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LIST OF ACRONYMS AND ABBREVIATIONS

3MDS	Multi-mode Magnetic Detection System
°C	Degrees Centigrade/Celsius
°F	Degrees Fahrenheit
µm	Micrometer
µPa	Micropascal(s)
ABR	Auditory brainstem response
AEP	Auditory evoked potential
AFAST	Atlantic Fleet Active Sonar Training
AIM	Acoustic Integration Model©
AIP	Air-independent propulsion
AM	Amplitude modulated
ANSI	American National Standards Institute
APA	Administrative Procedure Act
APR	Annual percentage growth rate
ASN (I&E)	Assistant Secretary of the Navy (Installations and Environment)
ASW	Anti-submarine warfare
ATOC	Acoustic Thermometry of Ocean Climate
AUSI	Autonomous Undersea Systems Institute
AUTEC	Atlantic Undersea Test and Evaluation Center
AUV	Autonomous undersea vehicle
AUVAC	Autonomous Undersea Vehicle Applications Center
BRS	Behavioral Response Study
CEE	Controlled exposure experiment
CEQ	Council on Environmental Quality
CFMC	Caribbean Fishery Management Council
CFR	Code of Federal Regulations
CIA	Central Intelligence Agency
CITES	Convention on International Trade in Endangered Species
CLFA	Compact Low Frequency Active
cm	Centimeter(s)
CNO	Chief of Naval Operations
COTS	Commercial off-the-shelf
CSM	Cross spatial matrix
CT	Computer tomography
CV	Coefficient of variation
CZ	convergence zone
CZMA	Coastal Zone Management Act
DASN(E)	Deputy Assistant Secretary of the Navy for Environment
dB	Decibel(s)

dB re 1 µPa @ 1 m	decibels relative to one micropascal measured at one meter from center of acoustic source
dB re 1 µPa²-sec	Decibels relative to one micropascal squared per second
DoC	Department of Commerce
DoD	Department of Defense
DoN	Department of the Navy
DSEIS	Draft Supplemental Environmental Impact Statement
EEZ	Exclusive Economic Zone
EFH	Essential fish habitat
EIS	Environmental impact statement
ELF	Extremely low frequency
EO	Presidential Executive Order
ESA	Endangered Species Act
ETP	Eastern Tropical Pacific
FAO	Food and Agriculture Organization
FEIS	Final Environmental Impact Statement
FLIR	Forward Looking Infrared
FM	Frequency modulated
FMC	Fishery Management Council
FMP	Fishery management plan
FMZ	Fishery Management Zone
FOEIS	Final Overseas Environmental Impact Statement
FSEIS	Final Supplemental Environmental Impact Statement
ft	Foot or feet
FY	Fiscal Year
GDP	Gross Domestic Product
GNP	Gross National Product
HAPC	Habitat Area of Particular Concern
HF	High frequency
HLA	Horizontal line array
HMS	Highly migratory species
hr	Hour(s)
Hz	Hertz
ICES	International Council for the Exploration of the Sea
ICP	Integrated Common Processor
ICW	Intracoastal Waterway
in	Inch(es)
ITS	Incidental take statements
ISAR	Inverse Synthetic Aperture Radar
ISSCAAP	International Standard Statistical Classification of Aquatic Animals and Plants
IUCN	International Union for Conservation of Nature
IUSS	Integrated Undersea Surveillance System

IWC	International Whaling Commission
kg	Kilogram(s)
km	Kilometer(s)
Kph	Kilometers per hour
kt/kts	Knot(s)
kHz	KiloHertz
lb/yd	Pound per yard
LF	Low frequency
LFA	Low Frequency Active
LFAS	Low Frequency Active Sonar
LFS SRP	Low Frequency Sound Scientific Research Program
LINTS	Linear Threshold Shift
LOA	Letter of Authorization
LTM	Long term monitoring
m	Meter(s)
M3	Marine mammal mitigation
MAD	Magnetic Anomaly Detection
MFA	Mid-frequency active
min	Minute(s)
MIT	Massachusetts Institute of Technology
MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MPA	Marine protected area
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
mt	Metric ton(s)
NA	North Atlantic or not available
NARW	North Atlantic Right Whale
NATO	North Atlantic Treaty Organization
NDAA	National Defense Authorization Act
NEPA	National Environmental Policy Act
NERR	National Estuarine Research Reserve
NM	National Monument
NMFS	National Marine Fisheries Service
nmi	Nautical mile(s)
NMNS	Natural Museum of Nature and Science
NMPAC	National Marine Protected Area Center
NMS	National Marine Sanctuary
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPAL	North Pacific Acoustic Laboratory
NPS	National Park System
NRC	National Research Council
NS	National Seashore
NUWC	Naval Undersea Warfare Center

NWR	National Wildlife Refuge
OBIA	Offshore biologically important areas
OCRM	Office of Ocean and Coastal Resource Management (NOAA)
OCS	Outer continental shelf
OEIS	Overseas Environmental Impact Statement
OMP	Office of Marine Programs
ONR	Office of Naval Research
OPAREA	Operating area
PADI	Professional Association of Diving Instructors
PLAN	Peoples Liberation Army Navy
PTS	Permanent Threshold Shift
RL	Received level
rms	Root mean square
ROD	Record of Decision
ROV	Remotely operated vehicle
R/V	Research vessel
SAG	Surface active group
SAR	Synthetic Aperture Radar
SARA	Species At Risk Act (Canada)
sec	Second(s)
SEIS	Supplemental Environmental Impact Statement
SEL	Sound exposure level
SEM	Scanning electron microscope
SL	Source level
SME	Subject matter expert
SOCAL	Southern California
SOEIS	Supplemental Overseas Environmental Impact Statement
Sonar	SOund NAvigation and Ranging
sp./spp.	Specie/species
SPD	Sound pressure difference
SPL	Sound pressure level
SRP	Scientific Research Program
SSP	Sound speed profile
SURTASS	Surveillance Towed Array Sensor System
T-AGOS	Tactical-Auxiliary General Ocean Surveillance
TOTO	Tongue of the Ocean
TTS	Temporary threshold shift
UME	Unusual mortality event
UN	United Nations
UNEP	United Nations Environmental Programme
UNOLS	University-National Oceanographic Laboratory System
U.S.	United States
USC	United States Code
USFWS	U.S. Fish and Wildlife Service

USNS	U.S. Navy ship
USS	U.S. ship
VLA	Vertical line array
WDPA	World Database on Protected Areas
WTO	World Trade Organization

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1.0 PURPOSE AND NEED

This Supplemental Environmental Impact Statement (SEIS)/Supplemental Overseas Environmental Impact Statement (SOEIS) for Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) sonar systems[1] provides supplemental analyses to the Final Overseas Environmental Impact Statement/Environmental Impact Statement (FOEIS/EIS) for SURTASS LFA Sonar (Department of the Navy [DoN], 2001) and the Final Supplemental Environmental Impact Statement (FSEIS) for SURTASS LFA Sonar (DoN, 2007a), which were filed with the United States (U.S.) Environmental Protection Agency in January 2001 and April 2007, respectively. This second supplemental analysis has been prepared in compliance with the National Environmental Policy Act (NEPA) of 1969 (42 United States Code [USC] §4321 et seq.)[2]; the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA (Title 40 Code of Federal Regulations [CFR] §§1500-1508); Navy Procedures for Implementing NEPA (32 CFR §775); and Executive Order (EO) 12114, Environmental Effects Abroad of Major Federal Actions[3].

References to Underwater Sound Levels
• **References to underwater sound pressure level (SPL) in this SEIS/SOEIS are values given in decibels (dBs), and are assumed to be standardized at 1 microPascal at 1 m (dB re 1 µPa @ 1 m [rms]) for source level (SL) and dB re 1 µPa (rms) for received level (RL), unless otherwise stated (Urick, 1983; ANSI, 2006).**   • **In this SEIS/SOEIS, underwater sound exposure level (SEL) is a measure of energy, specifically the squared instantaneous pressure integrated over time and expressed as an equivalent one-second in duration signal, unless otherwise stated; the appropriate units for SEL are dB re 1 µPa²-sec (Urick, 1983; ANSI, 2006; Southall et al., 2007).**   • **The term "Single Ping Equivalent" (SPE) (as defined in Chapter 4 and Appendix C of this SEIS/SOEIS) is an intermediate calculation for input to the risk continuum used in this document. SPE accounts for the energy of all the LFA acoustic transmissions that a modeled animal receives during an entire LFA mission (modeled for operations from 7 to 20 days). Calculating the potential risk from SURTASS LFA is a complex process and the reader is referred to Appendix C for details. As discussed in Appendix C, SPE is a function of SPL, not SEL. SPE levels will be expressed as "dB SPE" in this document, as they have been in the SURTASS LFA sonar FOEIS/FEIS and FSEIS documents (DoN, 2001 and 2007a).**

To meet long range-submarine detection necessary to provide U.S. forces with the time to react to and defend against potential undersea threats, the Navy developed the SURTASS LFA Sonar System. The proposed action herein is the employment by the U.S. Navy of up to four SURTASS LFA

1 In this SEIS/SOEIS, "SURTASS LFA sonar systems" refers to both the LFA and compact LFA (CLFA) systems, each having similar acoustic operating characteristics.

2 The provisions of NEPA apply to major federal actions that occur or have effects in the U.S., its territories, or possessions.

