohr et al., 2002).

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 can 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 to 60 kHz and 100 to 130 kHz (Kamminga and van Velden, 1987; Madsen et al., 2004; 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., 2004; Thomas and Turl, 1990).

- *Sperm Whale (Physeter macrocephalus)*

The sperm whale is listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and classified as vulnerable by the IUCN Red List of Threatened Species (Taylor et al., 2008). Jefferson et al. (2015) reported a putative global sperm whale population estimate of 360,000 individuals. The sperm whale stock in the North Pacific Ocean has been estimated to include 102,112 individuals (CV=0.155), while 4,559 sperm whales (CV=0.33) have been estimated for Hawaii stock (Bradford et al., 2017; Muto et al., 2018). The Indian Ocean stock of sperm whale is estimated as 24,446 individuals (IWC, 2016; Perry et al., 1999; Wade and Gerrodette, 1993).

With the largest distributional range of all cetaceans except killer whales, sperm whales are primarily found in deeper (>3,280 ft [1000 m]) polar, temperate, and tropical waters of the world's oceans and Mediterranean Sea (Reeves and Whitehead, 1997). Female sperm whales nearly always inhabit waters >3,281 ft (1,000 m) in depth far from land (Whitehead, 2018). 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 pattern at all, especially in the equatorial waters (Whitehead, 2018). In ocean waters between 40° N and 45° N, female sperm whales with calves often remain on breeding grounds throughout the year, while males migrate between low-latitude breeding areas and higher-latitude feeding grounds (Pierce et al., 2007; Rice, 1989; Whitehead, 2003). In the Northern Hemisphere, "bachelor" groups (males 15 to 21 yr old) generally leave warm waters at the beginning of summer to migrate to feeding grounds and in fall and winter, most bachelors return south, although some may remain in the colder northern waters during most of the year (Pierce et al., 2007). Specific breeding and foraging grounds are not well known for this species.

Sperm whales may make the longest and deepest dives of any mammal, with the maximum-recorded dive reaching 4,921 ft (1,500 m) (Davis et al., 2007), although examination of stomach contents of sperm whales suggests that sperm whales may dive as deep as 10,498 ft (3,200 m) (Clarke, 1976). Foraging dives to depths of 965 to 4,701 ft (294 to 1,433 m) and non-foraging dives to a water depth of 1,640 ft (500 m) were recently measured (Guerra et al., 2017; Joyce et al., 2017). In general, dive durations range between 18.2 to 65.3 min (Watkins et al., 2002). Foraging dives typically last about 30 to 65 min (Joyce et al, 2017; Papastavrou et al., 1989; Wahlberg, 2002), while non-foraging dives of about 30 min were measured (Joyce et al., 2017). Sperm whale's surface speeds generally average 0.7 to 2.2 kt (1.3 to 4 kph), with maximum speeds of about 5.1 kt (9.4 kph) (Jochens et al., 2008; Lockyer, 1997; Watkins et al., 2002; Whitehead, 2018). Dive swim rates range from 2.8 to 5.5 kt (5.2 to 10.1 kph) (Lockyer, 1997).

Audiograms measured from a sperm whale calf suggest a hearing 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 echolocation clicks with energy from less than 100 Hz to 30 kHz (Goold and Jones, 1995; Madsen et al., 2002a; 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 et al., 2002b; 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). Clicks are strongly directional, with SELs measured between 202 and 236 dB (Madsen and Møhl, 2000; Møhl et al., 2000; Møhl et al., 2003; Thode et al., 2002). Møhl (2003) reported that the maximum SL for sperm whale clicks was 236 dB with other calls ranging from 226 to 234 dB. Zimmer et al. (2005) reported SL of the sperm whale's HF sonar component of clicks that are used to search for prey as 229 dB (peak value), while the LF component is apparently used to conveys sound to conspecifics at large ranges and peak frequencies that are depth dependent to over 1,640 ft (500 m). Sperm whales also produce sounds including creaks, squeals, and trumpets as well as codas, which are series of 3 to 20 clicks that last from 0.2 to 2 sec and are social vocalizations (Whitehead, 2003 and 2018).

3.2.5.1.3 Potentially Occurring Pinnipeds

- *Hawaiian Monk Seal (Neomonachus schauinslandi)*

Hawaiian monk seals are listed as endangered under the ESA throughout its range, as endangered under the IUCN Red List of Threatened Species (Littnan et al., 2015), as depleted under the MMPA, and are 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, 2015b). 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 656-ft (200-m) isobath (excluding National

Security Exclusion zones off Kauai, Oahu and Kahoolawe) (NOAA, 2015b). The Hawaii stock of Hawaiian monk seals consists of two subpopulations: Northwest Hawaiian Islands (NWHI) and the Main Hawaiian Islands (MHI) (NMFS, 2018). Since the early 1990s, a small but increasing number of monk seals and an increasing number of annual births have been documented in the MHI (NMFS, 2018). The two subpopulations of Hawaiian monk seals are not isolated from one another, with seals moving between the two subpopulations and island groups (NMFS, 2018e). The subpopulation of Hawaiian monk seals that occurs in the NWHI, which encompasses 80 percent of the overall population, is currently considered stable and possibly increasing, while the MHI subpopulation continues to expand (NMFS, 2018 and 2018d). Six breeding groups within the NWHI subpopulation have been identified: Kure Atoll, Midway Islands, Pearl and Hermes Reef, Lisianski Island, Laysan Islands, and French Frigate Shoals (Littnan et al., 2015). The best available, most current population estimate for the Hawaii stock of Hawaiian monk seals is 1,427 individuals (95 percent confidence limit=1,542) (NMFS, 2018).

Hawaiian monk seals only occur throughout the subtropical waters of the Hawaiian Archipelago and Johnson Atoll (NOAA, 2011b), and may be found in water depths ranging from 3 to 984 ft (1 to 300 m) in shelf, slope, and bank habitats. Hawaiian monk seals come ashore (haul out) daily on a variety of substrates, including sandy beaches, rocky shores, rock ledges, and emergent reefs. Hawaiian monk seals from Kure Atoll, the westernmost atoll in the NWHI, may forage on Hancock Banks, NW of Kure Atoll. Although not a migratory species, Abernathy (1999) and Parrish et al. (2002) reported that Hawaiian monk seals might travel a distance of as much as 216 nmi (400 km) to forage. Hancock Banks are approximately 162 nmi (300 km) northwest of Kure Atoll and are characterized by a single pinnacle that is shallower than 1,476 ft (450 m), which is within the known foraging range for foraging Hawaiian monk seals. In this SEIS/SOEIS, Hawaiian monk seals are considered to potentially range and forage as far west as Hancock Banks, which is located within the Offshore Japan (25 to 40° N) modeling area (Model Area #8) for SURTASS LFA sonar. Hawaiian monk seals exhibit high site fidelity to their natal island (Gilmartin and Forcada, 2009), and pupping only occurs on sandy beaches.

Hawaiian monk seals spend a greater proportion of their time at sea; Wilson et al. (2017a) noted that on average, Hawaiian monk seals spent 49 percent of their time diving, 19 percent on the sea surface, and 32 percent of their time hauled out on land. Hawaiian monk seals appear to exhibit a single dive type, which is a square-shaped, benthic dive pattern that indicates more than 50 percent of the dive time is spent foraging along the seafloor in deeper more offshore waters; most dives (70 percent) occurred during daylight hours (Wilson et al., 2017). This species commonly dives to water depths less than 328 ft (100 m), but dives have been recorded as deep as 984 to 1,805 ft (300 to 550 m) (Parrish et al., 2002; Stewart et al., 2006). Wilson et al. (2017a) reported that Hawaiian monk seals in the MHI dove to water depths from 66 to 98 ft (20 to 50 m). 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 primarily shallow water depths from 33 to 131 ft (10 to 40 m) are typical (Stewart, 2009; Wilson, 2015). Kiraç et al. (2002) reported mean dive times of 6.4 min, while Wilson et al. (2017a) reported mean dive durations of 5.9 min. Swim speed data on the Hawaiian monk seal are sparse. Hawaiian monk seals swim near the bottom almost exclusively while at sea (Parrish et al., 2005 and 2008; Wilson, 2015). Parrish and Abernathy (2006) reported Hawaiian monk seals swimming with a velocity of 3.9 kt (7.2 kph).

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 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).

➢ *Spotted Seal (Phoca largha)*

Spotted or largha seals are classified as a least concern by the IUCN Red List of Threatened Species (Boveng, 2016). The Southern DPS of spotted seals, which consists of breeding concentrations in the Yellow Sea and Peter the Great Bay in the Sea of Japan, is listed as threatened under the ESA and depleted under the MMPA. No critical habitat has been designated for the spotted seal. The global population of the spotted seal is estimated to include 640,000 individuals (Boveng, 2016; Frost and Burns, 2018). 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. Conn et al. (2014) and Muto et al. (2018) estimated 461,625 spotted seals (95 percent CI: 388,732 to 560,348) in the Alaska stock/Bering Sea DPS. 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, 2016; Han et al., 2010; Nesterenko and Katin, 2008).

Spotted seals occur in cold temperate to Arctic waters of the North Pacific and Arctic oceans, including the Yellow Sea, East China Sea, Sea of Japan, Sea of Okhotsk, Bering Sea, and Chukchi Sea; spotted seals occur as far east in the Arctic Ocean as the Mackenzie River Delta and as far west as about 170° E (Boveng, 2016; Jefferson et al., 2015). Spotted seals are found either in open-ocean 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 (Boveng, 2016). The range of spotted seals contracts and expands in association with ice cover, and 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. As the ice cover increases in the northern waters of their range, 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).

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). London et al. (2014) noted that most spotted seal dives were to depths <230 ft (70 m) but dives from 230 to 656 ft (70 to 200 m) were observed primarily during the late winter and spring. Lowry et al. (1994) reported that spotted seals in the Chukchi Sea dove to waters <328 ft (100 m) in depth and that no dives exceeded <10 min in duration. Swim speeds range from 0.2 to 2.8 kt (0.4 to 5.2 kph), with an average speed of 1.2 kt (2.2 kph) have been observed (Lowry et al., 1998).

Spotted seals can hear underwater from 300 Hz to 56 kHz, with best sensitivity between 2 and 30 kHz at a threshold of ~ 55 dB, while in air, spotted seal's hearing sensitivity ranges from 6 Hz to 11 kHz (Sills et al., 2014). Underwater hearing sensitivity in a spotted seal has been measured to 72.4 kHz (Reichmuth et al., 2013). Recently, Cunningham and Reichmuth (2017) tested the ability of several pinniped species to hear high frequency (HF) sounds underwater; the ability of a 4-year old spotted seal to hear underwater sounds from 50 to 180 kHz was measured, with the spotted seal able to detect sounds up to 180 kHz, which was well beyond the limit of their presumed HF hearing capability. Adult spotted seals vocalize in the air and underwater (Frost and Burns, 2018). Underwater vocalization of captive spotted seals increased 1 to 2 weeks before mating and was higher in males than females, with the sounds produced including growls, drums, snorts, chirps, and barks that ranged in frequency from 500 Hz to 3.5 kHz (Richardson et al., 1995).

- *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, 2017). The Western Steller sea lion occurs west of Cape Suckling, Alaska (Loughlin and Gelatt, 2018). As a species, the Steller sea lion is classified as near threatened under the IUCN Red List of Threatened Species, with the Western Steller sea lion classified as endangered (Gelatt and Sweeney, 2016). Under the ESA, only the Western DPS of is listed as endangered under the ESA and depleted under the MMPA. The Western stock/DPS and Asian stock of the Western Steller sea lion occur within the study area for SURTASS LFA sonar. Critical habitat for both species (stocks/DPSs) of Steller sea lions is designated under the ESA in three geographic locations in the North Pacific Ocean, Gulf of Alaska, and the Bering Sea including: 1) Alaska rookeries, haulouts, and associated areas; 2) California and Oregon rookeries and associated areas; and 3) special aquatic areas in Alaska (Shelikof Strait area, Bogoslof area, and Seguam Pass area). Critical habitat designations include terrestrial, aerial, and aquatic habitat zones (NOAA, 1993a). The worldwide population size of Steller sea lions is estimated to be 160,867 (Gelatt and Sweeney, 2016). The Western U.S. stock and DPS (west of Cape Suckling, Alaska) is estimated at 53,303 sea lions (Muto et al., 2018), and the Western Asian stock (Russia to Japan) stock of Steller sea lions has been estimated to include 17,918 individuals (Burkanov, 2017; Muto et al., 2018), for a total Western Steller sea lion population of 71,221 individuals.

Steller sea lions are found in temperate to sub-polar waters and are widely distributed throughout the North Pacific Ocean from Japan/Korea and central California to the southern Bering Sea, including the Sea of Japan and Sea of Okhotsk (Jefferson et al., 2015). The northernmost rookery is found at Seal Rocks in Prince William Sound, Alaska, and the southernmost rookeries are found at Año Nuevo Island in California and Medny Island, in the Commander Islands, Kamchatka (Burkanov and Loughlin, 2007; Loughlin, 2009). Steller sea lions typically occur in coastal to outer continental shelf waters but cross deep oceanic waters in parts of their range (Jefferson et al., 2015; Loughlin and Gelatt, 2018). Steller sea lions are not migratory, but often disperse widely over the North Pacific after the breeding season.

Most dives by pup and juvenile Steller sea lions are of short duration (<1 min) and to shallow water depths (<33 ft [10 m]), although they are capable of diving to the same depths and dive durations as adults (Pitcher et al., 2005). Juvenile and sub-adult Steller sea lions dove to the maximum depth of 1,184 ft (361 m), which was the deepest measurable depth, and for the maximum durations of 4.9 min and 13.2 min, respectively (Rehberg and Burns, 2008). Female Steller sea lions on foraging trips during the breeding season dove to the maximum dive depth of 774 ft (236 m), while the longest dive was longer than 16 min; the average dive depth for foraging females was 97.1 ft (29.6 m) and the average dive time was recorded at 1.8 min (Rehberg et al., 2009). The deepest dive depth to which a Steller sea lion has been recorded diving is 1,391 ft (424 m). 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). A swim speed measured during dives was 2.7 kt (5 kph) (Merrick et al., 1994). Hindle et al. (2010) measured three adult Steller sea lions swimming at transit speeds from 3.5 to 4.5 kt (6.5 to 8.3 kph) and noted that these transit speeds were associated with minimal energetic costs.

Using behavioral methods, Kastelein et al. (2005) measured the underwater audiograms of a male and a female Steller sea lion. Maximum hearing sensitivity in the male Steller sea lion was at 1 kHz for 77 dB RL signals, with the range of best hearing between 1 and 16 kHz, at 10 dB from the maximum sensitivity; the average pre-stimulus responses occurred at low frequency signals (Kastelein et al., 2005). The maximum hearing sensitivity of the female Steller sea lion was 25 kHz for a RL signal of 73 dB RL (Kastelein et al., 2005). The reasons for the differences in hearing capability between the male and female adult Steller sea lions was not known.

Steller sea lions produce sounds both in air and underwater. The underwater sounds produced by Steller sea lions have been described as clicks and growls (Frankel, 2009; Poulter, 1968). The in-air sounds produced by male Steller sea lions, described as belches, growls, snorts, scolds, hisses, and LF roars appear to be part of territorial demonstrations during the breeding season (Kastelein et al., 2005). Females and their pups make in-air communication sounds that are described as bellows and bleats (Loughlin, 2009). No available data exist on seasonal or geographical variation in the sound production of this species.

3.2.5.2 Occurrence and Population Estimates of Marine Mammals in the Study Area for SURTASS LFA Sonar Training and Testing Activities

As the previous species-specific sections have illustrated, marine mammals are not homogeneously distributed throughout the study area for SURTASS LFA sonar training and testing activities. However, to effectively evaluate impacts to marine mammals potentially associated with SURTASS LFA sonar activities, information is not only needed about which marine mammals occur in all regions of the vast study area for SURTASS LFA sonar in the western and central North Pacific and eastern Indian oceans but also about when and how many are found in the study area. A temporal and spatial framework was needed to partition the study area and effective period into manageable components.

Since the behavioral ecology of most marine mammal species is mediated by seasonally driven changes in light, temperature, and associated prey availability, standard seasons have been used as the temporal framework. For this BE, four seasons defined according to the following monthly breakdown have been used:

- Winter: December, January, and February
- Spring: March, April, and May
- Summer: June, July, and August
- Fall: September, October, and November.

This seasonality is based on the Northern Hemisphere. For the part of the study area for SURTASS LFA sonar training and testing that lies in the Southern Hemisphere, austral seasons pertain, which are the reverse of this standard timeframe. Austral winter occurs from June through August while austral summer lasts from December through February.

Deriving a spatial framework for the effect's analysis required consideration of the geographic usage constraints (i.e., coastal standoff range) of SURTASS LFA sonar, the Navy's purpose for conducting SURTASS LFA sonar training and testing activities, and appropriate acoustic and environmental conditions. The Navy devised a spatial framework of 15 representative areas to model SURTASS LFA sonar training and testing activities in the central and western North Pacific and eastern Indian oceans that represent the acoustic regimes and marine mammal species potentially encountered during covered LFA sonar activities (Table 3-6).

Table 3-6. Locations of the 15 Representative Modeling Areas for Covered SURTASS LFA Sonar Training and Testing Activities.

Modeling Area	*Modeling Area Name*	*Location of Modeling Area Center*	*Notes*
1	East of Japan	38° N, 148° E	
2	North Philippine Sea	29° N, 136° E	
3	West Philippine Sea	22° N, 124° E	
4	Offshore Guam	11° N, 145° E	Navy Mariana Islands Testing and Training Area
5	Sea of Japan	39° N, 132°E	
6	East China Sea	26° N, 125° E	
7	South China Sea	14° N, 114° E	
8	Offshore Japan 25° to 40° N	30° N, 165° E	
9	Offshore Japan 10° to 25° N	15° N, 165° E	
10	Hawaii North	25° N, 158° W	Navy Hawaii-Southern California Training and Testing Area
11	Hawaii South	19.5° N, 158.5° W	Navy Hawaii-Southern California Training and Testing Area
12	Offshore Sri Lanka	5° N, 85° E	
13	Andaman Sea	7.5° N, 96° E	
14	Northwest of Australia	18° S, 110° E	
15	Northeast of Japan	52° N, 163° E	

With this spatial and temporal framework in place, deriving the associated marine mammal species and associated population numbers for each model area in each season was required. Marine mammal stocks and DPSs, as appropriate, were defined for each marine mammal species in each of the modeling areas. The potentially occurring marine mammal species, stocks, and DPSs for each modeling area were verified with distributional information and data from published scientific literature; government reports, including NMFS's stock assessment reports (SARs) for U.S. waters; and information from international organizations such as the IUCN and IWC.

Compiling population data and information is challenging for such a vast area as the study area for SURTASS LFA sonar training and testing activities. Yet, density and abundance estimates are a critical component of the effects analysis to estimate risk to marine mammal populations from activities occurring in the marine environment. Population estimates of marine mammals are difficult to obtain, as data must be collected over vast ocean areas on species that spend much of their time submerged beneath the sea surface. To collect sighting data sufficient to derive reasonable abundance or density estimates, however, multiple observations are required, often in areas that are not easily accessible (e.g., far offshore). For most cetacean species, abundances and densities are estimated using line-transect surveys or mark-recapture studies (e.g., Barlow, 2010; Barlow and Forney, 2007; Calambokidis et al., 2008), which usually provide a single abundance or density estimate for each species observed across broad geographic areas, such as waters within the U.S. EEZ off Hawaii. Though the single abundance or density provides a good average estimate of the total number of individuals in a specified area, it does not provide information on the species distribution or concentrations outside that limited area nor does it provide abundance or density estimate for other seasons that were not surveyed.

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/stock in all model areas or seasons. Despite the greater availability of abundance data, population-level data on potentially occurring marine mammals are very scarce for some of the 15 modeling areas, particularly in the Indian Ocean. Overall, no single source of abundance or density data exists in even one model area for every species, stock, or season. The process for developing abundance and density estimates for every species/stock in the 15 potential model areas in all seasons was a multi-step procedure that first utilized data with the highest degree of fidelity. In modeling areas where no abundance estimates were available for a stock, a surrogate abundance was needed. A surrogate abundance estimate derived for a similar oceanographic area for the same species or a conspecific was used. Abundance estimates were derived using the best available information and data (Table 3-7), including the most up-to-date NMFS draft SARs for U.S. Pacific waters (e.g., Carretta et al., 2018, and Muto et al., 2018).

Population-level data for the most marine mammal stocks in the Indian Ocean are scarce, as few areas of this vast ocean expanse have been surveyed for marine mammals. While the meager Indian Ocean abundance data were used when available, a more comprehensive approach was needed to estimate abundances and densities for the marine mammal stocks or DPSs occurring in the Indian Ocean model areas for SURTASS LFA sonar. Therefore, abundances for most stocks were estimated using surrogate data for the same species in a marine area with similar oceanographic and ecological characteristics.

Densities are estimates of the number of individuals in a species or stock that are present per unit area, typically per square nautical mile or kilometer. Statistically, density estimation of marine species, in particular marine mammals and sea turtles, is very difficult because of the large amount of survey effort (at-sea observation) required, often spanning multiple years and covering vast expanses of ocean, to obtain an adequate amount of data upon which to estimate densities. Line-transect sighting surveys (the most common type of “distance sampling” used for density derivation) typically focus on characterizing the probability of visually detecting an animal or group of animals so that the number of individuals missed during the observations can be quantified and estimated. The result of line-transect-based density estimation generally provides a single average density estimate for each species (unless stratification is performed), for the entire area covered by the survey, and usually is constrained to a specific timeframe or season. The estimate does not provide information on the species distribution or concentrations within that area and does not estimate density for other timeframes/seasons that were not surveyed. However, even given these provisos, line-transect based density estimates typically provide the best available density estimates.

Table 3-7. Marine Mammal Species, Stocks, Distinct Population Segments (DPSs), Abundances, and Density Estimates by Season as well as the Associated References for the 15 Proposed SURTASS LFA Modeling Areas in the Central and Western North Pacific Ocean and Indian Ocean Study Area for SURTASS LFA Sonar Training and Testing Activities (Reference Index Shown at End of Table).

Marine Mammal Species	Stock/DPS Name[18]	Abundance	Abundance References	Density (animals per km^2)[19]				Density Reference(s)
				Winter	Spring	Summer	Fall	
Model Area #1: East of Japan								
Blue whale	WNP	9,250	1, 5, 6	0.00001	0.00001		0.00001	1, 2, 3, 4
Fin whale	WNP	9,250	1, 7			0.0002	0.0002	1
Humpback whale	WNP stock and DPS[20]	1,328	8			0.00036	0.00036	4, 39
North Pacific right whale	WNP	922	9	0.00001[21]	0.00001			
Sei whale	NP	7,000	1, 10	0.00029	0.00029	0.00029	0.00029	11
Sperm whale	NP	102,112	12, 13	0.00123	0.00123	0.00123	0.00123	11
Model Area #2: North Philippine Sea								
Blue whale	WNP	9,250	1, 5,6	0.00001	0.00001		0.00001	1, 2, 3, 4
Fin whale	WNP	9,250	1, 7	0.0002	0.0002			1
Humpback whale	WNP stock and DPS	1,328	8	0.00089	0.00089		0.00089	4, 39
North Pacific right whale	WNP	922	9	0.00001	0.00001			
Sperm whale	NP	102,112	12, 13	0.00123	0.00123	0.00123	0.00123	11
Model Area #3: West Philippine Sea								
Blue whale	WNP	9,250	1, 5, 6	0.00001	0.00001		0.00001	1, 2, 3, 4
Fin whale	WNP	9,250	1, 7	0.0002	0.0002			1
Humpback whale	WNP stock and DPS	1,328	8	0.00089	0.00089		0.00089	4, 14

18 NP=North Pacific; WNP=Western North Pacific; CNP=Central North Pacific; WP=Western Pacific; ECS=East China Sea; IND=Indian; NIND=Northern Indian; SIND=Southern Indian

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

20 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 stocks under the MMPA and as DPSs under the ESA. Thus, the humpback whale and other species are listed by stock and DPS (DPS/stock) where relevant.

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 3-7. Marine Mammal Species, Stocks, Distinct Population Segments (DPSs), Abundances, and Density Estimates by Season as well as the Associated References for the 15 Proposed SURTASS LFA Modeling Areas in the Central and Western North Pacific Ocean and Indian Ocean Study Area for SURTASS LFA Sonar Training and Testing Activities (Reference Index Shown at End of Table).

Marine Mammal Species	*Stock/DPS Name*[18]	*Abundance*	*Abundance References*	*Density (animals per km²)*[19]				*Density Reference(s)*
				Winter	*Spring*	*Summer*	*Fall*	
Sperm whale	NP	102,112	12, 13	0.00123	0.00123	0.00123	0.00123	11
Model Area #4: Offshore Guam								
Blue whale	WNP	9,250	1, 5, 6	0.00001	0.00001		0.00001	1, 2, 3, 4, 11
Fin whale	WNP	9,250	1, 7	0.00001	0.00001		0.00001	2, 3
Humpback whale	WNP stock and DPS	1,328	8	0.00089	0.00089		0.00089	4, 14
Sei whale	NP	7,000	1, 10	0.00029	0.00029		0.00029	11
Sperm whale	NP	102,112	12, 13	0.00123	0.00123	0.00123	0.00123	13
Model Area #5: Sea of Japan								
Fin whale	WNP	9,250	1, 7	0.0009	0.0009		0.0009	2, 3
North Pacific right whale	WNP	922	9	0.00001	0.00001			
Western North Pacific gray whale	WNP stock/ Western DPS	140	5, 15	0.00001	0.00001	0.00001	0.00001	
Sperm whale	NP	102,112	12, 13	0.00123	0.00123	0.00123	0.00123	11
Spotted seal	Southern stock and DPS	3,500	16, 17, 18	0.00001	0.00001	0.00001	0.00001	
Model Area #6: East China Sea								
Fin whale	ECS	500	1, 7, 19	0.0002	0.0002	0.0002	0.0002	1
North Pacific right whale	WNP	922	9	0.00001	0.00001			
Western North Pacific gray whale	WNP stock/ Western DPS	140	5	0.00001	0.00001		0.00001	
Sperm whale	NP	102,112	12, 13	0.00123	0.00123	0.00123	0.00123	11
Spotted seal	Southern stock and DPS	1,000	16	0.00001	0.00001	0.00001	0.00001	
Model Area #7: South China Sea								
Fin whale	WNP	9,250	1, 7	0.0002	0.0002		0.0002	1

Table 3-7. Marine Mammal Species, Stocks, Distinct Population Segments (DPSs), Abundances, and Density Estimates by Season as well as the Associated References for the 15 Proposed SURTASS LFA Modeling Areas in the Central and Western North Pacific Ocean and Indian Ocean Study Area for SURTASS LFA Sonar Training and Testing Activities (Reference Index Shown at End of Table).

Marine Mammal Species	*Stock/DPS Name*[18]	*Abundance*	*Abundance References*	*Density (animals per km^2)*[19]				*Density Reference(s)*
				Winter	*Spring*	*Summer*	*Fall*	
Humpback whale	WNP stock and DPS	1,328	8	0.00036	0.00036		0.00036	4, 14
North Pacific right whale	WNP	922	9	0.00001	0.00001			
Western North Pacific gray whale	WNP stock/ Western DPS	140	5	0.00001	0.00001		0.00001	
Sperm whale	NP	102,112	12, 13	0.0012	0.0012	0.0012	0.0012	11
Model Area #8: Offshore Japan/Pacific (25° to 40° N)								
Blue whale	WNP	9,250	1, 5, 6	0.00001	0.00001		0.00001	1, 2, 3, 4
Fin whale	WNP	9,250	1, 7			0.0001	0.0001	1
Humpback whale	WNP stock and DPS	1,328	8			0.00036	0.00036	4, 39
Sei whale	NP	7,000	1, 10		0.00029	0.00029	0.00029	11
Sperm whale	NP	102,112	12, 13	0.0022	0.0022	0.0022	0.0022	20
Hawaiian monk seal	Hawaii	1,427	21	0.00001	0.00001	0.00001	0.00001	
Model Area #9: Offshore Japan/Pacific (10° to 25° N)								
Blue whale	WNP	9,250	1, 5, 6	0.00001	0.00001		0.00001	1, 2, 3, 4
Fin whale	WNP	9,250	1, 7	0.00001	0.00001			2, 3
Humpback whale	WNP stock and DPS	1,328	8	0.00036	0.00036		0.00036	4, 14
Sei whale	NP	7,000	1, 10	0.0029			0.0029	11
Sperm whale	NP	102,112	12, 13	0.00222	0.00222	0.00222	0.00222	20
Model Area #10: Hawaii North								
Blue whale	CNP	133	22	0.00005	0.00005		0.00005	22
Fin whale	Hawaii	154	22	0.00006	0.00006		0.00006	22
Sei whale	Hawaii	391	22	0.00016	0.00016		0.00016	22

Table 3-7. Marine Mammal Species, Stocks, Distinct Population Segments (DPSs), Abundances, and Density Estimates by Season as well as the Associated References for the 15 Proposed SURTASS LFA Modeling Areas in the Central and Western North Pacific Ocean and Indian Ocean Study Area for SURTASS LFA Sonar Training and Testing Activities (Reference Index Shown at End of Table).