3 The provisions of EO 12114 apply to major federal actions that occur or have effects outside of U.S. territories (the U.S. its territories, and possessions).

sonar systems for routine training, testing, and military operations[4] in the oceanic areas as presented in Figure 1-1. Based on current operational requirements, exercises using these sonar systems could occur in the Pacific, Atlantic, and Indian oceans, and the Mediterranean Sea. To reduce potential adverse effects on the marine environment, areas would be excluded as necessary to prevent 180-decibel (dB) sound pressure level (SPL) or greater within a specific geographic range of land and in offshore biologically important areas during biologically important seasons, and to prevent greater than 145-dB SPL at known recreational and commercial dive sites.

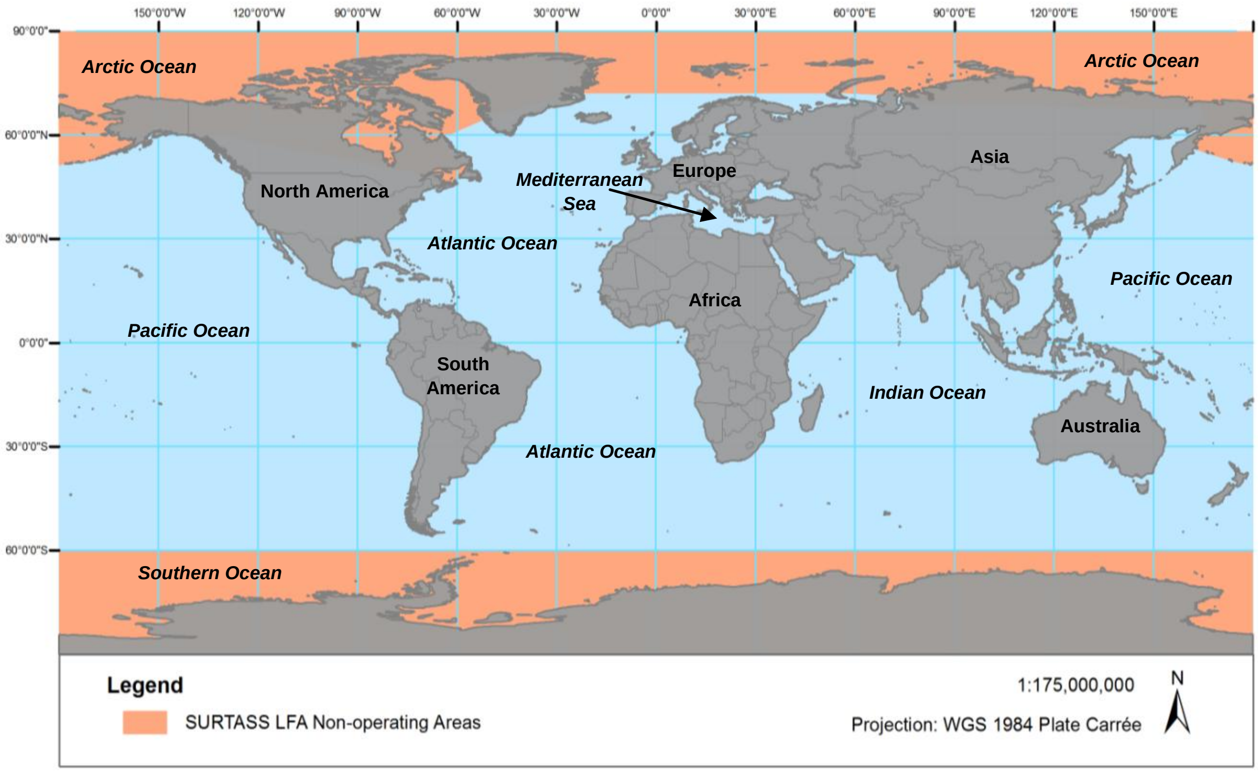

Figure 1-1. Potential areas of operation for SURTASS LFA sonar.

SURTASS LFA sonar systems are long-range sensors with both active and passive acoustic components that are able to operate day and night in most weather conditions. These systems operate in the low frequency (LF) band (below 1,000 Hertz [Hz]) within the frequency range of 100 to 500 Hz. The passive component, SURTASS, is a towed horizontal line array detection system that uses hydrophones to detect sound emitted or reflected from submerged targets. The active component of the system, LFA, is an augmentation to SURTASS and is planned for use when passive system performance is inadequate. LFA is comprised of a set of acoustic transmitting source elements suspended by cable from underneath ocean surveillance ships, such as the U.S. Navy Ship (USNS) IMPECCABLE (T-AGOS 23) and the VICTORIOUS Class (T-AGOS 19 Class). The active array transmits LF sound pulses that reflect off

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

objects that they encounter in the water. These reflected pulses return in the form of echoes that are received by the passive towed array through listening devices (hydrophones).

The FOEIS/EIS for SURTASS LFA sonar was completed in January 2001 by the Department of the Navy (DoN) with the National Marine Fisheries Service (NMFS) as a cooperating agency, in accordance with the requirements of NEPA and EO 12114. The Deputy Assistant Secretary of the Navy for Environment (DASN(E)) signed the Record of Decision (ROD) on 16 July 2002 (DoN, 2002), authorizing the operational employment of two SURTASS LFA sonar systems contingent upon the issuance by NMFS of letters of authorization (LOA) under the Marine Mammal Protection Act (MMPA) and incidental take statements (ITS) under the Endangered Species Act (ESA) for each vessel.

In April 2007, the DoN, with NMFS as a cooperating agency, completed the FSEIS for SURTASS LFA sonar in accordance with NEPA and EO 12114 (DoN, 2007a). On 15 August 2007, the Assistant Secretary of the Navy (Installations and Environment) (ASN (I&E)) signed the ROD authorizing the employment of four SURTASS LFA sonar systems (DoN, 2007b). The document focused on providing additional information regarding the environment that could potentially be affected by employment of SURTASS LFA sonar; providing additional information related to mitigation of the potential impacts from the system; addressing pertinent deficiencies raised by the U.S. District Court for the Northern District of California (herein referred to as the Court), including additional mitigation and monitoring, additional alternatives analysis, and analysis of the potential impacts of LF sound on fish; and providing the information necessary to apply for and receive a new five-year Rule. The new Rule would govern the authorization of incidental takes under the MMPA, as amended. The FSEIS also discussed proposed modifications to mitigation/interim operational restrictions, and provided details of updated analyses and research on the potential effects on fish, sea turtles, and marine mammals; marine mammal stranding events potentially related to anthropogenic noise; cumulative impacts; long-term monitoring; and ongoing and planned research.

Due to concerns raised recently during litigation over employment of the SURTASS LFA sonar system and to support issuance of a follow-on five-year Rule under the MMPA for employment of SURTASS LFA sonar systems, DASN(E) determined on 14 November 2008 that the purposes of NEPA and EO 12114 would be furthered by the preparation of an additional supplemental analysis related to the employment of the system. This analysis takes the form of this new SEIS/SOEIS.

Accordingly, DASN(E) directed that the new SEIS/SOEIS provide: 1) further analysis of potential additional offshore (greater than 12 nautical miles [nmi] [22.2 kilometers {km}]) biologically important areas (OBIA) in regions of the world where the Navy intends to use the SURTASS LFA sonar systems for routine training, testing, and military operations; 2) further analysis of whether using a greater coastal standoff distance where the continental shelf extends further than current standoff distance is practicable for SURTASS LFA sonar, at least in some locations; and 3) further analysis of cumulative impacts involving other active sonar sources. Once completed, information from these analyses will be used to assist the Navy in determining how to employ SURTASS LFA sonar, including the selection of operating areas that the Navy requires for routine training, testing, and military operations in annual requests for MMPA LOAs submitted to NMFS of the Department of Commerce's (DoC's) National Oceanic and Atmospheric Administration (NOAA).

The purpose of the SURTASS LFA sonar DSEIS/SOEIS is to:

- Address concerns of the Court in its 6 February 2008 Opinion and Order in relation to compliance with NEPA, ESA, and MMPA;
- Provide information to support the proposed issuance of MMPA incidental take regulations, the 2012 LOAs, and future LOAs as appropriate; and
- Provide additional information and analyses pertinent to the proposed action.

The Navy is the lead agency with NMFS as the cooperating agency, in accordance with NEPA regulations (40 CFR §1501.6).

On 21 January 2009, the Navy published a Notice of Intent (NOI) to prepare a SEIS/SOEIS for the employment of SURTASS LFA sonar, with NMFS as a cooperating agency (DoN, 2009a). In the NOI the Navy and NMFS solicited scoping comments on the above topics, to include OBIAs, greater coastal standoff, and cumulative effects. At the end of the 45-day scoping period, no comments had been received.

1.1 PURPOSE AND NEED FOR PROPOSED ACTION

The Navy's primary mission is to maintain, train, equip, and operate combat-ready naval forces capable of accomplishing American strategic objectives, deterring maritime aggression, and assuring freedom of navigation in ocean areas. The Secretary of the Navy and Chief of Naval Operations (CNO) have continually validated that Anti-Submarine Warfare (ASW) is a critical part of that mission – a mission that requires unfettered access to both the high seas and littorals[5]. In order to be prepared for all potential threats, the Navy must maintain ASW core competency through continual training in open-ocean and littoral environments.

Excerpts from Declaration of Rear Admiral John M. Bird, U.S. Navy to the United States District Court Northern District of California, 15 November 2007
SURTASS LFA (sonar) has enabled the Navy to meet the clearly defined, real-world national security need for improved ASW capability by allowing Navy Fleet units to reliably detect quieter and harder-to-find submarines at long range, before they get within their effective weapons range and can launch missiles or torpedoes against our ships or missiles against land targets, foreign or domestic. The operative word here is has. SURTASS LFA is a combat-ready system. But in order to protect U.S. and allied fleet assets, and merchant shipping, the operation of SURTASS LFA sonar and the training of our personnel must continue uninterrupted.