Marine Mammal Species	Stock/DPS Name[18]	Abundance	Abundance References	Density (animals per km^2)[19]				Density Reference(s)
				Winter	Spring	Summer	Fall	
False killer whale	Main Hawaiian Islands Insular stock and DPS	167	23, 24	0.0008	0.0008	0.0008	0.0008	25, 26,
Sperm whale	Hawaii	4,559	22	0.00158	0.00158	0.00158	0.00158	27
Hawaiian monk seal	Hawaii	1,427	21	0.00004	0.00004	0.00004	0.00004	21, 28
Model Area #11: Hawaii South								
Blue whale	CNP	133	22	0.00005	0.00005		0.00005	22
Fin whale	Hawaii	154	22, 23	0.00006	0.00006		0.00006	22
Sei whale	Hawaii	391	22	0.00016	0.00016		0.00016	22
False killer whale	Main Hawaiian Islands Insular stock and DPS	167	23, 24	0.0008	0.0008	0.0008	0.0008	25, 26
Sperm whale	Hawaii	4,559	22	0.00131	0.00131	0.00131	0.00131	27
Hawaiian monk seal	Hawaii	1,427	21	0.00004	0.00004	0.00004	0.00004	21, 28
Model Area #12: Offshore Sri Lanka								
Blue whale	NIND	3,691	29	0.00004	0.00004	0.00004	0.00004	28
Fin whale	IND	1,846	29	0.00001	0.00001	0.00001	0.00001	28
Sei whale	NIND	9,176	29, 30	0.00141	0.00045	0.00045	0.00095	28
Sperm whale	NIND	24,446	29, 30	0.00129	0.00118	0.00126	0.00121	28
Model Area #13: Andaman Sea								
Blue whale	NIND	3,691	29	0.00003	0.00003	0.00003	0.00003	28
Fin whale	IND	1,846	29	0.00001	0.00001		0.00001	28
Sperm whale	NIND	24,446	29, 30	0.00109	0.00099	0.00107	0.00105	28
Model Area #14: Northwest of Australia[22]								

22 Seasons are presented following Northern Hemisphere monthly breakdowns for consistency. That is, winter for this model area would be austral summer in the Southern Hemisphere where this model area is located.

Table 3-7. Marine Mammal Species, Stocks, Distinct Population Segments (DPSs), Abundances, and Density Estimates by Season as well as the Associated References for the 15 Proposed SURTASS LFA Modeling Areas in the Central and Western North Pacific Ocean and Indian Ocean Study Area for SURTASS LFA Sonar Training and Testing Activities (Reference Index Shown at End of Table).

Marine Mammal Species	*Stock/DPS Name*[18]	*Abundance*	*Abundance References*	*Density (animals per km^2)*[19]				*Density Reference(s)*
				Winter	*Spring*	*Summer*	*Fall*	
Blue whale	SIND	1,657	31, 32		0.00003	0.00003	0.00003	28
Fin whale	SIND	38,185	33, 34	0.00001	0.00099	0.00128	0.00121	28
Sei whale	SIND	13,854	35	0.00001	0.00001	0.00001	0.00001	28
Sperm whale	SIND	24,446	30	0.00096	0.00087	0.00097	0.00092	28
Model Area #15: Northeast of Japan								
Blue whale	WNP	9,250	1, 5, 6	0.00001	0.00001		0.00001	1, 2, 3, 4
Fin whale	WNP	9,250	1, 7		0.0002	0.0002	0.0002	1
Humpback whale	WNP stock and DPS	1,328	8		0.000498	0.000498	0.000498	28
North Pacific right whale	WNP	922	39			0.00001	0.00001	
Sei whale	NP	7,000	1, 10		0.00029	0.00029		11, 36
Western North Pacific gray whale	WNP stock/ Western DPS	140	5			0.00001	0.00001	
Sperm whale	NP	102,112	12, 13	0.0017	0.0022	0.0022	0.0022	20
Western Steller sea lion	Western/Asian stocks/Western DPS	71,221	23, 37	0.00001	0.00001	0.00001	0.00001	

TABLE 3-7 CITED LITERATURE REFERENCES

1. Tillman, 1977
2. Ferguson and Barlow, 2001
3. Ferguson and Barlow, 2003
4. LGL, 2008
5. Carretta et al., 2015
6. Stafford et al., 2001
7. Mizroch et al., 2009
8. Bettridge et al., 2015
9. Best et al., 2001
10. Mizroch et al.,2015
11. Fulling et al., 2011
12. Kato and Miyashita, 1998
13. Allen and Angliss, 2015
14. Acebes et al., 2007
15. Carretta et al., 2016
16. Han et al., 2010
17. Nesterenko and Katin, 2008
18. Boveng et al., 2009
19. Evans, 1987
20. LGL, 2011
21. NMFS, 2018
22. Bradford et al., 2017
23. Muto et al., 2018
24. Bradford et al., 2018
25. Bradford et al., 2014, 2015
26. Oleson et al., 2010
27. Forney et al., 2015
28. DoN, 2018
29. IWC, 2016
30. Wade and Gerrodette, 1993
31. Jenner et al., 2008
32. McCauley and Jenner, 2010
33. Branch and Butterworth, 2001
34. Mori and Butterworth, 2006
35. IWC, 1981
36. Murase et al., 2014
37. Burkanov, 2017
38. Calambokidis et al., 2008
39. Miyashita and Kato, 1998

When deriving density estimates for the 15 model areas, direct estimates from line-transect (sighting) surveys that occurred in or near the representative model areas were utilized first (e.g., Barlow, 2006). However, density estimates were not always available for each species/stock in all model areas. Ideally, density data would be available for all species for all areas in all seasons. In areas where survey data are limited, or non-existent, known or inferred habitat associations must be used to predict densities. When density estimates derived from line-transect or other surveys were not available in a model area, then density estimates from a region with similar oceanographic/environmental characteristics were extrapolated to that model area and species/stock. For example, the ETP has been extensively surveyed for marine mammals, with those survey data providing a comprehensive understanding of marine mammals in tropical and warm-temperate oceanic waters (Ferguson and Barlow, 2001, 2003; Wade and Gerrodette, 1993). Data from such well-studied areas are the foundation for population estimates of data-poor species of the western North Pacific and Indian Oceans, where stock and population-level data are scarce. 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. This is often the case for pilot whales, beaked whales, and pygmy and dwarf sperm whales (*Kogia* spp.). Density estimates are often available for these species-groups rather than the individual species in some model areas. 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 0.00001 animals per square kilometer (animals/km^2) was used to reflect the very low potential of occurrence in a specific SURTASS LFA sonar model area for data sparse species, such as the North Pacific right whale.

Density estimates for the potentially occurring marine mammal stocks in the modeled areas located in the Indian Ocean were derived from one source (Table 3-7), the Navy's Marine Species Density Database (NMSDD) (DoN, 2018). The NMSDD provides a systematic method for selecting the most appropriate density value for each species' stock in a given area and season. The NMSDD integrates direct survey sighting data with distance sampling theory to convolve designed-based density estimates, stratified-designed based density estimates, estimates from density spatial models, and habitat-suitability index models to result in spatially and seasonally explicit densities for most marine mammal species. Currently, the NMSDD is not publicly available since proprietary geospatial modeling data are included in the database, for which the Navy has established proprietary data sharing agreements. However, products of the Navy's database have been made available to the public, such as the *U.S. Navy Marine Species Density Database Phase III for the Hawaii-Southern California Training and Testing Study Area, NAVFAC Pacific Technical Report* (DoN, 2017c). This report has been used to support Navy environmental compliance documentation for Pacific testing and training areas. The citations for the sighting surveys or other data upon which the densities were derived in the NMSDD have been cited and incorporated herein when appropriate. Densities derived from the NMSDD for the potentially occurring marine mammal stocks were averaged over each modeled area during each season.

Predictions of potential environmental impacts are largely influenced by the accuracy with which the marine mammal abundances and densities are estimated for the selected geographic area and season, which is indicated with measures of uncertainty associated with the population estimates**.** Uncertainty in abundance and density estimates is typically expressed by the coefficient of variation (CV), which is calculated using standard statistical methods and describes the uncertainty as a percentage of the population mean. A CV can range upward from zero, indicating no uncertainty, to higher values approaching one that connotes a higher level of uncertainty about the population estimate. For example, a CV of 0.85 (or 85 percent) would indicate high uncertainty in a given population estimate.

When the CV exceeds 1.0, the estimate is very uncertain. Another method for characterizing uncertainty is a confidence interval (CI). This expression typically relates to the 95 percent probability that the “true” population value falls within the given CI range of values. Therefore, a CI with a wider range of values (e.g., 150 to 550) indicates that there is greater uncertainty about the true value than a CI with a smaller range of values (e.g., 300 to 400). When sufficient information about seasonal movements was available for marine mammal stocks in model areas or ocean regions, that seasonality is reflected in the density estimates. Density estimates were truncated to no more than five decimal places (Table 3-7).

4 ENVIRONMENTAL BASELINE

The purpose of the environmental baseline of existing conditions in the western and central North Pacific and eastern Indian oceans is for context on how other anthropogenic activities have affected the environment. This baseline provides the foundation against which effects potentially associated with the use of SURTASS LFA sonar during training and testing activities may be evaluated.

4.1 Physical Habitat

Use of SURTASS LFA sonar for training and testing activities entails the periodic deployment of acoustic transducers and receivers into the water column from ocean-going ships. SURTASS LFA sonar is deployed from ocean surveillance ships that are U.S. Coast Guard-certified for operations and operate in accordance with all applicable federal, international, and U.S. Navy rules and regulations related to environmental compliance, especially for discharge of potentially hazardous materials. SURTASS LFA sonar ships comply with all requirements of the CWA and APPS and associated discharge standards. SURTASS LFA sonar vessel movements are not unusual or extraordinary and are in line with routine operations of seagoing vessels. Therefore, no discharges of pollutants regulated under the APPS or CWA would result from the use of the sonar systems nor would unregulated environmental effects associated with the operation of SURTASS LFA sonar vessels occur.

4.2 Sound in the Environment

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

The potential impacts of SURTASS LFA sonar training and testing activities on the overall oceanic ambient noise level are reviewed in the following contexts:

- Recent reports on ambient sound levels in the world’s oceans;
- Operational parameters of the SURTASS LFA sonar system;
- Contribution of SURTASS LFA sonar training and testing activities to oceanic noise levels relative to other human-generated sources of oceanic noise; and
- Cumulative impacts from LFA sonar training and testing activities concurrent with other anthropogenic sources.

4.3 Oceanic Ambient Noise Environment

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).

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).

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).

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 contribute to the overall ocean soundscape, including noise from oil and gas exploration, seismic airgun activity, and renewable energy sources (e.g., wind farms) (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).

The impacts that climate change may 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).

A subject of scientific concern is ocean acidification and its potential impact on ocean noise due to changes in the LF acoustic absorption coefficient. 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).

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

When deployed and transmitting, transmissions from SURTASS LFA sonar training and testing activities will temporarily add to the ambient noise level in the frequency band (100 to 500 Hz) in which LFA sonar 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 LF signal with a duty cycle of less than 20 percent and an average pulse length of 60 sec. In the proposed activity, the Navy would transmit SURTASS LFA sonar for up to a total of 496 hours in years 1-4 and 592 hours in year 5 and into the foreseeable future. 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 x 10^{12} Joules of acoustic energy into the marine environment each year (Joules/yr); seismic airguns were estimated to contribute 3.9 x 10^{13} Joules/yr; and mid-frequency military sonar was estimated to contribute 2.6 x 10^{13} Joules/yr (Hildebrand, 2005). Scaling the calculations in Hildebrand (2005) to account for the proposed transmission hours, the contribution from 496 hours of LFA sonar transmissions would be 2.0 x 10^{11} Joules/yr and the contribution from 592 hours of LFA sonar transmissions would be 2.3 x 10^{11} Joules/yr. The percentage of the total anthropogenic acoustic energy budget added by LFA sonar source transmissions is estimated to be 0.29 and 0.34 percent, respectively, for years 1-4 and year 5 and beyond (Hildebrand, 2005). Therefore, within the existing ocean environment, the potential for accumulation of noise due to the intermittent transmission of SURTASS LFA sonar during training and testing activities is considered negligible.

5 EFFECTS OF THE PROPOSED ACTION ON CRITICAL HABITAT AND LISTED SPECIES

Of the potential stressors associated with the Navy's proposed use of SURTASS LFA sonar during training and testing activities, the only stressor that is likely to affect critical habitat or ESA-listed sea turtle, marine and anadromous fish, or marine mammal species is the transmission of LFA sonar signals. The described characteristics of the signals transmitted by the LFA sonar system and its operational parameters are considered in determining the potential for effects on ESA-listed marine species or critical habitat.

Potential effects to marine animals from the use of SURTASS LFA sonar during training and testing activities should be assessed in the context of the basic operational characteristics of the system:

- SURTASS LFA sonar equipped vessels are U.S. Coast Guard certified for operations. In addition, these vessels would operate in accordance with all applicable federal and U.S. Navy rules, regulations, and discharge standards related to environmental compliance. SURTASS LFA sonar vessel movements are not unusual or extraordinary and are in line with routine operations of seagoing vessels. Therefore, there should be no unregulated environmental impacts from the SURTASS LFA sonar vessels.
- At-sea activities would be temporary in nature. SURTASS LFA sonar training and testing activities would transmit a maximum of 496 transmission hours in years 1 to 4 and 592 transmission hours in Years 5 to 7 and continuing into the foreseeable future, regardless of the number of SURTASS LFA sonar equipped vessels.
- The maximum duty cycle (ratio of sound "on" time to total time) of SURTASS LFA sonar during training and testing activities is 20 percent. However, the typical duty cycle, based on historical LFA operational parameters since 2003, is nominally 7.5 to 10 percent. That is, 7.5 to 20 percent of the time, SURTASS LFA sonar could be transmitting while 80 to 92.5 percent of the time SURTASS LFA sonar would not be transmitting, thus adding no sound into the water.
- Wavetrains last between 6 and 100 sec with an average length of 60 sec.
- The typical LFA sonar signal is not a constant tone. The duration of each continuous frequency sound transmission is no longer than 10 sec.
- The source frequency is between 100 and 500 Hz.
- The SL of an individual source projector of the SURTASS LFA sonar array is approximately 215 dB re 1 µPa @ 1 m SPL or less. As measured by SPL, the sound field of the array can never be higher than the SL of an individual source projector.

The types of potential effects on marine species from SURTASS LFA sonar training and testing activities can be broken down into several categories:

- **Non-auditory effects:** Non-auditory effects include direct acoustic effects on tissue, indirect acoustic effects on tissue, and acoustically mediated bubble growth within tissues from supersaturated dissolved nitrogen gas. These types of effects have the potential to cause (1) resonance of the lungs/organs, (2) tissue damage, and (3) mortality.
- **Auditory effects**: Auditory effects 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 is considered auditory tissue injury that causes irreparable damage (Southall et al., 2007). Temporary threshold shift (TTS) is a lesser effect 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 damage occurs, so TTS is not considered an injury (Richardson et al., 1995)

- **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 use 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 effect, 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. As a result, during auditory masking, an animal may not be able to escape predacious attack, locate food, or find a reproductive partner.
- **Physiological stress**: Exposure to underwater sound may evoke a physiological response (e.g., release of 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 (NRC, 2005).

The potential for effects to ESA-listed species 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 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. The potential for effects to CH was considered principally within the context of the addition of sound energy to the marine environment while SURTASS LFA sonar is transmitting during training and testing activities. SURTASS LFA sonar transmissions represent a vanishingly small percentage of the overall annual underwater acoustic energy budget.

5.1 Potential Effects to ESA Critical Habitat

Critical habitat has been designated in the study area for SURTASS LFA sonar for the Hawaiian monk seal and the false killer whale's MHI Insular DPS (Table 3-2). The marine neritic and pelagic portions of these species' or DPS's CH have been evaluated for effects in association with SURTASS LFA sonar training and testing activities. The biological and/or physical features of the designated marine CH of these species or DPSs are a combination of characteristics most relevant to the conservation of each species or DPS. The key biological and/or physical features of the marine neritic and pelagic CH for the two species/DPSs under consideration include:

- Habitat areas:
    - sheltered nearshore marine areas for pupping and nursing
    - island-associated marine waters that are offshore, productive, and of varied water depths

- Prey: abundant and available prey in sufficient density, diversity, distribution, and abundance to support foraging;
- Bathymetry: marine waters up to 1,640 ft (500 m) in depth for juvenile and adult foraging;
- Water quality: free of pollutants or harmful substances;
- Anthropogenic
    - low human disturbance
    - sound levels of anthropogenic noise that would not significantly impair false killer whales' habitat use or occupancy.

5.1.1 Potential Effects on the Critical Habitat of the Hawaiian Monk Seal

The physical or biological features of the Hawaiian monk seal CH that support the species' life history needs include 1) areas with characteristics preferred by monk seals for pupping and nursing; 2) shallow, sheltered nearshore marine areas preferred by monk seals for pupping and nursing; 3) marine areas up to 1,640 ft (500 m) in depth preferred by juvenile and adult monk seals for foraging; 4) areas with low levels of human disturbance; 5) marine areas with adequate prey quantity and quality; and 6) significant shore areas used by monk seals for hauling out, resting, or molting (NOAA, 2015c).

Nearly all of the CH for the Hawaiian monk seal lies within the coastal standoff range for SURTASS LFA sonar, wherein the sound field generated by LFA sonar cannot exceed 180 dB re 1 µPa (rms) (SPL) within 12 nmi (22 km) of any emergent land. A small area of the monk seal's critical habitat at Penguin Bank extends beyond the coastal standoff range (Figure 3-2). However, per the CZMA consultation with the State of Hawaii for SURTASS LFA sonar, the Navy agreed not to use SURTASS LFA sonar in waters of Penguin Bank to the 600-ft (183-m) isobath, which is also the boundary of the Penguin Bank OBIA for SURTASS LFA sonar. Thus, the CH of the Hawaiian monk seal beyond the coastal standoff range at Penguin Bank would not be exposed to SURTASS LFA sonar training and testing activities.

5.1.1.1 Potential Effects to the Physical Features of Hawaiian Monk Seal Critical Habitat

Use of SURTASS LFA sonar entails the periodic deployment of acoustic transducers and receivers into the water column from ocean-going ships. The SURTASS HLA and LFA sonar VLA are deployed from ocean surveillance ships that are U.S. Coast Guard-certified for operations and that operate in accordance with all applicable Federal, international, and U.S. Navy rules and regulations related to environmental compliance, particularly for discharge of potentially hazardous materials. In particular, SURTASS LFA sonar ships comply with all requirements of the CWA and APPS. SURTASS LFA vessel movements are not unusual or extraordinary and are part of routine operations of seagoing vessels. Therefore, no discharges of pollutants regulated under the APPS or CWA would result from the operation of the SURTASS LFA sonar vessels or systems. In no way can the use of the SURTASS LFA sonar systems affect the physical processes or bathymetry of the waters in which the sonar would be used. Thus, the physical CH features of water quality or bathymetry would not be affected by SURTASS LFA sonar activities.

Deployment and use of the SURTASS LFA sonar systems results in no physical alterations to the marine environment other than the addition of ephemeral sound energy to the oceanic ambient noise environment only when the sonar is transmitting, which may affect but not adversely affect prey such as marine fish but not marine invertebrates. When deployed and transmitting, transmissions from SURTASS LFA sonar during training and testing activities would temporarily add to the ambient noise environment in the frequency band (100 to 500 Hz) in which LFA sonar operates, but the effect on the overall noise levels in the ocean would be minimal. Anthropogenic sources of ambient noise that are most likely to contribute to increases in ambient noise levels are commercial shipping, offshore oil and gas exploration and drilling, and naval and other uses of sonar (ICES, 2005; MMC, 2007). Hildebrand (2005) concluded that increases in anthropogenic oceanic sound sources most likely to contribute to increased noise in order of magnitude are commercial shipping, offshore oil and gas exploration and development, and naval and other sonar. The addition of even a small percentage to the ambient noise environment of the ocean would have no effect on the relevant physical features of the designated critical habitat. The Navy concludes that SURTASS LFA sonar training and testing activities may affect one physical feature of CH but would not adversely affect the physical features of CH designated for the Hawaiian monk seal.

5.1.1.2 Potential for Effects to the Biological Features of Hawaiian Monk Seal Critical Habitat

The remaining potential for CH effects associated with SURTASS LFA sonar training and testing activities would be to biological features of the habitat, namely to the availability and density of prey and the masking of important acoustic cues by the transmitted LFA sonar signals. Although most of the Hawaiian monk seal's prey would not be affected by SURTASS LFA sonar transmissions, fish may be affected by exposure to LFA sonar transmissions, but only if they are within close proximity (<0.54 nmi [<1 km]) to the transmitting sonar source. The Navy's analysis indicates a minimal to negligible potential for an individual fish to experience non-auditory or auditory effects or a stress response from exposure to SURTASS LFA sonar transmissions. A low potential exists for minor, temporary behavioral responses or masking effects to an individual fish when LFA sonar is transmitting, but no potential is estimated for fitness level consequences to fish stocks or DPSs. Since it is highly unlikely that a significant percentage of any fish stock would be in sufficient proximity during LFA sonar transmissions to experience such effects, there is minimal potential for LFA sonar to affect fish stocks. Thus, although exposure to SURTASS LFA sonar activities may affect fish prey species, no adverse effects are reasonably expected on the availability of prey fishes for the Hawaiian monk seal as the result of exposure to SURTASS LFA sonar during training and testing activities.

5.1.2 Potential Effects on the Critical Habitat of the MHI Insular DPS of False Killer Whales

One physical or biological feature of the designated critical habitat has been defined as being essential for the conservation of the MHI Insular DPS of false killer whales: island-associated marine habitat (NOAA, 2018b). Four characteristics support the critical habitat feature of island-associated marine habitat:

1. adequate space for movement and use within the continental shelf and slope habitat;
2. prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth;
3. waters free of pollutants of a type and amount harmful to MHI Insular false killer whales; and
4. sound levels that would not significantly impair false killer whales' use or occupancy (NOAA, 2018b).

In most areas of the waters surrounding the MHI, the coastal standoff range for SURTASS LFA sonar (12 nmi [22 km] from the shoreline of the MHI) is located closer to shore than the outer boundary of the CH for the MHI Insular DPS of the false killer whale, which is the 10,499-ft (3,200 m) isobath (Figure 3-3). Thus, SURTASS LFA sonar RLs would not exceed 180 dB SPL (rms) in waters of the coastal standoff range

(< 12 nmi from shore). Nearly 40 percent of the CH is located outside the coastal standoff range for SURTASS LFA sonar. As noted above, no SURTASS LFA sonar activities would not be conducted in the waters over Penguin Bank to the extent of the 600 ft (183 m) depth contour.

5.1.2.1 Potential Effects on the Critical Habitat Physical/Biological Features of MHI Insular DPS of False Killer Whales

Overall, the use of SURTASS LFA sonar for training and testing activities in Hawaiian waters where CH for the MHI Insular DPS for false killer whales has been designated may affect the primary constituent elements of this DPS's CH but would not reasonably be expected to have any adverse effects. Only the SURTASS and LFA sonar arrays are deployed into the marine environment during training and testing activities. With the exception of underwater sound production, no aspect of training and testing activities would reasonably be expected to affect the spatial use of false killer whales. As a result, the use of SURTASS LFA sonar for training and testing activities in Hawaiian waters would not reasonably be expected to have any effect on the physical characteristics of the false killer whale CH since the spatial availability nor sound levels in the continental shelf and slope habitat would be significantly affected.

Only one biological characteristic of the MHI Insular DPS of false killer whale CH is defined, that of prey availability (large pelagic fish and squid) of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth of false killer whales. The Navy has determined that no mortality of marine invertebrates such as squid is reasonably expected to occur from exposure to LFA sonar training and testing activities nor are population level effects likely. Thus, squid prey would not be affected by SURTASS LFA sonar training and testing activities. Marine fishes, however, may be affected by exposure to LFA sonar transmissions, but only if they are located within close range (<0.54 nmi [<1 km]) to the transmitting LFA sonar source. The Navy's analysis indicates a minimal to negligible potential for an individual fish to experience non-auditory or auditory effects or a stress response from exposure to SURTASS LFA sonar transmissions. A low potential exists for minor, temporary behavioral responses or masking effects to an individual fish when LFA sonar is transmitting, but no potential is estimated for fitness level consequences to fish stocks. Since it is highly unlikely that a significant percentage of any prey fish stock would be in sufficient proximity during LFA sonar transmissions to experience such effects, there is minimal potential for LFA sonar to affect prey fish stocks of false killer whales. Thus, no adverse effects are reasonably expected on the quantity, quality, and availability of prey fishes as the result of exposure to SURTASS LFA sonar training and testing activities. Accordingly, SURTASS LFA sonar training and testing activities would not significantly affect the biological characteristic of prey availability of the MHI Insular DPS of the false killer whale's designated CH.

SURTASS LFA sonar is deployed from ocean surveillance ships that are U.S. Coast Guard-certified for operations and operate in accordance with all applicable federal, international, and U.S. Navy rules and regulations related to environmental compliance, especially for discharge of potentially hazardous materials. SURTASS LFA sonar vessels comply with all requirements of the CWA and the Convention, and their vessel movements are not unusual or extraordinary and are part of routine operations of seagoing vessels. Therefore, no discharges of pollutants regulated under the APPS or CWA would result from SURTASS LFA sonar training and testing activities nor would unregulated environmental effects from SURTASS LFA sonar training and testing activities occur.

The transmission of LF sound is the one stressor associated with SURTASS LFA sonar training and testing activities that could possibly impact the physical supporting characteristics of spatial availability and sound levels in the island-associated marine environment of the false killer whale. Portions of the designated CH of the MHI Insular DPS of false killer whales are located within the coastal standoff range for SURTASS LFA sonar training and testing activities wherein the power level of LFA sonar transmissions would be limited, while about 40 percent of the CH lies beyond the spatial extent of the coastal standoff range.

When deployed and transmitting, transmissions from SURTASS LFA sonar would temporarily add to the ambient noise level in the frequency band (100 to 500 Hz) in which LFA sonar transmits, but the effect on the overall noise levels in the ocean would be minimal. With HF/M3 monitoring and associated LFA sonar shutdown protocol in areas outside the coastal standoff zone, false killer whales would be detected before entering the LFA mitigation zone and LFA sonar transmissions would be suspended before whales could be exposed to a sound field greater than 180 dB (rms). The overall hearing sensitivity of false killer whales ranges between 2 to 115 kHz, with best sensitivity found between 16 and 24 kHz, and their echolocation clicks are centered around 40 kHz (Kloepper et al., 2010; Yuen et al., 2005). Therefore, the frequencies produced by SURTASS LFA sonar are outside the known hearing range of false killer whales and are additionally well below their frequencies of best hearing sensitivity and echolocation.

The Navy's conclusion of the potential effect associated with exposure to training and testing activities using SURTASS LFA sonar on CH of the MHI Insular DPS of false killer whales is that the primary constituent elements of the CH may be affected but not adversely affected. Some aspects of two supporting characteristics of the biological and physical features of the CH may be affected ephemerally by training and testing activities but no lasting effects on the features of the CH are reasonably anticipated.

5.2 Potential Effects to ESA-Listed Marine Species

5.2.1 Potential Effects to ESA-listed Sea Turtle Species

Although it is known that sea turtles can hear LF sound (Lavender et al., 2014; Martin et al., 2012), limited information is available on their behavioral and physiological responses to underwater LF sound. Very few studies exist on the potential effects of underwater sound on sea turtles and most of the available research examined the effects of sounds of much longer duration or of different types (e.g., seismic airgun) than LFA sonar signals (McCauley et al., 2000). 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). To address this lack, a working group organized under the ANSI Committee S3, Subcommittee 1, Animal Bioacoustics, developed sound exposure guidelines for fish and sea turtles (Popper et al., 2014).

The lack of information on sea turtle's hearing sensitivity is confounded by a lack of population data for sea turtles in the open ocean. The best available population estimates (abundances) for all sea turtle species are underestimates as they nearly always are nesting counts of females when they come ashore to nest and lay their eggs. The 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 from their open ocean distribution. Nearly all species of sea turtles occur in low numbers over most of their ranges, resulting in greatly and widely dispersed distributions in the open ocean. Coupled with low numbers dispersed over enormous geographic areas is the additional complexity of some sea turtle's lifestages, such as the leatherback and olive ridley turtles, which spend their entire lives dispersed widely in pelagic waters, while the early lifestages of other sea turtle species spend only 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.

5.2.1.1 Non-auditory Effects

No data are available on the potential for LF sound to cause non-auditory injury in sea turtles. Direct injury to sea turtles from exposure to SURTASS LFA sonar is unlikely because of relatively lower peak pressures and slower rise times of LFA sonar signals compared to 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.

5.2.1.2 Auditory Effects

No studies have been conducted on hearing loss in any sea 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 to 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) from LFA sonar.

In *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)*, an auditory weighting function and an exposure function in sound exposure level (SEL) were developed to estimate onset TTS and PTS (DoN, 2017a). Both functions estimate the most sensitive hearing of sea turtles at a frequency of approximately 170 Hz, with sensitivity decreasing rapidly at frequencies above and below. For SURTASS LFA sonar operating at frequencies between 100 and 500 Hz, the most protective calculations would utilize auditory weighting and thresholds at 170 Hz. Therefore, the threshold for onset TTS is 200 dB re 1 μPa^2-sec and onset PTS is 220 dB re 1 μPa^2-sec and would be weighted by 0 dB (DoN, 2017a). To calculate the distance at which onset TTS and onset PTS might occur from exposure to SURTASS LFA sonar, the length of a nominal LFA transmission (60 sec) must be considered. If the assumption is made that all RLs are at the same sound pressure level (SPL) RL (i.e., the animal and vessel remain at the same distance and depth from each other for an entire minute), the thresholds are lowered by approximately 18 dB ($10 \times \log_{10}[60 \text{ sec}] = 17.8$). This results in SPL thresholds for onset TTS and onset PTS of 182 dB re 1 µPa and 202 dB re 1 µPa, respectively. Based on simple spherical spreading (i.e., TL based on $20x\log_{10}[\text{range}\{m\}]$), sea turtles would need to be within 143 ft (44 m) or 14 ft (4 m), respectively, for the duration of an entire 60-sec LFA transmission to experience onset TTS or onset PTS.

For sea turtles to experience auditory impacts, they would need to swim at approximately 3 kt (5.6 kph) for the 60-sec signal of the SURTASS LFA sonar, to match its speed. This speed is faster than average swim speeds of sea turtles (Chapter 3), but within the range of their fastest swim speeds. However, the HF/M3 active sonar mitigation measure is able to detect sea turtles within the 180 dB re 1 µPa mitigation zone (a range of approximately 0.54 nmi [1 km]). Thus, it is unlikely that a sea turtle would remain within 143 ft (44 m) of the LFA sonar for an entire 60-sec signal without being detected to experience TTS. It is even more unlikely that a turtle would be within 14 ft (4 m) of the LFA sonar to experience PTS.

5.2.1.3 Behavioral Change

Behavioral responses of sea turtles 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 of 86 observed turtles (or 57 percent) 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.