The challenges faced by the U.S. Navy today are very different from those faced at the end of the Cold War nearly two decades ago. Since the early 1990s, U.S. Navy ASW strategy has had to shift from a known Soviet adversary to "uncertain potential adversaries" with less well understood and defined strategies and goals (Benedict, 2005). The wide proliferation of diesel-electric submarines, a Chinese undersea force that is growing in size and tactical capability, and a resurgent Russian submarine service mean that U.S. ASW capability must meet more technologically-capable threats in a wider range of ocean environments (Benedict, 2005; ONI, 2009a and 2009b). Due to the advancement and use of quieting technologies in diesel-electric and nuclear submarines, undersea threats are becoming increasingly difficult to locate using the passive acoustic technologies that were effective during the Cold War. The range at which U.S. ASW assets are able to identify submarine threats is decreasing, and at the same time, improvements in torpedo design are extending the effective weapons range of those same threats (Benedict, 2005).

To meet this long-range submarine detection need, the U.S. Navy has investigated the use of a broad spectrum of acoustic and non-acoustic technologies. These are discussed in detail in subchapter 1.1.4. Of the technologies evaluated, low frequency active sonar is the only system capable of meeting the U.S. Navy's long-range ASW detection needs in a variety of weather conditions during the day and night.

5 See Subchapter 1.1.3 below for definition of "littoral."

SURTASS LFA sonar is providing a quantifiable improvement in the Navy's undersea detection capabilities and therefore markedly improving the survivability of U.S. Naval forces in hostile ASW scenarios.

The proposed action meets the need of the U.S. Navy for improved long-range submarine detection capability, which is essential to providing U.S. forces the time necessary to react to and defend against potential undersea threats. It is critical that U.S. forces be able to identify threats while remaining at a safe distance beyond a submarine's effective weapon's range (Davies, 2007).

1.1.1 NATURE OF THE SUBMARINE THREAT

Today's maritime strategies rely heavily on quiet submarines to accomplish various offensive and defensive missions: patrol the littorals, blockade strategic chokepoints[6], and stalk aircraft carrier battle groups. Being inherently covert, submarines can conduct intrusive operations in sensitive areas, and can be inserted into a conflict situation early with a minimal likelihood of being detected. These vessels also have the ability to carry many different weapons systems: torpedoes, long-range cruise missiles, anti-ship mines, and ballistic nuclear missiles (Benedict, 2005; ONI, 2009a). These capabilities make submarines, both nuclear and diesel-electric powered, stealthy and flexible strategic assets. Under competent command a submarine is an excellent weapon and a capable intelligence-gathering platform (Davies, 2007). Because they require fewer operational and support resources, submarines are being increasingly seen as an effective and cost-efficient way to ensure domestic defense and to pursue blue-water power projection (Goldstein and Murray, 2003). For countries that lack or cannot afford large conventional naval forces these benefits are amplified even more.

Technologically, the submarines being produced today are much more advanced than those of even a few decades ago (Friedman, 2007a). Submarines from many nations are better armed, more capable, and able to stay submerged for a longer period of time than earlier vessels (Davies, 2007). For both conventional diesel-electric and nuclear submarines, quieting technology has increased stealth and thus operational effectiveness. These technologies include hull coatings that minimize echoes, sound isolation mounts for machinery, and improved propeller design, and are being employed in new submarine projects and as upgrades to older boats. As this technology has improved the predominant sources of ship noise (i.e., hull flow noise, propeller noise, and propulsion machinery noise) have been reduced. As an example, between 1970 and 1990 the sound signature levels of Soviet submarines were reduced dramatically, by over 30 dB SPL, due to the implementation of quieting technology. Depending on the characteristics of the ocean environment the vessel was operating in, this could "decrease surveillance ranges by thirtyfold to a thousandfold" and reduce passive detection ranges from hundreds of miles to only a few (Tyler, 1992).

Toward the end of the Cold War passive sonars increasingly relied on "non-traditional"[7] sound signatures to identify submarine threats (Friedman, 2007a). Since the early 1990s this trend has continued, with the addition of air-independent propulsion (AIP) systems leading to as much as a 10 to 20 dB SPL additional reduction in diesel/electric submarine noise signatures. In many cases this employment of "low observability" technology is able to minimize a submarine's sound signature, and prevent or delay detection and identification, while simultaneously increasing the efficiency of a submarine's own sensors through the reduction of "self noise" (Nitschke, 2007). Improvements in submarine operational performance and quieting technology are further complimented by the proliferation of advanced weapons

6 A chokepoint is a strategic strait or canal that can be closed or blocked to stop sea traffic. Major chokepoints in the Indian Ocean area include the Straits of Hormuz, Straits of Malacca, and the Bab el-Mandab Strait.

7 The traditional sounds used to passively detect and identify ASW targets include; engine noise, sound from cavitation, or in the case of a nuclear powered submarine, sound from constant reactor cooling. These types of "traditional" sound signatures can be reduced though improved propeller design, the use of hull coatings, or sound isolating engine mounts. More difficult to control are "non-traditional" sounds, these might include crew noises or sounds from improperly maintained shipboard equipment.

and delivery systems, including submarine-launched cruise missiles, such as the supersonic BrahMos being jointly developed by Russia and India, and the submarine-launched ballistic missile capability being refined by China (Friedman, 2007b; DoD, 2009; ONI, 2009a).

At the same time as technological innovation has taken place, an increasing number of nations are developing or purchasing the technical expertise and capability necessary for the domestic manufacture of undersea assets. Although the proliferation of undersea capability through the purchase of the latest vessels and armament from Russian and Western Europe is troubling, the real threat comes from the transfer of submarine-related technology and training that often appends such transactions (Benedict, 2005; Davies, 2007). The number of countries that possess and operate nuclear submarines is also continuing to grow, with China rapidly improving its capacity to build effective nuclear-powered vessels, and India launching its first indigenously build nuclear submarine, the INS ARIHANT (ONI, 2009a; Rai, 2009).

In the early 21st century, the global submarine threat is becoming more diverse, with a greater number of nations operating newer and more-advanced submarines in a variety of environments. Many nations, including the Russian Federation and the People's Republic of China, have publicly declared that their submarines are the single most potent ship in their fleets, and the centerpiece of their respective navies. Iran, India, and Pakistan have made similar statements concerning the importance of submarines in national strategic planning. Iran has even gone so far as to suggest that Iranian undersea forces could be used for power projection into the Indian Ocean and to limit access to the Persian Gulf by blocking the Straits of Hormuz (Iranian State Television, 2008; ONI, 2009a and 2009b).

Kaplan (2009) notes that the Indian Ocean, bounded by two strategic chokepoints, the Straits of Malacca and Hormuz, will be the site of the major maritime arms race of the 21st century. Approximately 90 percent of all global goods and 65 percent of all oil currently travel by sea. Already an important waterway, the Indian Ocean is expected to grow more important economically and strategically in the coming decades (Kaplan, 2009). Throughout the western Pacific and Indian Oceans, a sea area which bridges the Arabian Peninsula through Southeast Asia and Japan, a striking number of nations are acquiring and modernizing their submarine forces (ONI, 2009b).

The Russian Federation has refocused its efforts on naval modernization and innovation (Yemelyanenkov, 2008). This has meant the completion of a number of pending submarine projects as well as the modernization and re-commissioning of several capable vessels, including the Typhoon Class *Dmitry Donskoy*, a nuclear-powered ballistic missile submarine. In addition, on 15 April 2007, the first of the new *Borei*-class of nuclear-powered ballistic missile submarine, the *Yuriy Dolgorukiy,* was launched at Sevmash Severodvinsk shipyard (Yemelyanenkov, 2008). The reinvigoration of Russian shipyards has additionally meant the greater availability of platforms and subsequent technology transfer to other countries in the region, including India, the Peoples Republic of China, and Indonesia.

Chinese development of undersea technology has accelerated noticeably in the last decade. It is likely that the rapid growth of the Chinese economy, from a Gross Domestic Product of $1.95 trillion in 2000 to $4.19 trillion in 2008, has contributed to an expanding military budget. Though Chinese maritime strategy has generally favored a policy of “offshore active defense,” recent activity suggests that the nation is attempting to project power further into the South China and Philippine Seas (DoD, 2009). One example of this is the 8 March 2009 harassment of the USNS IMPECCABLE (T-AGOS 23)[8], which is one of the current SURTASS LFA platforms, by several Chinese vessels, including an intelligence-gathering ship, a fisheries patrol vessel, an oceanographic administration vessel, and two trawlers. The Peoples Liberation Army Navy (PLAN) has approximately 60 operational submarines, of which eight are nuclear-powered (Funnel, 2009). Since the early 1990s the PLAN has shifted to focus efforts on the construction of a

8 This 5,370-ton ship is managed by the U.S. Military Sealift Command, under U.S. Navy operational command. T-AGOS stands for Tactical-Auxiliary General Ocean Surveillance. The IMPECCABLE was conducting standard underwater ocean surveillance in international waters, 75 nmi off Hainan Island, at the time of the incident.

smaller number of high-capability platforms (ONI, 2009a). The PLAN is already quite capable and of concern to other regional powers that fear Chinese projection of power in the Indian Ocean and potential impacts in the Taiwan Strait and regional shipping lanes.

In India, more than two decades of effort culminated in the launching of the INS ARIHANT on 26 July 2009 (Rai, 2009). The nuclear-powered ballistic missile submarine was developed with design assistance from the Russian Navy and is anticipated to be the first of five indigenously built submarines of the Indian ARIHANT class (Indian Express, 2007; Unnithan, 2009). These vessels would be a compliment to the existing German-built and Russian-built submarines in the Indian fleet. India may also be leasing two *Akula*-class Russian submarines, and recently completed negotiations to build six *Scorpene*-class diesel-electric submarines in India that will be equipped with Mesma® AIP systems.

Pakistan is also seeking to bolster its submarine fleet through domestic construction, with the commissioning on 26 September 2008 of its second domestically built *Agosta* 90B vessel.. This is Pakistan's third vessel of the class under a contract with the French shipbuilding firm DCN International, which involves not only the construction of submarines but also the transfer of technology (Pakistan Newswire, 2008). Additionally, the Pakistani Navy is in negotiations for the construction of several German-designed U 214 submarines, which would also be built in Pakistan. Other Southeast Asian nations that are in negotiations for or are seeking to acquire submarines in the region include Bangladesh, Indonesia, Singapore, Taiwan, and Malaysia (Choong, 2007; Liton, 2009).

Over 40 countries have operational submarines, and many are planning to increase the numbers in their naval fleets (Table 1-1). When the FSEIS was completed in 2007, there were 470 submarines operational or being built. Since that time, the number of submarines has increased substantially to between 582 and 613 that are operational or being built.

1.1.2 UNIQUE THREAT POSED BY DIESEL-ELECTRIC SUBMARINES

During the Cold War, the principal ASW threat to U.S. forces came from nuclear-powered Soviet missile and attack submarines in an open-ocean environment. These submarines, though fast, well armed, and capable, could be effectively monitored using passive sonar. Passive systems technology has traditionally been the dominant means used by U.S. Naval forces to conduct long-range surveillance and initial classification of enemy undersea threats. These passive systems, which were developed to a high degree of sophistication during the Cold War, had the benefit of stealth, emitting no noise that could be detected by enemy forces. They were particularly effective tools against the relatively noisy Soviet submarines and allowed effective, accurate tracking at significant distance (Tyler, 1992).

In recent years, the use of relatively inexpensive diesel-electric submarines has caused interest in submarine technology and undersea capability to increase dramatically. World War II-era diesel-electric submarines were quiet, however, they were restricted in their underwater operations by a requirement to surface or snorkel frequently to recharge their batteries, which left them more vulnerable to detection during those periods. With the advent of AIP systems, these quiet, diesel-electric submarines can operate for much longer periods of time underwater and are the primary ASW threat facing the U.S. military today. AIP, a term that encompasses several technologies, allows conventional submarines to operate submerged for much longer periods without the need to surface to run their diesel generators from atmospheric oxygen to recharge batteries. One of the most promising AIP technologies uses fuel cells such as those being installed on German U 212A and U 214 submarines. Conventional submarines rely on electric motors for propulsion while submerged, and underwater performance is hampered by the limited capacity of marine batteries and the need to periodically surface and recharge. AIP greatly increases their capability by allowing the diesel-electric submarine to operate submerged for greater lengths of time, potentially for several weeks to a month (Whitman, 2001).

Table 1-1. **World inventory of operational and building submarines[9] (Funnell, 2009; ONI, 2009a and 2009b; Rai, 2009).**

COUNTRY	TOTAL NUCLEAR POWERED	TOTAL NUCLEAR BUILDING	TOTAL CONVENTIONAL & NON-NUC AIP	TOTAL CONVENTIONAL BUILDING	MINI-SUBS[10]
ATLANTIC/BALTIC/MEDITERRANEAN/BLACK[11]					
Algeria			2		
Bulgaria			1		
Canada			4		
Egypt[12]			4		
Germany			10	6	
Greece			8	4	
Israel			3	2	
Italy			7	2	
Netherlands			4		
Norway			6		
Poland			5		
Portugal			1	2	
Spain			4	4	
Sweden			5		
Turkey			14		
Ukraine			1		
SOUTH AMERICA					
Argentina			3		
Brazil			5		
Chile			4		
Columbia			2		2
Ecuador			2		
Peru			6		
Venezuela			2	3	
WESTERN PACIFIC/INDIAN OCEAN[13, 14]					

9 World submarine inventory does not include training, research, or rescue subs. Additionally, this inventory does not include underwater autonomous or swimmer delivery vehicles.
10 Included are mini-subs of tactical value; non-swimmer delivery vehicles with the ability to deliver torpedoes or mines.
11 Libya possesses two Foxtrot class submarines of questionable operational capability. The country may be acquiring one or two Kilo class Russian diesel-electric submarines in the near future.
12 Egypt may be in negotiations with Germany for the acquisition of several Dolphin class submarines.

Table 1-1. World inventory of operational and building submarines[9] (Funnell, 2009; ONI, 2009a and 2009b; Rai, 2009).

COUNTRY	TOTAL NUCLEAR POWERED	TOTAL NUCLEAR BUILDING	TOTAL CONVENTIONAL & NON-NUC AIP	TOTAL CONVENTIONAL BUILDING	MINI-SUBS[10]
Australia			6		
Indonesia			2		
Iran			3	3	9
Japan			19	4	
Malaysia				2	
North Korea			23		65
Pakistan			5	3 – 4	3
Singapore			4		
South Africa			3		
South Korea			10	12 – 13	2
Taiwan			2		
US/UK/FRANCE/RUSSIA/CHINA/INDIA					
United States	70	18			
United Kingdom	12	4 – 7			
France	9	10			
Russia	42	5 - 10	19	2	
Peoples Republic of China	9	4 – 6	53	2 – 10	
India	1	4 – 12	16	6	
Total Nuclear	142				
Total Nuclear Building		45 – 63			
Total Conventional/Non-Nuclear AIP			269		
Total Conventional/Non-Nuclear AIP Building/Conversion				54 – 64	
Total Mini-Subs					76
Projected World Submarine Population (42 Countries)					582 – 613

Diesel electric submarines, with and without the inclusion of AIP, have several characteristics which make their operation different from that of nuclear submarines. These include their ability to operate in several modes, some of which are almost entirely silent, such as when they run entirely on battery power. A

13 The Bangladesh Navy has pledged, in a recently released 10-year naval development plan, to purchase an undisclosed number of submarines by 2019 (Liton, 2009).

14 In December 2009, the Vietnamese government assigned a contract to purchase six Russian Kilo class diesel-electric submarines along with a variety of other military hardware (Pham, 2009).

significant capability of diesel-electric submarines is their ability to shut down most machinery while hovering motionless near the ocean floor. An experienced diesel-electric submarine operator could remain stationary and nearly undetectable in this state for as long as breathable air was available. Additionally, diesel-electric submarines have benefited from the same advances in quieting technology used on larger nuclear-powered submarines. Due to their smaller size, the current generation of diesel-electric submarines is ideally suited for operation in littoral and near-shore areas. The combination of advanced quieting technologies and AIP makes the modern diesel-electric submarine a formidable threat.

With batteries and fuel cells achieving higher capacities and as AIP technology matures, the advantages of nuclear-powered submarines over diesel-electric submarines equipped with AIP will continue to narrow. Quite the contrary, future naval activities are no longer principally designed to combat open-ocean, nuclear submarine threats; will most likely occur throughout the strategic areas of the World's oceans and sea lanes; and will utilize quieter, advanced diesel-electric submarines.

1.1.3 ASW Challenges in the Littoral Environment

The Navy defines "littoral" as the region that horizontally encompasses the land/water mass interface from 50 statute miles (80 km) ashore to 200 nmi (370 km) at sea; extends vertically from the bottom of the ocean to the top of the atmosphere and from the land surface to the top of the atmosphere (Naval Oceanographic Office, 1999). The term littoral is one of the most misunderstood terms used in naval warfare. The common definition of littoral means pertaining to the shore or a shore or coastal region, while the marine science definition refers to the shallow-water zone between low- and high-tide. The Navy's meaning differs because it is based on a tactical, not geographic or environmental, perspective relating to overall coastal operations, including all assets supporting a particular operation regardless of how close, or far, from the shore they may be operating.

The U.S. military anticipates that future naval conflicts are most likely to occur within the littoral or coastal areas. This is a further complication to the Naval ASW mission and a distinct change from the Cold War era, where conflicts were most likely to occur in mid-ocean areas. The shift from open ocean areas to shallower, acoustically complex, near-shore areas forces extensive changes in the ways in which ASW operations can be conducted. Littoral areas have greatly variable and frequently high underwater background noise. This is largely a result of commercial shipping and complex underwater acoustic propagation conditions, such as multi-path propagation, which makes detection of underwater threats much harder and detection ranges shorter (Farrel, 2003)

A predominant factor affecting passive sonar usefulness in the littoral environment is the fact that over the past decades, while submarines have been becoming quieter, underwater ambient noise levels in littoral ocean areas have increased (Ort et al., 2003). With passive sonar alone, it is likely that U.S. Forces would not have adequate time to react to and defend against enemy submarine threats. SURTASS LFA sonar provides the U.S. Navy with the most effective and best available means to monitor submarines at long range in littoral areas, at distances sufficient to allow them to be detected and tracked before they pose a threat to U.S. or allied naval/land forces, or civilian coastal targets.

The U.S. and other nations have conducted research on numerous acoustic and non-acoustic solutions to this problem, including active sonar. According to the Netherlands Organization for Applied Scientific Research–Physics and Electronics Laboratory, "The smaller and quieter coastal diesel-electric and midget submarines can only be detected in the noisy coastal environments by a low frequency active sonar (LFAS) approach" (Ort et al., 2003). Their work and the research of other organizations have shown that LFAS is successful at long-range detection, even in shallow water. Active sonar does not depend on the submarine target to generate noise; therefore, the use of active sonar eliminates advantages gained by the use of quieting technologies.