Watwood et al. (2016) tagged green sea turtles in Port Canaveral, Florida to monitor their movements during a mid-frequency, pier-side submarine sonar test. No significant long-term displacement was exhibited, though the authors note that Port Canaveral is an urban habitat and turtles may be less likely to respond than naive populations. Popper et al. (2014) estimated the probability for behavioral impacts to be low at all distances from LF sonar. Given the best available data from airgun exposures, a behavioral response threshold of 175 dB re 1 µPa SPL rms based on seismic data was developed by the Navy and NMFS (DoN, 2017a). This RL could occur at a distance of approximately 1 nmi (2 km) from the SURTASS LFA sonar.

5.2.1.4 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.

5.2.1.5 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.

5.2.1.6 Overview of Potential Effects on Sea Turtles

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 difficult to conduct (NMFS, 2012), but available information suggests that there is a low to moderate potential for impacts to occur (Table 5-1). DoN (2017a) developed an auditory weighting function and an exposure function to estimate onset TTS and PTS as 200 dB re 1 µPa^2-sec and 220 dB re 1 µPa^2-sec, respectively. As discussed above, a sea turtle would need to remain within 143 ft (44 m) or 14 ft (4 m), respectively, for the entire 60-sec duration of an LFA sonar transmission to experience onset of TTS or onset of PTS. This would require a sea turtle to swim at approximately 3 kt (5.6 kph) for the duration of the 60-sec signal, which is faster than their average swim speeds, without being detected by the HF/M3 active sonar mitigation measure. The best estimate of a threshold for behavioral response (175 dB re 1 µPa SPL rms) is based on airgun exposure data (DoN, 2017a); this RL could occur at a distance of approximately 1 nmi (2 km) from the transmitting SURTASS LFA sonar, which is within the LFA mitigation zone.

Table 5-1. Sea Turtle Exposure Thresholds for Low Frequency Sonar (DoN, 2017a; Popper et al., 2014).

Type of Animal	*PTS*	*TTS*	*Masking*	*Behavior*
Sea turtles	220 dB re 1 µPa^2-sec (weighted)	200 dB re 1 µPa^2-sec (weighted)	(N) Low (I) Low (F) Low	175 dB re 1 µPa SPL rms

(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)

Given these thresholds, the probability of occurrence for TTS is low and PTS is extremely low. No evidence exists that sea turtles use sound to communicate or capture prey, so if any hearing loss were to occur, the potential for an important biological function to be affected is likely limited.

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 exposed to SURTASS LFA transmissions in a modeling site. Given that the majority of sea turtles encountered in the oceanic areas in which LFA sonar is proposed to be used 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 use 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 and traveling at a speed of three to four knots, the potential for impacts from exposure to LFA sonar is considered negligible. To summarize, exposure to SURTASS LFA sonar transmissions may affect but is not expected to adversely affect ESA-listed sea turtle species or DPSs.

5.2.2 Potential Effects to ESA-listed Marine and Anadromous Fish Species

The ANSI Sound Exposure Guideline technical report developed sound exposure guidelines for fishes in which they identified three types of fishes depending on how they might be affected by underwater sound (Popper et al., 2014). The categories include fishes with no swim bladder or other gas chamber (e.g., sharks); 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 (e.g., channel catfish). DoN (2017c) extended these categories to include one more type of fishes: those with a swim bladder involved in hearing and having high-frequency hearing sensitivity (up to 110 kHz). Data suggest that most species of marine fish either lack a swim bladder (e.g., sharks and flatfishes) or have a swim bladder not involved in hearing and can only detect sounds below 1 kHz. Some marine fishes (clupeiforms) with a swim bladder involved in hearing can detect sounds to about 4 kHz (Colleye et al., 2016; Mann et al., 1997 and 2001). One subfamily of clupeids, Alosinae, can detect high- and very high-frequency sounds (i.e., frequencies from 10 to 100 kHz, and frequencies above 100 kHz, respectively), although auditory thresholds at these higher frequencies are elevated and the range of best hearing is still in the LF range (below 1 kHz) similar to other fishes. Even though the potentially occurring ESA-listed marine and anadromous fish species only fall into two of the categories, information on potential effects to all fishes is presented herein.

All fishes with a swim bladder involved in hearing are most sensitive to sound since they can detect particle motion and pressure. These guidelines are based on sound pressure levels, which are the best available data. However, it is recognized that particle motion stimulates the otolith organs and is the fundamental element in hearing for fishes (Popper and Hawkins, 2018).

5.2.2.1 Non-auditory Effects

A few fish species were tested in captive or laboratory settings for non-auditory injuries (e.g., barotrauma, hemorrhaging or rupturing of organs or tissues) when exposed to SURTASS LFA sonar signals and seismic airguns, neither source, despite being very intense (Kane et al., 2010; Popper et al., 2007; Popper et al., 2005; Song et al., 2008). In all fishes tested, 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 2017 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. Non-impulsive sound sources (e.g., sonar, acoustic modems, and sonobuoys) have not been known to cause direct injury or mortality to fish under conditions that would be found in the wild (Halvorsen et al., 2012; Kane et al., 2010; Popper et al., 2007). Potential direct injuries (e.g., barotrauma, hemorrhage, or rupture of organs or tissue) from non-impulsive sound sources, such as sonar, are unlikely because of slow rise times, lack of a strong shock wave such as that associated with an explosive, and relatively low peak pressures.

5.2.2.2 Auditory Effects

A number of studies have examined the impacts of high-intensity sound on the sensory hair cells of the ear, but the most relevant studies 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, but hearing appeared to return to, or close to, normal within about 24 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. 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 sonar sound result in unrecoverable hearing loss in rainbow trout; 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 2017 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. Considering the signal durations of these exposures, 324 and 648 seconds, results in cumulative sound exposure levels of 218 and 220 dB re 1 μPa^2-sec, respectively (Kane et al., 2010; Popper et al., 2007). In addition, exposure of fishes with a swim bladder involved in hearing to LF sonar at a SPL of 195 dB re 1 μPa for 324 sec (cumulative sound exposure level of 215 dB re 1 μPa^2-sec) resulted in TTS (Halvorsen et al., 2013). As a conservative measure, the threshold for TTS from exposure to LF sonar for all fish hearing groups with a swim bladder was rounded down to a cumulative SEL of 210 dB re 1 μPa^2-sec (DoN, 2017c).

To receive an exposure that would exceed the thresholds of 210 dB SEL_{cum}, an individual fish would need to be within (3.3 ft (1 m) of an LFA projector (SL of 215 dB re 1 μPa at 1 m) for more than 2 sec or within the general proximity of the array (<0.54 nmi [<1 km] where the RL is 180 dB rms) 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, the sensory hair cells of fishes can regenerate, unlike in marine mammals where hair cell loss is permanent (Smith et al., 2006).

5.2.2.3 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[23] 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"[24] 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 addition to the studies incorporated by reference, fishes exposed to low-frequency vessel noise had varying responses. Juvenile Ambon damselfish and European eels showed slower reaction times and lacked startle responses to predatory attacks during both simulated and actual predation experiments during exposures to vessel noise (Simpson et al., 2015; Simpson et al., 2016). In contrast, larval Atlantic cod showed a stronger anti-predator response and were more difficult to capture during simulated predator attacks (Nedelec et al., 2015).

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 would result in behavioral responses that would not normally be encountered in the wild 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 the impacts described here are measurable responses. However, none of these responses rises 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

23 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.

24 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.

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 SPL rms 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. The potential exists 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.

5.2.2.4 Masking

No data exist on masking in 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 the authors 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 assessed 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). The potential exists for temporary masking to occur within the frequency range of 100 to 500 Hz during LFA sonar transmissions (nominal duration of 60 sec), but with a maximum duty cycle of 20 percent, any masking that occurred would be minimal.

5.2.2.5 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 gallons [67 liters]) 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 remain within proximity (<0.54 nmi [<1 km]) of the transmitting LFA sonar, which is unlikely since the sonar array and vessel are moving through the ocean.

5.2.2.6 Overview of Potential Effects on Fishes

Given the studies of sound exposure to fishes, the potential for effects 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 DoN (2017c) to account for the signal duration of exposure and add fishes with high-frequency hearing sensitivity, shows that the probability of an effect is low to moderate and would require fishes to be within close proximity (<0.54 nmi [<1 km]) of the transmitting LFA sonar (Table 5-2). The potential is minimal to negligible for an individual fish to experience non-auditory impacts, auditory impacts, or a stress response. The potential is low for minor, temporary behavioral responses by or masking of an individual fish to occur when LFA sonar is transmitting and there is no potential for fitness level consequences. Since it is highly unlikely that even a minimal part of any fish stock or DPS would be in sufficient proximity to the LFA sonar source while it is transmitting to experience potential auditory, non-auditory, or stress responses, the potential for SURTASS LFA sonar to affect fish stocks is low. Thus, exposure to SURTASS LFA sonar transmissions may affect but is not expected to adversely affect those potentially occurring ESA-listed fish stocks or DPSs.

Table 5-2. Summary of Fish Exposure Thresholds for Low Frequency Sonar (DoN, 2017a; Popper et al., 2014).

Type of Fish	Recoverable Injury	TTS	Masking	Behavior
Fish: No swim bladder	>218 dB SEL_{cum}	NC	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low
Fish: Swim bladder not involved in hearing	>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}	210 dB SEL_{cum}	(N) Moderate (I) Low (F) Low	>197 dB SPL_{rms}
Fish: Swim bladder involved in hearing and high-frequency hearing sensitivity	NC	210 dB SEL_{cum}	NC	NC

(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); NC=no criteria

5.2.3 Potential Effects to ESA-listed Marine Mammal Species

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, 2011, 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 sounds sources or may be pertinent to the assessment of impacts associated with SURTASS LFA sonar. A quantitative analysis of the potential effects on marine mammals from exposure to LFA sonar is included in a subsequent section of this BE.

5.2.3.1 Non-auditory Effects

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 were provided in previous documentation for SURTASS LFA sonar (DoN, 2007, 2012, 2017b) and related conclusions are incorporated by reference herein.

No new data have emerged to contradict any of the assumptions or conclusions in previous LFA documentation, especially the conclusion that SURTASS LFA sonar transmissions are not expected to cause gas bubble formation or strandings, particularly those of beaked whales. No strandings have occurred coincident to SURTASS LFA sonar in more than sixteen years of its use, and no research indicates that strong avoidance reactions to LFA sonar would occur that would increase the risk of gas bubble formation.

5.2.3.2 Auditory Effects

One potential effect associated with 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 threshold shift and the level, duration, and frequency of the stimulus (DoN, 2017a; NMFS, 2016). These studies are typically conducted such that threshold shifts of 6 dB represent the upper limit of noise exposure. None of these studies has 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.

In addition to impacts on hair cells measured as threshold shifts, studies have shown that very large temporary threshold shifts can result in neural degeneration, resulting in auditory injury. Kujawa and Liberman (2009) found that noise exposures that produced a TTS of 40 dB, measured 24-hr post-exposure, resulted in loss of afferent nerve synapses and cochlear neurons in mice. Similar impacts were demonstrated in guinea pigs, where a TTS of approximately 50 dB, measured 24 hr post-exposure, resulted in neural degeneration (Lin et al., 2011). This observed neural degeneration is an auditory injury that will cause loss of hearing sensitivity, though it occurs under exposure conditions that result in high levels of TTS (40 to 50 dB measured 24 hours after exposure).

The best available data are used for the analysis of potential auditory impacts and, when necessary, protective 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, 2017b) are incorporated by reference herein. Houser (2017) reviewed the development of auditory weighting functions for marine mammals, the primary use of which has been to predict and prevent noise-induced hearing loss.

NMFS (2018f) provided guidance for assessing the impacts of anthropogenic sound on marine mammals under their regulatory jurisdiction, which includes whales, dolphins, seals, and sea lions. The guidance specifically defines hearing groups, develops auditory weighting functions, and 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 hearing groups of marine mammals were defined (NMFS, 2018f):

- 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 (DoN, 2017a; NMFS, 2018f). 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 5-1). These weighting functions are applied to individual sound received levels to reflect the susceptibility of each hearing group to noise-induced threshold shifts, which is not the same as the range of best hearing.

NMFS (2018f) defined acoustic threshold levels at which PTS is predicted to occur for each 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 hearing group (Figure 5-1; Table 5-3), 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 5-3).

5.2.3.3 Behavioral Change

The primary potential impact on marine mammals from exposure to LFA sonar is behavioral responses, which do not necessarily constitute significant changes in biologically important behaviors. 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

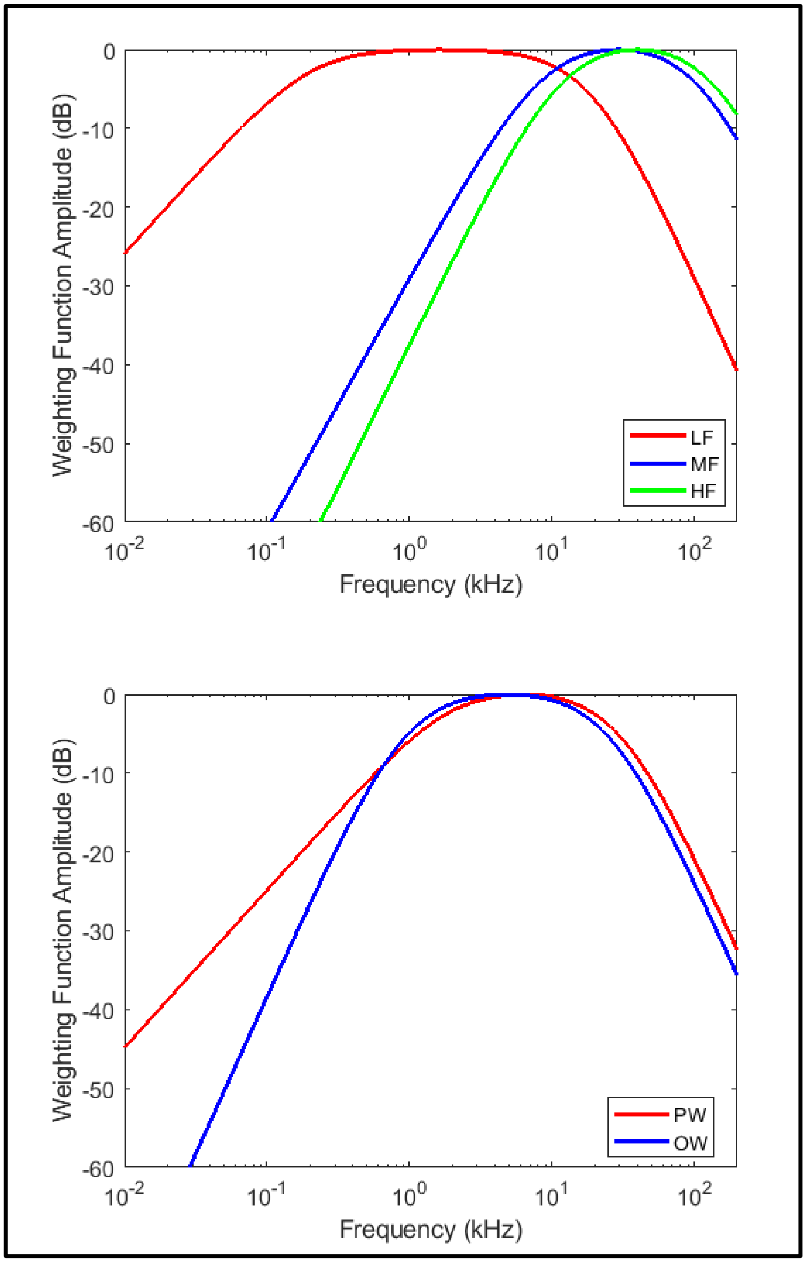

Figure 5-1. Auditory Weighting Functions for Cetaceans (Top Panel: LF, MF, and HF Species) and Pinnipeds (Bottom Panel: PW, OW) (NMFS, 2018f).

individuals can lead to population-level consequences and affect 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). Even though much of the research and information summaries that follow are not specific to ESA-listed marine mammals, all information on behavioral .