A prime example of the importance of littoral areas is in the waters of Eastern Asia, including the shallow waters of the South China Sea, East China Sea, Sea of Japan, and Philippine Sea. Other areas are in the

Middle East, the Persian Gulf, Strait of Hormuz, and Gulf of Oman. Many of the world's busiest sea lanes pass through these waters, carrying billions of dollars in American investments and a significant amount of the world's trade goods (Farrell, 2003).

1.1.4 NON-ACOUSTIC ALTERNATIVE ASW DETECTION TECHNOLOGIES

Non-acoustic ASW detection technologies were reviewed in the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001) to determine their usefulness in the long-range detection of submarines. These technologies included radar, laser, magnetic, infrared, electronic, electric, hydrodynamic, and biologic detection systems. The analysis presented in Subchapter 1.2.1 of the FOEIS/EIS was reviewed and updated. The analysis presented in the FOEIS/EIS remains valid except as noted below and the contents are incorporated herein by reference.

- **Radar:** Synthetic Aperture Radar (SAR) allows for the long-range detection of surfaced submarine wakes or periscope "feathers" from satellites and aircraft. This system is of limited operational use because 1) the submarine must either be underway on the surface or at periscope depth with the periscope deployed, and 2) there must be a confluence of near-perfect meteorological and oceanographic conditions (which rarely occur) for the system to function. Additionally, SAR is most effective when being used to observe fixed objects, such as terrain, cities, and military bases. Inverse Synthetic Aperture Radar (ISAR) is a technique to generate a two-dimensional high resolution image of a target. In situations where other radars display only a single unidentifiable bright moving pixel, the ISAR image is often adequate to discriminate between various missiles, military aircraft, and civilian aircraft. ISAR is best used against moving targets, including surfaced submarines (FAS, 1998).
- **Magnetic:** The AN/ASQ-233 Multi-Mode Magnetic Detection System (3MDS) is the latest generation of airborne Magnetic Anomaly Detection (MAD) technology for use by rotary-wing and fixed-wing ASW platforms. This system is based on the helium-4 atomic magnetometer technology. Helium sensor technology has been incorporated into experimental and developmental airborne and sea bottom sensor systems going back to the 1970s. 3MDS provides the warfighter with a MAD localization and attack sensor that performs better than the MAD sensor systems currently fielded in the U.S. Navy's P-3C Orion aircraft and SH-60B Seahawk helicopter fleets. 3MDS will also provide detection capability of extremely low frequency (ELF) electromagnetic signatures, which does not exist with the older systems (ONR, 2008). However, 3MDS only provides short-range detection.
- **Infrared:** High Performance Mobility Forward Looking Infrared (FLIR), is based on the SeaFLIR® III imaging system and includes a laser rangefinder, a choice of mid or large format thermal imager, an image intensified television and laser pointer, coupled with navigation inputs to provide precise geo-locating capability. However, infrared detection is limited to "line-of-sight" and, therefore, if deployed from an aircraft or surface vessel, can only provide short- to medium-range detection (AIA, 2009).
- **Optical:** Over the last two decades research has been conducted at universities and Navy laboratories in an attempt to exploit spectral and polarization information present in the light reflected from targets and backgrounds relevant to Naval missions. Missions can range from the detection and targeting of specific platforms to the monitoring of marine mammals whose presence will impact naval acoustic testing. Other missions include naval search and rescue, near-shore mine detection, and many other surveillance and reconnaissance operations. This research has revealed that spectral and polarization information is exploitable using an appropriate electro-optical system. Current Naval electro-optical imaging systems are designed for very general applications utilizing three-color video technologies. While producing high quality pictures and subsequent situational awareness, the systems are not designed for target detection and are not capable of exploiting narrowband spectral or polarization information present in the light reflected from the target (ACT, 2009).

Although non-acoustic detection methods have demonstrated some utility in detecting submarines, this review supports the conclusion in the FOEIS/EIS that they cannot reliably provide U.S. forces with long-range detection (hundreds of nautical miles) and longer reaction times due to a number of critical factors:

- Limited range of detection;
- Meteorological and oceanographic limitations;
- Unique operating requirements; and/or
- Requirements for the submarine to be at or near the surface for detection.

Active and passive acoustic sensors continue to be the primary and most effective detection method for diesel and nuclear submarines in deep ocean and littoral areas.

1.2 BACKGROUND

Consistent with responsible stewardship of the environment, the U.S. Navy is firmly committed to the protection of marine species and is mindful of the potential effects that man-made sound may have upon marine life. The Navy has conducted research on the potential for effects of low- and mid-frequency active sonar systems on some marine species, and has demonstrated that, under certain circumstances and conditions, use of active sonar can have an effect upon particular marine species.

Compliance with numerous environmental laws and regulations is mandatory. This process of balancing national security with environmental stewardship of the oceans is complex, costly, and lengthy.

1.2.1 INITIAL REGULATORY COMPLIANCE AND LITIGATION

Prior to NMFS promulgating the current five-year Rule (NOAA, 2007a) and LOAs, there were a number of key regulatory and litigation events. The timeline and details about these events are included here for context and perspective.

1.2.1.1 Initial NEPA Compliance

The NEPA process for SURTASS LFA sonar began on 18 July 1996, when the Navy published its notice of intent (NOI) to prepare an EIS/OEIS for SURTASS LFA sonar under NEPA and EO 12114 (DoN, 1996). The process culminated with the signing of the ROD on 16 July 2002 (DoN, 2002). During the NEPA analysis the Navy recognized there were scientific data gaps concerning the potential for moderate-to-low exposure levels to affect cetacean hearing ability or modify biologically important behavior. As a result of this limitation, the Navy sponsored independent, scientific field research referred to as the Low Frequency Sound Scientific Research Program (LFS SRP). This groundbreaking research program found that the potential for SURTASS LFA sonar to cause these effects would be minimal.

1.2.1.2 Initial MMPA and ESA Authorizations

Based on the scientific analyses detailed in the Navy LOA application and further supported by information and data contained in the Navy's FOEIS/EIS (DoN, 2001), NMFS determined that the operations of SURTASS LFA sonar would employ means of effecting the least practicable adverse impact on the species or stock, that would result in the incidental harassment of only small numbers of marine mammals, have no more than a negligible impact on the affected marine mammal stocks or habitats, and would not have an unmitigable adverse impact on the availability of such species or stocks for taking for subsistence uses. Consequently NMFS issued the initial LOA (NOAA, 2002a) under the MMPA Final Rule (50 CFR Part 216 Subpart Q) (NOAA, 2002b) for the operation of SURTASS LFA Sonar on research vessel (R/V) *Cory Chouest*. The ESA section 7 consultation on the issuance of the above MMPA final rule and the associated LOAs found that NMFS' action was not likely to jeopardize the continued existence of threatened or endangered species under NMFS' jurisdiction or destroy or adversely modify critical habitat that has been designated for those species. The first biological opinion (BiOp) issued by NMFS was a 5-year programmatic document on the MMPA rule making (NMFS, 2002a). It was followed by the annual

BiOp for the LOAs. After the initial LOA was issued in 2002, the Navy requested annual renewals in accordance with 50 CFR §216.189 for the remaining four years of the 2002 Final Rule for the R/V *Cory Chouest* and USNS IMPECCABLE. NMFS subsequently issued the LOAs (NOAA, 2003a, 2004, 2005, and 2006a).

1.2.1.3 National Defense Authorization Act

On November 24, 2003 the National Defense Authorization Act for Fiscal Year 2004 (NDAA FY04) (Public Law 108-136) was passed by Congress. Included in this law were amendments to the MMPA (16 U.S.C. 1361 et seq.) that apply where a "military readiness activity" is concerned. Of special importance for SURTASS LFA sonar take authorization, the NDAA amended Section 101(a)(5) of the MMPA, which governs the taking of marine mammals incidental to otherwise lawful activities. The term "military readiness activity" is defined in Public Law 107-314 (16 U.S.C. §703 note) to include all training and operations of the Armed Forces that relate to combat; and the adequate and realistic testing of military equipment, vehicles, weapons and sensors for proper operation and suitability for combat use. NMFS and the Navy determined that the SURTASS LFA sonar testing, training and military operations that are the subject of NMFS' Final Rule constituted a military readiness activity because those activities constitute "training and operations of the Armed Forces that relate to combat" and constitute "adequate and realistic testing of military equipment, vehicles, weapons and sensors for proper operation and suitability for combat use."

The provisions of this act that specifically relate to SURTASS LFA sonar concern revisions to the MMPA, as summarized below:

- Amended definition of "harassment" as it applies to military readiness activities and scientific activities conducted on behalf of the Federal government.
- Level A "harassment" defined as any act that injures or has the *significant* potential to injure a marine mammal or marine mammal stock in the wild.
- Level B "harassment" defined as any act that disturbs or is *likely to disturb* a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering *to a point where the patterns are abandoned or significantly altered*.
- Secretary of Defense may invoke a national defense exemption not to exceed two years for Department of Defense (DoD) activities after conferring with the Secretary of Commerce and the Secretary of Interior, as appropriate.[15]
- NMFS' determination of "least practicable adverse impact on species or stock" must include consideration of personnel safety, practicality of implementation, and impact on the effectiveness of the military readiness activity.
- Eliminated the "small numbers" and "specified geographic region" requirements from the incidental take permitting process for military readiness activities.