Table 5-3. PTS and TTS Acoustic Threshold Levels for Marine Mammals Exposed to Non-impulsive Sounds (NMFS, 2018f).

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 of any marine mammals have been presented to provide a thorough overview of behavioral changes.

An example of the amount of data needed to link a disturbance with an animal's health and how that may affect vital rates that would result in population-level consequences can be seen in a study of southern elephant seals (New et al., 2014). Southern elephant seals return to the same haul-out location twice a year after foraging trips, allowing animals to be sedated for health assessments and instruments to be attached to the animals and recovered after a foraging trip for at-sea measurements. Having such long-term access to the same animals is highly unusual in marine mammal research, but such individualized measurements that help inform linkages between behavioral responses and populations.

Several review papers have been published in recent years that summarize the research that has occurred on potential effects of noise on wildlife. Shannon et al. (2016) conducted a systematic and standardized review of the scientific literature published from 1990 to 2013 on the effects of anthropogenic noise on both terrestrial and aquatic wildlife. Their review found that 37 percent of studies focused on birds and 28 percent focused on aquatic mammals, including marine mammals. A vast majority (81 percent) of the research has been conducted in North America or Europe, with a rapid increase in the volume of published, peer-reviewed articles since 2010. In evaluating 242 papers, 88 percent reported a statistically measured biological response to noise exposure (i.e., statistics determined that the response was outside what would be considered normal variation and was in fact a differential response), but only a small number investigated impacts to population persistence (survival, reproductive fitness), community interactions (predator-prey), and ecosystem services (pollination).

Another systematic literature review (370 papers) and analysis (79 studies, 195 data cases) found that behavioral response in cetaceans was best explained by the interaction between sound source type (continuous, sonar, or seismic/explosion) and hearing group (Gomez et al., 2016). Sound levels received by the animal were not part of the model best explained by the data, demonstrating that more severe behavioral responses were not consistently associated with higher RL, but that the type of source transmitting the acoustic energy was a key factor, highlighting the importance of context of exposure in impact analysis. Finally, Southall et al. (2016) summarized the suite of recent field experiments studying cetacean responses to simulated or actual active military sonars in the 1 to 8 kHz frequency range. Several of these studies are discussed later, but a common theme is the context-dependent nature of behavioral responses (e.g., Friedlaender et al., 2016; Goldbogen et al., 2013b; Miller et al., 2014b).

The Low Frequency Sound Scientific Research Program (LFS SRP) in 1997 to 1998 provided important results and insights regarding how baleen whales responded to 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 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 and Fristrup, 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 transmitting at source levels of 170 to 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, 2012 and 2017 SEISs for SURTASS LFA sonar (DoN, 2001, 2007, 2012, 2017b), which 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 5-2).

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 (Figure 5-2). The steepness of the curve, termed the risk transition sharpness parameter, is defined as 10 for LFA sonar.

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. None have used a LF (<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 that are presented herein for awareness. Southall et al. (2016) 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 MF sonar signals. Blue whales exposed to simulated mid-frequency sonar showed complex, though brief, avoidance responses (Goldbogen et al., 2013a). 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-

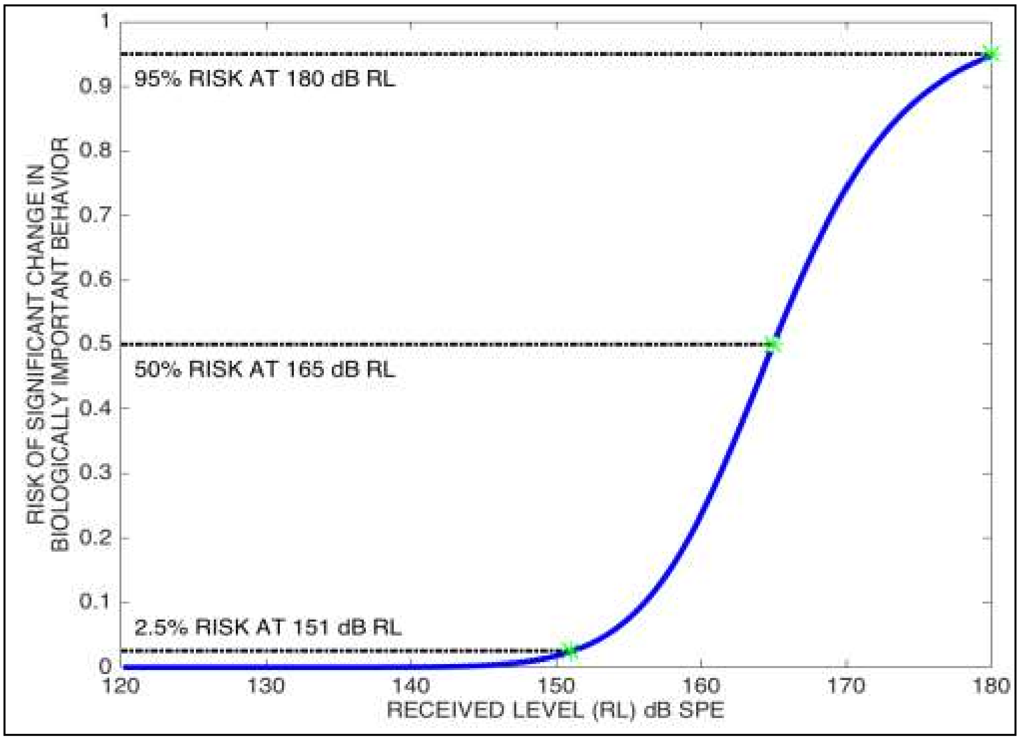

Figure 5-2. Risk Continuum Function for SURTASS LFA Sonar Analysis that Relates the Risk of Significant Change in Biologically Important Behavior to Received Levels in Decibels, Single Ping Equivalent (SPE).

water dives. Body orientation and horizontal displacement away from the source were additional responses. The addition of information on the water column and prey fields as explanatory variables explained approximately five times more of the variability in blue whale behavior (Friedlaender et al., 2016). When changes in prey fields were considered, blue whales had greater responses to pseudo-random noise, a unique stimulus in their environment, than they did to MF sonar, to which they may be habituated.

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 to 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 change point 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., 2014b). 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 at received levels from 73 to 158 dB re 1µPa.

Curé et al. (2016) also found stronger responses by sperm whales to killer whale vocalizations and 1 to 2 kHz sonar upsweeps than the 6-7 kHz sonar signals. However only playbacks of killer whale vocalizations produced grouping behavior, an indication of predator detection. Thus, the actual signal structure was shown to be an important predictor of response, more so than received sound level. This study also demonstrated the value of referencing response strength to the response to a known biologically important signal (i.e., killer whales).

Two minke whales were exposed to simulated naval sonar in the 1 to 4 kHz frequency range (Kvadsheim et al., 2017). The first animal was exposed to 1.3 to 2.0 kHz upsweeps at a maximum source level of 214 dB re 1µPa at 1m. This whale began to respond at a received level of 83 dB re 1 µPa with a brief change in diving behavior and later responded at a received level of 156 dB re 1 µPa by increasing its speed from approximately 2.2 to 11.2 miles per hour (mph) (1 m/s to 5 m/s) and moving in a more linear direction, directly away from the sonar source, which was classified as an '8' on the Southall et al. (2007) severity scale (Sivle et al., 2015). The second whale was presented with a complex series of sweeps and tone between 3.5 and 4.05 kHz with a maximum source level of 210 dB re 1µPa at 1m (Kvadsheim et al., 2017). This whale began avoiding the source and swimming away in a more linear fashion at a received level of 149 dB re 1µPa, but it did not increase its speed.

Vocalizing minke whales were tracked with the hydrophone array at the U.S. Navy Barking Sands training range off Kauai, HI (Martin et al., 2015). The mean number of animals within the 3,780 km^2 training range was estimated as 3.64 before training, 2.81 whales during training but without MF sonar transmissions, 0.69 whales during MF sonar transmissions, and 4.44 whales following training activities. It is not known if the decrease was due to whales leaving the area or simply an alternation of their acoustic behavior.

Additional peer-reviewed papers have been published considering the impact of LF sound on marine mammals. Risch et al. (2012) documented reduction in humpback whale vocalization concurrent with transmissions of the low-frequency Ocean Acoustic Waveguide Remote Sensing (OAWRS) system, at distances of 108 nmi (200 km) from the source. The LF pulses recorded in Stellwagen Bank NMS had a bandwidth of approximately 50 Hz, duration of 1 sec, and mean center frequencies of 415, 734, and 949 Hz (Risch et al., 2012). The OAWRS source appears to have affected more whales, by producing a greater response with a lower sound source level, than reported from the Phase III of the Low Frequency Sound Scientific Research Program LFS SRP, even though OAWRS had a lower RL (88 to 110 dB re 1 µPa) than the LFA signal. Gong et al. (2014) assessed the effects of the OAWRS transmissions on calling rates on Georges Bank and determined constant vocalization rates of humpback whales, with a reduction occurring before the OAWRS system began transmitting. Risch et al. (2014) pointed out that the results of Risch et al. (2012) and Gong et al. (2014) are not contradictory, but rather highlight the principal point of their original paper that behavioral responses depend on many factors, including range to source, RL above background noise level, novelty of signal, and differences in behavioral state.

Humpback whale foraging behavior appears to be negatively affected by low-frequency vessel noise (Blair et al., 2016). Ten foraging whales with non-invasive archival tags were studied in Stellwagen Bank NMS in the western North Atlantic Ocean. Ship noise collected on the archival tags was assessed with seven parameters of feeding behavior. As the RL of vessel noise increased, three parameters of foraging behavior decreased: number of side roll feeding events, ascent rate, and descent rate (Blair et al., 2016). Reducing in foraging behavior of individual whales could lead to population-levels impacts of shipping noise on foraging success.

A series of playback experiments using vessel noise and seismic airgun signals was conducted with humpback whales migrating along the east coast of Australia. One analysis considered the effects of both vessel presence and received level of airgun transmissions (Dunlop et al., 2017). While neither stimulus produced abnormal behaviors, the presence of the vessel, with and without operating airguns, did alter behavior, reducing dive time. The airgun signals caused a prolonged increase in respiration rate, a decrease in dive time, and movement of travel path away from the sound source (as indicated by the reduction in southward movement). This avoidance was more likely at received SELs greater than 135 dB re $1\mu Pa^2$-s and at ranges less than 2.2 nmi (4 km). A similar experiment with a single 20 cubic inch or 140 cubic inch airgun found that avoidance was more likely within 1.6 nmi (3 km) of the vessel and at SELs greater than 140 dB re $1\mu Pa^2$-s, with no response during control periods, indicating avoidance was due to the air guns and not the source vessel itself (Dunlop et al., 2017).

In summary, the results of these studies show that behavioral responses can occur at a range of received levels and may or may not rise to the level of biologically significant impacts. The current scientific literature on the possible effects of LF sound transmissions on marine species provide no contradictory information showing different potential behavioral impacts than those documented by the LFS SRP. The results of the SRP remain the best available data to estimate the potential for biologically important behavioral responses to the use of SURTASS LFA sonar since the studies used the SURTASS LFA sonar and exposed LF specialists while engaged in critical behaviors. The risk continuum function, which is based on LFS SRP data, continues to be used to define behavioral effects from exposure to LFA sonar. Additionally no other studies have been conducted with low frequency sonars or other non-impulsive sources that utilize frequency bands similar to SURTASS LFA sonar that could be used to supplement the SRP results. The Navy acknowledges the age of the LFS SRP data, but as noted previously, the mere age of these data does not invalidate them, their contributions to science, nor the conclusions based upon those data.

5.2.3.4 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 be 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 be able to counteract masking by involuntarily increasing the source level of their vocalizations in the presence of noise, known as the Lombard effect or reflex. The SLs of killer whale and beluga vocalizations 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). Another mechanism may be to increase their calling rate or change the call structure, as demonstrated by gray whales when exposed to vessel noise (Dahlheim and Castellote, 2016). Changes in call structure included increased source level, more frequency-modulated calls, and an increased number of pulses per call. 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 no longer than 10 sec. 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 use, 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. 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.

5.2.3.5 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 (NRC, 2005), there has been broadened research into marine mammal responses to environmental stressors and linking these responses to costs at the individual level that may have repercussions 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. A study with southern elephant seals (New et al., 2014) highlights the linkages between animal foraging success, environmental change, and population growth rates, and the level of data needed for such an assessment.

A 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). A recently-capture beluga whale showed a two-phase heart rate response to noise exposures (frequencies of 19 to 38 kHz, levels of 150 to 160 dB). The heart rate response was indicative of changes in response to stress or emotionally negative external stimuli in terrestrial mammals and humans (Bakhchina et al., 2017). After one year of captivity, the beluga whale showed no response to the same or more intense noise exposures, indicating habituation within the dolphinarium.

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 modifications 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.

5.2.3.6 Quantitative Effects Analysis for Marine Mammals

The Navy conducted a risk assessment to analyze and assess potential impacts associated with using SURTASS LFA sonar during training and testing activities in the western and central North Pacific and eastern Indian oceans. 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, 2017b), 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.

Fifteen representative model areas in the western and central North Pacific and eastern Indian oceans were analyzed to represent the acoustic regimes and marine mammal species that may be encountered during LFA sonar training and testing activities (Table 3-6). To estimate the potential impacts to marine mammals in each of the model areas, a list of marine mammal stocks likely to be encountered in each region, by season, was developed and abundance and density estimates were derived from the most current published literature and documentation available (Chapter 3).

Modeling was conducted for one 24-hr period in each of the four seasons in each model area. 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, 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, which equates to a total of 2.4 transmission hours). The acoustic field around the LFA sonar source was predicted with the Navy standard parabolic equation propagation model using the defined LFA sonar operating parameters. Each marine mammal species potentially occurring in a model area in each season was simulated by creating animats (model simulated animals) programmed with behavioral values describing their dive and movement patterns, including dive depth, dive duration, surfacing time, swimming speed, and direction change.

The Acoustic Integration Model© (AIM) integrated the acoustic field created from the underwater transmissions of LFA sonar with the three-dimensional (3D) 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 that animal to experience PTS and then TTS was considered using the NMFS (2018f) acoustic guidance thresholds. If an animal was not predicted to experience PTS or TTS, then the sound energy received over the 24-hr modeled period was calculated as dB SPE and used as input to the LFA risk continuum function to assess the potential risk of a behavioral reaction. A step-wise process is undertaken to ensure that each individual is considered for only one potential impact (i.e., there is no double counting). The potential for PTS is 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 only considered for one acoustic impact during a 24-hr exposure scenario.

To estimate the potential impacts for each marine mammal stock on an annual basis, several calculation steps are required. The first step is to calculate the potential impact for one LFA sonar transmission hour. The 24-hr modeling results for each season are for 2.4 transmission hours (i.e., the SURTASS LFA sonar was simulated to transmit at a 10 percent duty cycle, so 24 hours of LFA sonar use equate to 2.4 sonar transmission hours). Therefore, the impact estimates from 24 hours of LFA sonar use (2.4 transmission hours) were divided by 2.4 to transform the results into potential impacts on a per transmission hour basis. Then, because the use of SURTASS LFA sonar is not driven by any seasonal factors, and SURTASS LFA sonar training and testing activities are likely to occur with equal frequency in any of the four seasons, the per transmission hour impact estimates for each season were averaged to provide a single annual per transmission hour impact estimate. At this point, the average impact of an hour of SURTASS LFA sonar transmissions during any time of the year has been calculated for every ESA-listed species or DPS.

The second step for calculating the potential impacts from all SURTASS LFA sonar training and testing transmissions within a year is to determine the number of LFA sonar transmission hours that might occur in each model area, for each activity. To develop the total annual LFA sonar transmission hours, the Navy determined the training and testing activities that occur each year, the number of transmission hours conducted during each activity, and the model areas in which each activity is expected to occur (Table 5-4), as not all proposed activities would occur in all modeled areas. To calculate the potential impact in each model area for each activity, the number of annual LFA sonar transmissions hours for each activity was evenly distributed across the model areas in which that activity might occur. The hours were evenly distributed across model areas because there is an equal chance of activities happening in each model area identified for an activity; the Navy is not aware of any planning factors that would influence the distribution of activity hours among model areas. For example, the execution of vessel and equipment maintenance is estimated to require 64 total transmission hours, which are planned to occur only in either Model Area #2 or Model Area #3. Therefore, the 64 transmission hours were equally distributed to Model Areas #2 and #3, or 32 hours in each model area, for vessel and equipment maintenance activities.

The third step was to determine the number of model areas in which each ESA-listed stock or DPS of marine mammals may occur for each activity. The fourth step was to select the maximum per hour effect for each stock that may occur in the model areas for that activity. For instance, for maintenance activities that occur in model areas #2 and #3, if a stock occurs in both model areas, whichever per hour effect estimate for that stock was higher between the two modeling areas was selected for all subsequent calculations for estimating the effects from maintenance activities.

The final step was to multiply the results of steps two, three, and four to calculate the potential annual effects per activity, which are then summed across the stocks for a total potential effect for all activities. The maximum estimate of the per hour effect (result of step three) was multiplied by the planned transmission hours for each activity per model area (result of step two) and by the number of model areas in which the stock might occur for that activity (result of step four). The result is the maximum potential effect per stock for each activity, allowing flexibility for the activity to occur in any season and

Table 5-4. Activities and Maximum Transmission Hours Per Year Expected in each of the 15 Representative Model Areas.

Model Area Number/Name	*Activity (Maximum Transmission Hours Per Year)*					
	Contractor Crew Training (80)	*MILCREW Training (96)*	*Navy Exercise Support (96)*	*Maintenance (64)*	*Acoustic Research Testing (160)*	*Years 5+: New LFA Sonar System Testing (96)*
1 /East of Japan		X			X	X
2 /North Philippine Sea	X	X	X	X	X	X
3 /West Philippine Sea	X	X	X	X	X	X
4 /Guam		X	X		X	X
5 /Sea of Japan		X			X	X
6 /East China Sea		X			X	X
7 /South China Sea		X	X		X	X
8 /Offshore Japan (25 to 40N)		X			X	X
9 /Offshore Japan (10 to 25N)		X			X	X
10 /Hawaii-North		X	X		X	X
11 /Hawaii-South		X	X		X	X
12 /Offshore Sri Lanka		X			X	X
13 /Andaman Sea		X			X	X
14 /Northwest Australia		X			X	X
15 /Northwest Japan		X			X	X

any of the planned model areas for that activity. These maximum effects per activity are summed across the stocks for Years 1 to 4 (Table 5-5) and Years 5 and beyond (Table 5-6).

To help explain the modeling process, the potential effects to the sperm whale are described as an illustrative example. Four stocks of the ESA-listed sperm whale are found in the study area, with the NP stock in all model areas, the Hawaii stock in Model Areas #10 and 11, the NIND stock in Model Areas #12 and 13, and the SIND stock in Model Area #14. Contractor training (total of 80 transmission hr) and maintenance (total of 64 transmission hr) may occur in Model Areas #2 or 3, for a total of 144

Table 5-5. Maximum Total Annual MMPA Level B Harassment of Potentially Occurring ESA-listed Marine Mammals Requested for Years 1 to 4 by SURTASS LFA Sonar Training and Testing Activities (Species, Stocks, and DPSs Listed Alphabetically).

Marine Mammal Species	*Stock or DPS*[25]	*Maximum Annual MMPA Level B Harassment: Years 1 to 4*					
		Behavior (Individuals)	*Behavior (Percent Stock)*	*TTS (Individuals)*	*TTS (Percent Stock)*	*Total Level B (Individuals)*	*Total Level B (Percent Stock)*
Blue whale	CNP	3.12	2.39%	0	0.00%	3	2.39%
	NIND	0.43	0.00%	0	0.00%	0	0.00%
	WNP	6.58	0.07%	83	0.83%	90	0.90%
	SIND	0.81	0.07%	0	0.00%	1	0.07%
Fin whale	ECS	1.88	0.37%	7	1.42%	9	1.80%
	Hawaii	3.49	2.30%	0	0.00%	3	2.30%
	IND	0.14	0.00%	0	0.00%	0	0.00%
	SIND	13.17	0.04%	9	0.02%	22	0.05%
	WNP	259.28	2.85%	2,299	24.70%	2,558	27.55%
Humpback whale	WNP stock and DPS	315.07	23.82%	2,788	210.03%	3,103	233.84%
North Pacific right whale	WNP	3.65	0.33%	85	9.24%	89	9.57%
Sei whale	Hawaii	9.46	2.39%	9	2.39%	19	4.78%
	SIND	0.16	0.00%	0	0.00%	0	0.00%
	NP	220.27	3.23%	3,058	43.73%	3,278	46.97%
	NIND	3.93	0.04%	0	0.00%	4	0.04%
Western North Pacific gray whale	WNP stock and Western DPS	0.45	0.33%	0	0.00%	0	0.00%
False killer whale	Main Hawaiian Islands Insular stock and DPS	0.69	0.41%	0	0.00%	1	0.41%
Sperm whale	Hawaii	105.88	2.34%	0	0.00%	106	2.34%
	NIND	33.32	0.14%	0	0.00%	33	0.14%

25 CNP=Central North Pacific; NP=North Pacific; WNP=Western North Pacific; ECS=East China Sea; NIND=Northern Indian; SIND=Southern Indian; IND=Indian; DPS=distinct population segment

Table 5-5. Maximum Total Annual MMPA Level B Harassment of Potentially Occurring ESA-listed Marine Mammals Requested for Years 1 to 4 by SURTASS LFA Sonar Training and Testing Activities (Species, Stocks, and DPSs Listed Alphabetically).

Marine Mammal Species	*Stock or DPS*[25]	*Maximum Annual MMPA Level B Harassment: Years 1 to 4*					
		Behavior (Individuals)	*Behavior (Percent Stock)*	*TTS (Individuals)*	*TTS (Percent Stock)*	*Total Level B (Individuals)*	*Total Level B (Percent Stock)*
Sperm whale (Continued)	NP	1,429.07	1.28%	0	0.00%	1,429	1.28%
	SIND	15.70	0.07%	0	0.00%	16	0.07%
Hawaiian monk seal	Hawaii	9.71	0.69%	0	0.00%	10	0.69%
Spotted seal	Southern stock and DPS	0.43	0.04%	0	0.00%	0	0.00%
Western Steller sea lion	Western/Asian stock, Western DPS	2.17	0.00%	0	0.00%	2	0.00%

Table 5-6. Maximum Total Annual MMPA Level B Harassment of Potentially Occurring ESA-listed Marine Mammals Requested for Years 5 through 7 by SURTASS LFA Sonar Training and Testing Activities (Species, Stocks, and DPSs Listed Alphabetically).

Marine Mammal Species	*Stock or DPS*[26]	*Maximum Annual MMPA Level B Harassment: Years 5 to 7*					
		Behavior (Individuals)	*Behavior (Percent Stock)*	*TTS (Individuals)*	*TTS (Percent Stock)*	*Total Level B (Individuals)*	*Total Level B (Percent Stock)*
Blue whale	CNP	3.73	2.85%	0	0.00%	4	2.85%
	NIND	0.59	0.00%	0	0.00%	1	0.00%
	WNP	8.44	0.00%	114	1.14%	123	1.14%
	SIND	0.81	0.07%	0	0.00%	1	0.07%
Fin whale	ECS	2.59	0.51%	10	1.96%	12	2.47%
	Hawaii	4.17	2.74%	0	0.00%	4	2.74%
	IND	0.20	0.00%	0	0.00%	0	0.00%
	SIND	18.11	0.05%	12	0.02%	30	0.07%
	WNP	347.52	3.81%	3,107	33.42%	3,455	37.23%
Humpback whale	WNP stock and DPS	381.92	28.87%	3,884	292.62%	4,266	321.49%
North Pacific right whale	WNP	4.77	0.44%	117	12.71%	122	13.15%
Sei whale	Hawaii	11.29	2.85%	11	2.85%	22	5.70%
	SIND	0.22	0.00%	0	0.00%	0	0.00%
	NP	302.27	4.43%	4,204	60.13%	4,507	64.57%
	NIND	5.40	0.05%	0	0.00%	5	0.05%
Western North Pacific gray whale	WNP stock and Western DPS	0.59	0.44%	0	0.00%	1	0.44%
False killer whale	Main Hawaiian Islands Insular stock and DPS	0.82	0.49%	0	0.00%	1	0.49%
Sperm whale	Hawaii	126.38	2.80%	0	0.00%	126	2.80%
	NIND	45.81	0.20%	0	0.00%	46	0.20%
	NP	1,855.21	1.68%	0	0.00%	1,855	1.68%

26 CNP=Central North Pacific; NP=North Pacific; WNP=Western North Pacific; ECS=East China Sea; NIND=Northern Indian; SIND=Southern Indian; IND=Indian; DPS=distinct population segment

Table 5-6. Maximum Total Annual MMPA Level B Harassment of Potentially Occurring ESA-listed Marine Mammals Requested for Years 5 through 7 by SURTASS LFA Sonar Training and Testing Activities (Species, Stocks, and DPSs Listed Alphabetically).

Marine Mammal Species	*Stock or DPS*[26]	*Maximum Annual MMPA Level B Harassment: Years 5 to 7*					
		Behavior (Individuals)	*Behavior (Percent Stock)*	*TTS (Individuals)*	*TTS (Percent Stock)*	*Total Level B (Individuals)*	*Total Level B (Percent Stock)*
Sperm whale (Continued)	SIND	21.58	0.10%	0	0.00%	22	0.10%
Hawaiian monk seal	Hawaii	12.75	0.91%	0	0.00%	13	0.91%
Spotted seal	Southern stock and DPS	0.59	0.05%	0	0.00%	1	0.05%
Western Steller sea lion	Western/Asian stock, Western DPS	2.98	0.00%	0	0.00%	3	0.00%

transmission hr spread across both model areas or 72 transmission hr per model area (result of step two). Only the NP stock of sperm whale occurs in these two model areas. The potential impact in Model Area #2 is 1.41 behavioral takes per transmission hour, while in Model Area #3, 1.27 behavioral takes per transmission hour were computed. Since 1.41 behavioral takes per transmission hour is the greater or maximum take of the two model areas in which these two activities may occur, 1.41 behavioral takes per transmission hour is selected as the maximum (result of step four). The potential impact of 1.41 behavioral takes per transmission hour is multiplied by 72 transmission hours per model area and by 2 model areas (since sperm whales may occur in both model areas; result of step three) for a total potential impact of 203.04 behavioral takes for both contractor training and maintenance activities for the NP stock of sperm whales. The algebraic equation for these steps is presented below:

$$1.41\ \frac{takes}{transmission\ hr}\ x\ 72\frac{transmssion\ hr}{mission\ area}\ x\ 2\ mission\ areas = 203.04\ takes$$

The use of LFA sonar for naval exercises support may occur in Model Areas #2, 3, 4, 7, 10, and 11 for a total of 96 transmission hours. This results in 16 transmission hours per model area, when the 96 transmission hours are divided equally among the 6 model areas (result of step two). Two stocks of sperm whale might be exposed to transmissions from the naval exercise support activity: the NP stock occurs in Model Areas #2, 3, 4, and 7 (result of step three is four model areas for the NP stock) and the Hawaii stock occurs in Model Areas #10 and 11 (result of step three is two model areas for the Hawaii stock). The maximum potential impact in any of the modeling areas in which the NP stock occurs is 1.41 behavioral takes (result of step four); the maximum potential impact in any of the modeling areas in which the Hawaii stock occurs is 1.60 behavioral takes (result of step four). Thus, for the NP stock, the potential impact of 1.41 behavioral takes per transmission hour is multiplied by 16 transmission hours per model area and by four model areas for a total potential impact of 90.24 behavioral takes from SURTASS LFA use during naval exercise support activities. For the Hawaii stock, the potential impact of 1.60 behavioral takes per transmission hour is multiplied by 16 transmission hours per model area and by 2 model areas for a total potential impact of 51.20 behavioral takes from SURTASS LFA use during naval exercises support activities.

The same process occurs for the remaining LFA sonar activities (MILCREW training and acoustic research in years 1 to 4, plus the addition of new LFA sonar system testing in years 5 to 7), which may occur in all fifteen model areas. To develop the overall potential effect from all SURTASS LFA sonar transmissions within a year to each ESA-listed marine mammal stock or DPS, the potential impacts to each stock from each individual activity are then summed to derive the total maximum potential effect on an annual basis in Years 1 to 4 (Table 5-5) and Years 5 to 7 (Table 5-6). This is a conservative estimate since it is based on the maximum potential effect to a stock across all model areas in which an activity may occur. Therefore, if the activity occurs in a different model area than the area where the maximum potential effect was predicted, the actual potential effect could be less than that estimated. However, since the Navy cannot forecast where a specific activity may be conducted this far in advance, this maximum estimate provides the Navy with the flexibility to conduct its training and testing activities across all model areas identified for each activity.

The potential for PTS (MMPA Level A) is considered within the context of the mitigation and monitoring efforts that would occur whenever SURTASS LFA sonar is transmitting. Mitigation monitoring is designed to detect marine mammals before they are exposed to 180 dB SPL RLs. The NMFS (2018f) acoustic guidance for estimating the potential for PTS defines weighted thresholds as sound exposure levels. The length of a nominal LFA sonar transmission is 60 sec, which lowers the thresholds by approximately 18 dB SEL (10 x log10 [60 sec] =17.8) if the assumption is made that all RLs are at the same SPL. In addition to signal duration, hearing sensitivity must be considered. If transmissions at 300 Hz are considered for this example, as it is in about the middle of the frequency range of LFA sonar 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 × log10 [range in meters]), all functional hearing groups except LF cetaceans would need to remain within 22 ft (7 m) for the entirety of an LFA sonar transmission (60 sec) to potentially experience PTS. An LF cetacean would need to remain within 135 ft (41 m) for the entirety of an LFA sonar transmission to potentially experience PTS. Based on the mitigation procedures used during SURTASS LFA sonar activities, the chances of this occurring are negligible. Therefore, no PTS (MMPA Level A harassment) is expected with the implementation of mitigation measures.