1.2.1.4 Initial Litigation

As a result of litigation filed in August 2002, the Court issued a tailored Preliminary Injunction on 15 November 2002 for operations of SURTASS LFA sonar in a stipulated area in the northwest Pacific Ocean/Philippine Sea, and south and east of Japan. The Court issued a ruling on the parties' motions for summary judgment in the SURTASS LFA sonar litigation on 26 August 2003. The Court found deficiencies in the Navy's and NMFS' compliance under NEPA, ESA, and MMPA. The Court, however,

15 SURTASS LFA sonar has never been deployed under this national defense exemption.

indicated that a total ban of employment of SURTASS LFA sonar would pose a hardship on the Navy's ability to protect national security by ensuring military preparedness and the safety of those serving in the military from hostile submarines. Based on Court-directed mediation between the parties, the Court issued a tailored Permanent Injunction on 14 October 2003, allowing SURTASS LFA sonar operations from both R/V *Cory Chouest* and USNS IMPECCABLE (T-AGOS 23) in stipulated areas in the northwest Pacific Ocean/Philippine Sea, Sea of Japan, East China Sea, and South China Sea with certain year-round and seasonal restrictions. On 7 July 2005, the Court amended the injunction to expand the potential areas of operation based on real-world contingencies.

Under the Court's opinion, NMFS was found to have improperly conflated its negligible impact determinations with small numbers requirements. As a result of the NDAA FY04 amendments to the MMPA eliminating this issue, the Court vacated and dismissed the MMPA small numbers and specific geographic regions claims on 2 December 2004.

1.2.2 CURRENT REGULATORY COMPLIANCE AND LITIGATION

In response to the Court's October 2002 Opinion and Order granting a Preliminary Injunction, the DASN(E) decided that the purposes of NEPA would be served by supplemental analysis for employing SURTASS LFA sonar systems. On 11 April 2003, DASN(E) directed the Navy to prepare a SEIS to address concerns identified by the Court to provide additional information regarding the environment that could potentially be affected by SURTASS LFA sonar systems, and additional information related to mitigation. On 26 September 2003, NMFS agreed to be a fully cooperating agency in the preparation and review of the SEIS. The information developed from this analysis was used to support the Navy's application for the second five-year Rule under the MMPA (DoN, 2006a) and the Navy's Biological Assessment for Section 7 consultation under the ESA (DoN, 2006b).

1.2.2.1 Supplemental Regulatory Compliance and Litigation

The Draft SEIS (DSEIS) was completed in November 2005 (DoN, 2005a) with the 90-day comment period ending in February 2006. During this period, three public hearings were held, in Washington, D.C.; San Diego, CA; and Honolulu, HI. Ninety-seven (97) comments were received on the DSEIS.

The Final SEIS (FSEIS), which included detailed responses to all comments received, was completed in May 2007 (DoN, 2007a). The purpose of the first SURTASS LFA Sonar SEIS was to:

- Address concerns of the U.S. District Court for the Northern District of California in its 26 August 2003 Opinion and Order in relation to compliance with the NEPA, ESA, and MMPA[16];
- Provide information necessary to apply for a new five-year Rule that would provide for incidental takes under the MMPA when the current Rule expired in 2007, taking into account legislative changes to the MMPA and the need to employ up to four SURTASS LFA sonar systems;
- Analyze potential impacts for LFA system upgrades; and
- Provide additional information and analyses pertinent to the proposed action.

1.2.2.2 Current MMPA and ESA Authorizations

On 12 May 2006, the Navy submitted an Application to NMFS requesting an authorization under Section 101 (a)(5)(A) of the MMPA for the taking of marine mammals by Level A and Level B harassment incidental to the deployment of SURTASS LFA sonar systems for military readiness activities, to include routine training, testing, and military operations (DoN, 2006a). The activities are associated with the employment of up to four SURTASS LFA sonar systems for a period of five years (16 August 2007 to 15 August 2012).

16 On 2 December 2004, the Court vacated and dismissed the MMPA claims based on the National Defense Authorization Act Fiscal Year 2004 (NDAA FY04) amendments to the MMPA.

The Navy submitted a Biological Assessment for the Employment of SURTASS LFA Sonar on 9 June 2006, requesting that NMFS review the document (DoN, 2006b). The Navy further requested a Biological Opinion/Incidental Take Statement under Section 7 of the ESA for a period of five years (16 August 2007 to 15 August 2012).

On 28 September 2006, NMFS published a Notice of Receipt of Application and a request for public comments on the Navy's application for authorization to take marine mammals incidental to the operation of SURTASS LFA sonar systems (NOAA, 2006b). The public comment period closed on 30 October 2006. These comments were considered in the development of the Proposed and Final Rules. A Proposed Rule for the renewal of the regulations governing SURTASS LFA sonar MMPA authorization was published on 9 July 2007 (NOAA, 2007b) with a 15-day public comment period. NMFS filed the Final Rule on 15 August 2007 and published on 21 August 2007 (NOAA, 2007c). The initial LOAs under the 2007 Rule were issued by NMFS to the Chief of Naval Operations (N872A) for the R/V *Cory Chouest* and the USNS IMPECCABLE for the period 16 August 2007 to 15 August 2008 (NOAA, 2007a).

NMFS issued, on 14 August 2007, its Biological Opinion on the effects of NMFS' Permits, Conservation and Education Division's proposal to promulgate regulations allowing NMFS to authorize the taking of marine mammals incidental to the Navy's employment of SURTASS LFA sonar in accordance with Section 7 of the ESA, as amended (16 U.S.C. 1531 et seq.) (NMFS, 2007a). On 15 August 2007 (as amended on 17 August 2007), NMFS issued its Biological Opinion/Incidental Take Statement on the effects of the proposed LOAs (effective 16 August 2007 to 15 August 2008) to take marine mammals incidental to the Navy's employment of SURTASS LFA sonar in accordance with Section 7 of the ESA, as amended (16 U.S.C. 1531 et seq.) (NMFS, 2007b and 2007c). The opinions concluded that the proposed LOAs and any takes associated with activities authorized under those regulations were not likely to jeopardize threatened or endangered species in the action area, and that the proposed action was not likely to destroy or adversely modify designated critical habitats.

1.2.2.3 Litigation of Current Regulatory Compliance

On 17 September 2007, a number of plaintiffs filed a lawsuit challenging actions by the Navy and NMFS regarding compliance with NEPA, MMPA, ESA, and the Administrative Procedure Act (APA) for the operation of SURTASS LFA sonar.

On 6 February 2008, the Court issued its Opinion and Order granting in part Plaintiffs' motion for a Preliminary Injunction and required the parties to meet and confer on the precise terms of the Preliminary Injunction. Mediation sessions were held on 26 March 2008 and 27 May 2008 at the U.S. District Court, Northern District of California, in San Francisco, CA.

During the mediation on 26 March 2008, agreement was reached that SURTASS LFA sonar would operate in the Western Pacific areas stipulated in the 2003 Permanent Injunction, as amended in 2005, with the following modifications:

- Stipulated LFA Operational Agreement permitting SURTASS LFA sonar operations up to, but not within, 22 km (12 nmi) from the coast—when necessary to continue tracking an existing underwater contact or when operationally necessary to detect a new underwater contact to maximize opportunities for detection.
- Additional terms include assuring the LFA sound field does not exceed 180 dB re 1 µPa (rms) at a distance of less than 18 nmi from:
    - Islands of the Luzon Strait, including the Bashi Channel; and
    - Eastern coastlines of the islands of the Ryukyu Archipelago.

During the mediation on 27 May 2008, agreement was reached on overall settlement of the litigation, which included the agreement that SURTASS LFA sonar could operate in the Hawaii operating areas. The settlement also permits SURTASS LFA sonar operations up to 22 km (12 nmi) from the coast when necessary to continue tracking an existing underwater contact, or when operationally necessary to detect a new underwater contact to maximize opportunities for detection within the Hawaii operating areas.

On 12 August 2008, the Court approved the settlement and, on 29 August 2008, the Court signed the Stipulated Voluntary Dismissal with Prejudice, which effectively ended the litigation. The LOAs issued by NMFS to the USNS ABLE, USNS IMPECCABLE, USS EFFECTIVE, and USNS VICTORIOUS for the remainder of the current Rule are and will be based on the expanded operating areas described above.

1.2.3 SYSTEM UPGRADES

SURTASS LFA is part of the Integrated Undersea Surveillance System (IUSS), which is designed to detect, classify, and track diesel-electric and nuclear submarines operating in both shallow and deep regions of littoral and oceanic waters. The majority of IUSS operational sensors were developed based on deep-water, open-ocean threat scenarios. However, to meet current and future surveillance requirements, IUSS sensors must be adapted or developed to operate in littoral or regional ocean areas where conflicts are most likely to occur. Additionally, IUSS active sensors must possess the ability to work independently or cooperatively with other IUSS, Navy, and allied nations' assets. Three different modes of operation are considered: 1) mono-static[17] or independent operations, 2) bi-static operations where one system functions as the active source and other assets function as the receiver; and 3) multi-static operations where multiple active sources are employed cooperatively with multiple receivers.

To meet these emergent requirements, the Navy initiated a program to upgrade individual undersea surveillance systems. This included SURTASS LFA sonar system upgrades and modifications necessary to install and operate LFA from the smaller VICTORIOUS Class (T-AGOS 19 Class) ocean surveillance ships (Figure 1-2). For the active system, this upgrade is known as Compact LFA, or CLFA, and is currently installed onboard the USNS ABLE (T-AGOS 20) and USNS EFFECTIVE (T-AGOS 21). Also included are upgrades to the SURTASS array capabilities for shallow-water operations and enhanced passive detection capabilities.

1.3 ENVIRONMENTAL IMPACT ANALYSIS

As stated earlier, the purpose of this DSEIS/SOEIS is to address recent concerns raised during litigation over employment of the SURTASS LFA sonar system, and to support issuance of a follow-on five-year Rule under the MMPA for employment of SURTASS LFA sonar systems. This DSEIS/SOEIS provides further analyses of the following:

- Potential additional OBIAs (greater than 22 km [12 nmi]) in regions of the world where the Navy intends to use the SURTASS LFA sonar systems for routine training, testing, and military operations.
- Whether using a larger coastal standoff distance where the continental shelf extends further than current standoff distance is practicable for SURTASS LFA sonar, at least in some locations.
- Potential cumulative impacts involving concurrent use of SURTASS LFA sonar with other active sonar sources.

17 Mono-static means the active source and receiver are co-located. For SURTASS LFA sonar, the LFA transducers in a vertical line array are the source and the horizontal towed line array is the receiver.

Figure 1-2. VICTORIOUS class (T-AGOS 19 Class) ocean surveillance ship.

Additional Draft SEIS/SOEIS analyses include:

- Updating literature reviews, especially for fish, sea turtles, and marine mammals;
- New subchapter on protected habitats, including ESA Critical Habitat, Essential Fish Habitat, and Marine Protected Areas;
- Updated literature review on commercial fisheries, marine mammal strandings, cumulative effects from anthropogenic oceanic noise, cumulative effects on socioeconomic resources; and
- Mitigation measures: changes due to increased number of OBIAs.

Information from these analyses is used to assist the Navy in determining how to employ SURTASS LFA sonar, including the selection of operating areas that the Navy requires for routine training, testing, and military operations in requests for MMPA LOAs submitted to NMFS.

1.4 ANALYTICAL CONTEXT

For the most part, there have been no substantial changes to the framework for the development of the analytical context since the FSEIS (DoN, 2007a). The following Subchapters address this topic in more detail.

1.4.1 ADEQUACY OF SCIENTIFIC INFORMATION ON HUMAN DIVERS

There have been no significant changes to the knowledge or understanding for the potential effects of LF sound on humans in water since the FSEIS relating to the establishment of the 145-dB re 1 µPa (rms) (RL) criterion for recreational and commercial divers (DoN, 2007a). The information in Subchapter 1.4.1 of the FOEIS/EIS (DoN, 2001) concerning the research by the Naval Submarine Medical Research Laboratory, numerous universities, and private organizations, which was the basis for establishing the criterion, remains valid, and the contents are incorporated herein by reference.

1.4.2 ADEQUACY OF SCIENTIFIC RESEARCH ON MARINE ANIMALS

There have been changes to the knowledge and understanding of the potential for LF sound to affect marine species since the FSEIS. Although some of the new information is substantial, it does not change the framework of the analytical context of the FOEIS/EIS and FSEIS. Where there were scientific data gaps regarding the potential for effects from LF sound on marine life, conservative assumptions were made (see Subchapter 1.4.3 below). Therefore, the analyses and conclusions in both the FOEIS/EIS and FSEIS were conservative, meaning that the analysis overstates the potential impacts to marine mammals. Several key scientific papers and research that are relevant to the conservative assumptions of the FOEIS/EIS and FSEIS are discussed in this subchapter.

Based on Southall et al. (2007), the criteria utilized in the FOEIS/EIS and FSEIS were conservative and remain valid for that document's analysis of the potential effects of LF sound on marine animals. The contents of Subchapter 1.4.2 of the FOEIS/EIS and FSEIS relating to data gaps on marine species for the assessment of potential risk through exposure to LF sound and the research funded by the Navy to fill these gaps are incorporated herein by reference. Additional and updated information on the potential effects on marine mammals and fish from LF sound are included in this DSEIS/SOEIS, and are outlined below.

For the purposes of the SURTASS LFA sonar analyses presented in the FOEIS/EIS and FSEIS, marine animals exposed to received levels ≥180 dB re 1 µPa (rms) were evaluated as if they were injured. This level was considered conservative.

1.4.2.1 Estimating the Potential for Injury to Marine Mammals

There have been changes to the knowledge and understanding of the potential for LF sound to affect marine mammal species since the FSEIS. Southall et al. (2007) is a benchmark paper written by a panel of scientific experts in the fields of biology and acoustics, with the purpose of: 1) reviewing the expanding literature on marine mammal hearing and physiological and behavioral responses to anthropogenic sound, and 2) proposing [acoustic] exposure criteria for certain effects; i.e., the exposure levels above which adverse effects on various groups of marine mammals are expected. The paper addresses the potential for onset of temporary threshold shift (TTS) and permanent threshold shift (PTS) from underwater acoustic exposure and discusses options for attempting to address adverse behavioral response. These topics are covered without directly linking them to existing regulations such as the MMPA or ESA. Extant research on these topics is discussed in some detail and recommendations for overcoming shortfalls in both data and basic research issues are presented in this DSEIS/SOEIS.

Southall et al. (2007) proposed injury criteria based on the onset of PTS for LF/mid frequency (MF)/high frequency (HF) marine mammal groups exposed to non-pulse sound types, which included discrete acoustic exposures from SURTASS LFA sonar:

- For LF, MF, and HF cetaceans: SPL: 230 dB re 1 µPa (peak) (flat); SEL: 215 dB re 1 μPa^2-sec.
- For pinnipeds (in water): SPL: 218 dB re 1 µPa (peak) (flat); SEL: 203 dB re 1 μPa^2-sec.

As stated in the FOEIS/EIS (p. 10-47), the sound field of the LFA array (i.e., the actual pressure or maximum [rms] SPL received levels observed surrounding the LFA array) can never be higher than the source level of an individual projector, or 215 dB re 1 µPa at 1 m (rms). The theoretical "point source" level and beam pattern for the whole array is only valid when range from the array is sufficient for the array to appear as a point source (i.e., the receiver location is in the far field or approximately 100 m or more from the array). Thus, when compared to the dual criteria for "non-pulse" sources as presented in Southall et al. (2007), the SPL criterion of 230 dB re 1 μPa (peak) (flat) cannot be exceeded, while the SEL criterion of 215 dB re 1 μPa^2-sec, can only be exceeded if an animal stays within approximately 10 m of the array for the full 60 seconds of a typical transmission (i.e., the animal must be adjacent to the source and then move in the speed and direction of the source ship for the entire 60 seconds). Therefore, it is highly unlikely that SURTASS LFA sonar creates sound fields that exceed either of the above dual proposed injury criteria. The Southall et al. (2007) panel of experts considered the noise exposure criteria to be an initial step in an iterative process to understand and predict the effects of noise on marine mammals. To remain consistent with the previous FOEIS/EIS (DoN, 2001), FSEIS (DoN, 2007a), MMPA Rules and LOAs, and ESA biological opinions, this DSEIS/SOEIS will continue to utilize the 180-dB SPL (RL) criteria for injury to marine mammals with the understanding that this value is now considered to be extremely conservative. As an illustration of this conservativeness, if it is assumed that an animal remains at a range where it receives an SPL of 180 dB re 1 μPa (rms) (i.e., within about 1 km of the moving source and it remains undetected) for over 10 hours of LFA transmissions at 12 minute intervals (or 5 transmissions per hour) and with 60-sec durations, the equivalent SEL received level for this situation is 215 dB re 1 μPa^2-sec (i.e., 180 + 10×Log [60 sec] + 10×Log [50 signals] = 180 + 18 + 17 = 215).

Since the FOEIS/EIS, concerns have been raised about direct impacts on marine mammal tissue, indirect impacts on tissues surrounding a structure, and acoustically-mediated gas bubble growth within tissues from supersaturated dissolved nitrogen gas. These issues were discussed in the FSEIS. Regarding bubble formation as a casual mechanism between acoustic exposure and stranding events, Southall et al. (2007) states that at present there is scientific disagreement and/or complete lack of existing information regarding important points to establish explicit exposure criteria for this proposed mechanism.

There has been no direct evidence of any injury or stranding of marine mammals either during the brief periods of the SURTASS LFA sonar research projects in the late 1990s (which were conducted close to land, with extensive monitoring and during periods of high marine mammal densities, and in areas where SURTASS LFA sonar will not operate) nor since LFA operations were resumed in 2003 (DoN, 2007c and 2008).

1.4.2.2 Estimating the Potential for Behavioral Effects to Marine Mammals

There have been no significant changes to the knowledge or understanding of the potential for SURTASS LFA sonar sound to significantly modify biologically important behavior in marine mammals since the FSEIS. Findings from the Navy-funded Low Frequency Sound Scientific Research Program (LFS SRP) did not reveal any significant change in a biologically important behavior in LF marine mammals, and the risk analysis estimated very low risk. The information in Subchapter 1.4.2.2 of the FOEIS/EIS concerning the LFS SRP remains valid, and the contents are incorporated herein by reference.

1.4.2.3 Masking

There have been changes to the knowledge or understanding of the potential for SURTASS LFA sound to mask underwater sounds that are biologically important to marine mammals since the FSEIS, as discussed in Subchapter 4.3.2.4 of this document. However, the conclusions reached in the FOEIS/EIS with regard to masking in marine animals were that any masking effects would be temporary and are expected to be negligible because the SURTASS LFA sonar bandwidth is very limited (approximately 30 Hz), signals do not remain at a single frequency for more than ten seconds, and the system is off at least 90 percent of the time. Therefore, the information in Subchapter 1.4.2.3 of the FOEIS/EIS remains valid, and the contents are incorporated herein by reference.

1.4.2.4 Estimating the Potential for Injury to Fish Stocks

There has been significant advancement in the knowledge and understanding of the potential for SURTASS LFA sound to affect marine fish species since the FSEIS. Several recent studies have shown that sounds substantially above 180 dB re 1 µPa (rms) (RL) have little or no effects on the physiology of fish (e.g., Popper et al., 2005a and 2007; Hastings et al., 2008).