The primary impact anticipated from SURTASS LFA sonar transmission is MMPA Level B harassment of marine mammals. For all but three of the 24 stocks or DPSs of ESA-listed marine mammal species, the maximum annual percent of the stock or population that may experience Level B incidental harassment is less than 14 percent, regardless of the year during the effective period (Tables 5-5 and 5-6). This means that during one 24-hr period during a year, less than 14 percent of the population may react to SURTASS LFA sonar by changing behavior, moving a small distance, or experiencing TTS. Three stocks or DPSs of ESA-listed marine mammals, the WNP DPS and stock of humpback whales, the WNP stock of sei whales, and the WNP stock of fin whales, have the potential to experience MMPA Level B incidental harassment greater than 14 percent during any year from 1 through 7 and beyond. The highest percentage of a population that may experience MMPA Level B harassment at 233.84 percent and 321.49 percent in years 1 through 4 and years 5/beyond, respectively, is the WNP stock and DPS of humpback whales (Tables 5-5 and 5-6). This means that each individual whale in the population of WNP humpback whales may react behaviorally or experience TTS two to three times during a year. The percentage of the WNP stock and DPS of humpback whales that may experience Level B harassment is influenced by the size of the population, which is small, with only 1,328 individuals in the stock/DPS (Bettridge et al., 2015). The second highest estimated Level B harassment that a stock/DPS may experience is 46.97 percent and 64.57 percent during year 1 through 4 and year 5 and beyond, respectively, of the WNP stock sei whales (Tables 5-5 and 5-6).

The number of individual marine mammals that may be impacted over the seven years of the proposed training and testing activities of SURTASS LFA sonar has been estimated. The maximum number of individual marine mammals potentially affected in one year during years 1 to 4 (with 496 SURTASS LFA sonar transmission hours each year) and years 5 to 7 (with 592 SURTASS LFA sonar transmission hours each year) were multiplied to yield the total number of individuals potentially affected over seven years (Table 5-7). For example, for the WNP stock of the blue whale, four years of 496 transmission hours (years 1 to 4; 90 individuals per year x 4 years = 360 individuals) plus three years of 592 transmission hours (years 5 to 7; 123 individuals per year x 3 years = 369 individuals) are summed for an estimate of 729 WNP blue whales that might be affected over the seven-year duration of the proposed SURTASS LFA sonar training and testing activities. These 7-year estimates are conservative estimates since they are based on the maximum potential effect to a stock/DPS across all model areas in which an activity may occur. Therefore, if the activity occurs in a different model area than the area where the maximum

Table 5-7. Maximum MMPA Level B Harassment of Potentially Occurring ESA-listed Marine Mammals by SURTASS LFA Sonar Training and Testing Activities for Years 1 to 4 and Years 5 to 7 (Annual Totals) and Total Overall for 7-Year Authorization Period (Species and Stocks Listed Alphabetically).

Marine Mammal Species	*Stock/DPS*[27]	*Maximum Annual Level B Harassment, Years 1-4*		*Maximum Annual Level B Harassment, Years 5-7*		*Total Overall Level B Harassment for 7-year Period (Individuals)*
		Individuals	*Percent Stock*	*Individuals*	*Percent Stock*	
Blue whale	CNP	3	2.39%	4	2.85%	24
	NIND	0	0.00%	1	0.00%	3
	WNP	90	0.90%	123	1.14%	729
	SIND	1	0.07%	1	0.07%	7
Fin whale	ECS	9	1.80%	12	2.47%	72
	Hawaii	3	2.30%	4	2.74%	24
	IND	0	0.00%	0	0.00%	0
	SIND	22	0.05%	30	0.07%	178
	WNP	2,558	27.55%	3,455	37.23%	20,597
Humpback whale	WNP stock and DPS	3,103	233.84%	4,266	321.49%	25,210
North Pacific right whale	WNP	89	9.57%	122	13.15%	722
Sei whale	Hawaii	19	4.78%	22	5.70%	142
	SIND	0	0.00%	0	0.00%	0
	NP	3,172	45.37%	4,361	62.37%	25,771
	NIND	4	0.04%	5	0.05%	31
Western North Pacific gray whale	WNP stock and Western DPS	0	0.00%	1	0.44%	3
False killer whale	Main Hawaiian Islands Insular stock and DPS	1	0.41%	1	0.49%	7
Sperm whale	Hawaii	106	2.34%	126	2.80%	802

27 CNP=Central North Pacific; NP=North Pacific; NIND=Northern Indian; SIND=Southern Indian; IND=Indian; WNP=Western North Pacific; ECS=East China Sea; WP=Western Pacific; DPS=distinct population segment

Table 5-7. Maximum MMPA Level B Harassment of Potentially Occurring ESA-listed Marine Mammals by SURTASS LFA Sonar Training and Testing Activities for Years 1 to 4 and Years 5 to 7 (Annual Totals) and Total Overall for 7-Year Authorization Period (Species and Stocks Listed Alphabetically).

Marine Mammal Species	*Stock/DPS*[27]	*Maximum Annual Level B Harassment, Years 1-4*		*Maximum Annual Level B Harassment, Years 5-7*		*Total Overall Level B Harassment for 7-year Period (Individuals)*
		Individuals	*Percent Stock*	*Individuals*	*Percent Stock*	
Sperm whale (Continued)	NIND	33	0.14%	46	0.20%	270
	NP	1,429	1.28%	1,855	1.68%	11,281
	SIND	16	0.07%	22	0.10%	130
Hawaiian monk seal	Hawaii	10	0.69%	13	0.91%	79
Spotted seal	Southern stock and DPS	0	0.00%	1	0.05%	3
Western Steller sea lion	Western/Asian stock, Western DPS	2	0.00%	3	0.00%	17

potential effect was predicted, the actual potential effect could be less than that estimated. However, since the Navy cannot forecast where a specific activity may be conducted this far in advance, this maximum estimate provides the Navy with the flexibility to conduct its training and testing activities across all model areas identified for each activity.

5.2.3.7 Overview of Potential Effects on Marine Mammals

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 80 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. NMFS (2018f) 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. During Years 1 through 4 of the authorization period, the highest quantified MMPA Level B take of an ESA-listed marine mammal stock or DPS is 234 percent to the WNP DPS and stock of humpback whales, while 322 percent Level B takes are estimated for the same WNP humpback whale DPS during Years 5 through 7 of the authorization period. This equates to an estimated 3,103 and 4,266 MMPA Level B exposures, respectively, for Years 1 to 4 and Years 5 to 7 in a small stock and DPS that includes an estimated 1,328 individuals (Bettridge et al., 2015).

6 CUMULATIVE EFFECTS

As defined by the ESA [50 C.F.R. § 402.02], "cumulative effects" are those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area. Any U.S. state activities would be conducted in the waters within 3 nmi (5.6 km) from shore, which is the limit of state waters and would be included in the coastal standoff range for SURTASS LFA sonar. As such, it is unlikely that any cumulative effects from SURTASS LFA sonar use and state actions are anticipated. Thus, this evaluation of cumulative effects focuses principally on activities of private or commercial organizations. For the purposes of this evaluation, public documents prepared by federal, state, and local government agencies form the primary sources of information regarding reasonably foreseeable relevant current and future projects in the western and central North Pacific and eastern Indian oceans. The categories of actions considered in this cumulative effects assessment include maritime traffic (i.e., commercial shipping), seismic exploration, and alternative energy development.

6.1 Maritime Traffic

Although the total number of sea-going commercial ships around the world is difficult to quantify, both the carrying capacity and number of ships has increased significantly over the last several decades. The number of ships greater than 100 tons was estimated in 2012 to include 86,300 vessels, of which 57,400 are cargo carriers (Hellenic Shipping News, 2013). Tournadre (2014) estimated that between 1992 and 2002, maritime ship traffic increased by 60 percent, averaging about 6 percent per year, with the largest increases in maritime traffic occurring in the Indian Ocean and South China and East China seas. The number of ships worldwide poses risks to marine species not only from the noise they generate but also due to the potential for ship strikes, particularly to marine mammals, which could potentially kill or injure protected species. Glass et al. (2010) suggested that not all cetaceans struck by vessels are detected, especially in deep ocean waters.

The dominant 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).

6.2 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 assess accurately 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 in the SURTASS LFA sonar study area include waters off southeast Asia. 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.

6.3 Alternative Energy Developments

The development of alternative sources of energy, particularly energy generated by ocean winds, is an area of increasing commercial and government expenditure and exploration around the world. As energy generation from offshore wind farms increases, so too does the underwater noise levels generated from the operation of the wind farms, which should be the focus of additional research. The first offshore wind facility in the U.S. was constructed in Rhode Island waters, with additional siting surveys occurring off New England and the mid-Atlantic. Offshore wind energy generators, or wind farms, not only generate energy but also generate underwater noise, usually associated with the operation of turbines but also during the construction of the wind farms (e.g., pile-driving, dredging, and trenching). Pile-driving during wind farm construction can generate noise measured at 205 dB re 1 µPa @ 100 m (Sun et al., 2012). The sound generated by wind turbines are pure tones below 1 kHz, but typically below 700 Hz, with sound pressure levels between 109 to 127 dB re 1 µPa rms measured at distances of between 46 to 131 ft (14 to 40 m) from the wind turbine foundations (Madsen et al., 2006; Tougaard et al., 2009).

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/).

6.4 Cumulative Effects

The greatest cumulative effect associated with the employment of SURTASS LFA sonar in combination with other known current or planned maritime activities is the increase in the ambient noise environment, whether on a transient basis from sonar and seismic sound transmissions or a more persistent basis from ship traffic and wind-power installations. Seismic exploration and wind-farm construction and development activities are principally focused in continental shelf waters and in Arctic waters, which are not operational areas for SURTASS LFA sonar. SURTASS LFA sonar training and testing activities would most likely overlap with maritime shipping traffic or possibly commercial high sea fisheries. While the sounds generated by both ship traffic and SURTASS LFA sonar are both in similar frequency bands, the contribution of LFA sonar operations to the ambient noise environment is miniscule. 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 x

10^{13} Joules/yr; and mid-frequency military sonar was estimated to contribute 2.6 x 10^{13} Joules/yr (Hildebrand, 2005). Scaling the calculations in Hildebrand (2005) to account for the proposed transmission hours, in years 1 to 4, the contribution from 496 hours of LFA transmissions would be 2.0 x 10^{11} Joules/yr and in years 5 and beyond, the contribution from 592 hours of LFA sonar transmissions would be 2.3 x 10^{11} Joules/yr. The percentage of the total anthropogenic acoustic energy budget added by LFA source transmissions is estimated to be 0.29 and 0.34 percent, respectively for years 1 to 4 and year 5 and beyond (Hildebrand, 2005).

The vast majority of effects on ESA-listed marine species expected from the potential combined sound generated by LFA sonar, seismic, shipping, and wind-farms are most likely to be behavioral in nature, likely to be temporary effects, 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. Even if an ESA-listed marine species occurred in the vicinity of a wind-farm, the sound level, although more persistent than the other potentially occurring cumulative activities, generated by a wind farm is sufficiently low that even in combination with other transient but more high powered sounds generated by other maritime activities are not expected to adversely affect individuals or populations. No injury or mortality would reasonably be expected due to the cumulative effect of SURTASS LFA sonar training and testing activities in concert with other listed maritime actions. Likewise, the potential for non-auditory, auditory, or masking effects from even a combination of the listed activities are not likely to adversely affect any listed species or DPSs. The most likely cumulative effect on any listed species or DPS would be from behavioral responses including modified behavior such as aversion or increased dive times or even temporary displacement. Such changes may affect ESA-listed species but are not likely to adversely affect individuals or populations of ESA-listed marine and anadromous fishes, sea turtles, or marine mammals.

7 SUMMARY AND CONCLUSIONS

In this BE, the Navy evaluated the status of 25 species or DPSs of ESA-listed marine and anadromous species of sea turtles, fishes, and marine mammals that may potentially occur in the study area for SURTASS LFA sonar training and testing activities in the western and central North Pacific and eastern Indian oceans. Marine neritic and pelagic CH designated for two ESA-listed species/DPS have also been evaluated for effects associated with exposure to SURTASS LFA sonar training and testing activities.

Based on this thorough evaluation, the Navy concludes that the training and testing activities of SURTASS LFA sonar may affect but are not likely to adversely affect the 14 species or DPSs of sea turtles as well as marine and anadromous fishes (Table 7-1) evaluated herein. SURTASS LFA sonar activities may affect and are likely to adversely affect the 11 threatened and endangered species or DPSs of potentially occurring marine mammals. The Navy has additionally concluded that SURTASS LFA sonar training and testing activities in the western and central North Pacific and eastern Indian oceans may affect but are not likely to adversely affect the primary constituent elements of the designated CH of the Hawaiian monk seal and MHI Insular DPS of the false killer whale.

Table 7-1. Estimated Effects on ESA-listed Sea Turtle, Marine and Anadromous Fish, and Marine Mammal Species, DPSs, or ESUs Resulting from Exposure to SURTASS LFA Sonar Training and Testing Activities.

ESA-Listed Species	*DPS or ESU*	*May Affect But Not Adversely Affect*	*May Affect and is Likely to Adversely Affect*
	Sea Turtles		
Green turtle	Central West Pacific DPS, Central North Pacific DPS, East Indian-West Pacific DPS, North Indian DPS	X	
Hawksbill turtle		X	
Leatherback turtle		X	
Loggerhead turtle	Southeast Indo-Pacific Ocean DPS, North Indian Ocean DPS, North Pacific Ocean DPS	X	
Olive ridley turtle		X	
	Marine and Anadromous Fishes		
Chinook salmon	All ESUs	X	
Chum salmon	Columbia River and Hood Canal Summer-run ESUs	X	
Coho salmon	Central California Coast Coho, Lower Columbia River, Oregon Coast, and Southern Oregon/Northern California Coasts ESUs	X	
Giant manta ray		X	
Oceanic whitetip shark		X	
Sakhalin sturgeon		X	
Scalloped hammerhead shark	Indo-West Pacific DPS	X	

Table 7-1. Estimated Effects on ESA-listed Sea Turtle, Marine and Anadromous Fish, and Marine Mammal Species, DPSs, or ESUs Resulting from Exposure to SURTASS LFA Sonar Training and Testing Activities.

ESA-Listed Species	*DPS or ESU*	*May Affect But Not Adversely Affect*	*May Affect and is Likely to Adversely Affect*
Sockeye salmon	Snake River Sockeye and Lake Ozette ESUs	X	
Steelhead trout	All DPSs and ESUs	X	
Marine Mammals			
Blue whale			X
Fin whale			X
Gray whale	Western North Pacific DPS		X
Humpback whale	Western North Pacific DPS		X
North Pacific right whale			X
Sei whale			X
False killer whale	Main Hawaiian Islands Insular DPS		X
Sperm whale			X
Hawaiian monk seal			X
Spotted seal	Southern DPS		X
Western Steller sea lion	Western DPS		X

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