Due to the lack of scientific data relating to the potential for LF sound to affect fish stocks, an independent scientific research program was funded to examine whether exposure to high-intensity, low frequency sonar, such as SURTASS LFA, would affect fish. The fish controlled exposure experiment (CEE), which was conducted in 2005 and 2006 by the University of Maryland, was designed to examine the effects of LFA on hearing, the structure of the ear, and selected non-auditory systems in a salmonid (rainbow trout) channel catfish and hybrid sunfish. The results, first presented in the FSEIS (pp. 4-10 to 4-18) (Popper et al., 2005a; Halvorsen et al., 2006), have been updated based on peer-reviewed, published results (Popper et al., 2007). The results clearly show that there are no pathological effects from sound exposures up to received levels of 193 dB re 1 µPa (rms) (Kane et al., 2010). This is consistent with the initial results reported in the FSEIS.

1.4.2.5 Marine Mammal Strandings

There have been no significant changes to the knowledge or understanding of the potential for strandings caused by use of SURTASS LFA. The data presented on beaked whale strandings in Subchapter 3.2.5.1 of the FOEIS/EIS are still valid and are incorporated herein by reference. Additional information on marine mammal strandings was presented in Subchapter 4.4.3 of the FSEIS and its contents are incorporated herein by reference. None of these strandings involved SURTASS LFA sonar and there have been no strandings reported since the FSEIS was published that were coincident with recent SURTASS LFA sonar operations.

1.4.3 ANALYTICAL APPROACH

There have been no significant changes to the basic SURTASS LFA sonar analytical approach and the associated conservative assumptions. The information concerning the conservative procedures and assumptions in research and modeling, developed by the independent scientific team and utilized in the analyses in Subchapter 1.4.3 of the FOEIS/EIS, remains valid, and the contents are incorporated herein by reference and also listed below. The details of the analytical approach used in this document are presented in Appendix C—Marine Mammal Impact Analysis and Harassment Level Calculation.

Even though the injury criteria proposed by Southall et al. (2007) is higher than the criteria used for the impact analyses in the FOEIS/EIS and FSEIS, this DSEIS/SOEIS will continue to utilize the 180-dB criteria for injury to marine mammals as stated in Subchapter 1.4.2 above, with the understanding that this value is now considered to be extremely conservative. With either criterion, no injuries to marine species are anticipated.

1.4.3.1 Conservative Assumptions in Research and Modeling

The FOEIS/EIS (DoN, 2001) sought a more realistic scenario, which would reveal conservative but plausible risk estimates, by incorporating a consistent moderately conservative bias. Where necessary, the analysis relied on conservative procedures and assumptions in research and modeling that were independently developed by the scientific team associated with the SURTASS LFA sonar program. This conservative approach continues through the analysis and modeling completed for this document and includes the following procedures and assumptions:

1. <u>Human Diver Hearing</u>—The comprehensive study conducted by the Office of Naval Research (ONR) and Navy Submarine Medical Research Laboratory (NSMRL) between June 1997 and November 1998 in conjunction with a consortium of university and military laboratories (see FOEIS/EIS TR 3 [Cudahy et al., 1999]) concluded that the maximum intensity used during testing (157 dB re 1 µPa

[rms] RL) did not produce evidence of physiological damage in human subjects. Furthermore, there was only a 2% aversion reaction subjectively reported as "very severe" by divers at 148 dB re 1 µPa (rms) RL. NSMRL adopted a very conservative approach and determined that scaling back the intensity by 3 dB (which equates to a 50% reduction in signal strength) would provide a suitable margin of safety for commercial and recreational divers. Hence, operation of SURTASS LFA sonar systems would be restricted to 145 dB re 1 µPa (rms) in known areas of recreational and commercial diving.

- 145-dB Diver Geographic Restrictions Not Included in Modeling**—**To facilitate the modeling of potential impacts to marine mammals, the geographic restriction of 145 dB re 1 µPa (rms) for recreational and commercial dive sites was not included in the AIM analysis. For regions with known recreational and commercial dive sites (predominantly coastal areas), this is more restrictive, in that its application overrides the 180-dB restriction, usually requiring the SURTASS LFA sonar vessel to operate farther offshore.

2. Use of Baleen Whales as Indicator Species—As described in the FOEIS/EIS, Subchapters 1.4.1.1 and 4.2 (DoN, 2001), baleen whales (mysticetes) were used as indicator species for other marine animals in the LFS SRP studies because they are the animals that are the most likely to have the greatest sensitivity to LF sound, have protected status, and have shown avoidance responses to LF sounds.
3. Use of 180-dB Criterion**—**For the purposes of the SURTASS LFA sonar analyses presented in the FOEIS/EIS, the FSEIS and this DSEIS/SOEIS, all marine animals exposed to RLs ≥180 dB re 1 µPa (rms) are evaluated as if they are injured. A single-ping RL of 180 dB re 1 µPa (rms) was assumed for the modeling; this level is considered conservative, as detailed herein.
4. Risk Transition**—**The parameter of the risk continuum (for SURTASS LFA sonar) that controls how rapidly risk transitions from low to high values with increasing RL was set at a value that produced a curve with a more gradual transition than curves developed by the analyses of migratory gray whale studies of Malme et al. (1984). The choice of a more gradual slope than the empirical data was consistent with other decisions to make conservative assumptions when extrapolating from other data sets.
5. Risk Threshold**—**The assumption that risk (for SURTASS LFA sonar) could begin at 119 dB re 1 µPa (rms) is a practical approximation of the RL below which the risk of a significant change in a biologically important behavior approaches zero. In all three phases of the LFS SRP (Clark et al., 2001), most animals showed little to no response to SURTASS LFA sonar signals at RLs up to 155 dB re 1 µPa (rms), and those individuals that did show a response resumed normal activities within tens of minutes.
6. Cumulative Exposure—Another conservative assumption involved the potential effects of cumulative exposure. The analysis assumed that the single-ping equivalent (SPE) level scaled in accordance with previous studies of TTS that dealt with continuous sound, even though SURTASS LFA sonar pings would be separated by 6 to 15 minutes of silence. The 7.5 to 10% (nominal) duty cycle of SURTASS LFA sonar transmissions implies that any cumulative exposure would be less than that for continuous sounds.
7. Number of Marine Mammals Potentially Affected**—**The acoustic modeling simulations incorporated conservative assumptions regarding the fraction of the regional stock in the area potentially affected by the hypothetical SURTASS LFA sonar operation and their animal movement patterns. Scientific data are typically reported with 95 percent confidence intervals. However, to run the acoustic model, an exact number of animals must be specified. Therefore, the upper end of the 95% confidence interval was used for stock densities and abundances.

1.4.4 NEPA Disclosure Statement for Incomplete and Unavailable Information

There have been no significant changes to the NEPA disclosure statement. The information in Subchapters 1.4.4 of the FOEIS/EIS and FSEIS concerning incomplete and unavailable information remain valid and the contents are incorporated herein by reference.

Therefore, under 50 CFR §1502.22(b), the Navy acknowledges that there is incomplete and unavailable information. This information is not expected to change the evaluation of the potential effects of SURTASS LFA sonar in relationship to reasonably foreseeable significant impacts. This DSEIS/SOEIS updates the information and data provided in the FOEIS/EIS and FSEIS and provides evaluations and summaries of existing credible scientific evidence.

2.0 DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

This chapter provides a description of SURTASS LFA sonar technology and the alternatives being considered for its employment, including the No Action Alternative. The proposed action is Navy employment of up to four SURTASS LFA sonar systems.

Pursuant to direction by the Deputy Assistant Secretary of the Navy (Environment) (DASN(E)) to the Chief of Naval Operations (N8) to develop a second supplemental EIS (SEIS)/supplemental OEIS (SOEIS), this document provides additional information regarding the environment that could potentially be affected by employment of SURTASS LFA sonar. This SEIS/SOEIS provides further analysis of potential additional offshore (greater than 22 km [12 nmi]) biologically important areas (OBIAs) in regions of the world where the Navy intends to employ the SURTASS LFA sonar systems for routine training and testing as well as for military operations; further analysis of whether, in some locations, using a larger coastal standoff range for SURTASS LFA sonar where the continental shelf extends further than the current standoff range, is practicable; and further analysis of the potential for cumulative impacts involving other active sonar sources.

References to Underwater Sound Levels
• **References to underwater sound pressure level (SPL) in this SEIS/SOEIS are values given in decibels (dBs), and are assumed to be standardized at 1 microPascal at 1 m (dB re 1 µPa at 1 m [rms]) for source level (SL) and dB re 1 µPa (rms) for received level (RL), unless otherwise stated (Urick, 1983; ANSI, 2006).** • **In this SEIS/SOEIS, underwater sound exposure level (SEL) is a measure of energy, specifically the squared instantaneous pressure integrated over time and expressed as an equivalent one-second in duration signal, unless otherwise stated; the appropriate units for SEL are dB re 1 µPa^2-sec (Urick, 1983; ANSI, 2006; Southall et al., 2007).** • **The term "Single Ping Equivalent" (SPE) (as defined in Chapter 4 and Appendix C of this SEIS/SOEIS) is an intermediate calculation for input to the risk continuum used in this document. SPE accounts for the energy of all of the LFA acoustic transmissions that a modeled animal receives during an entire LFA mission (modeled for operations from 7 to 20 days). Calculating the potential risk from SURTASS LFA is a complex process and the reader is referred to Appendix C for details. As discussed in Appendix C, SPE is a function of SPL, not SEL. SPE levels will be expressed as "dB SPE" in this document, as they have been in the SURTASS LFA sonar FOEIS/FEIS and FSEIS documents (DoN, 2001 and 2007a).**

2.1 GENERAL SYSTEM DESCRIPTIONS

SURTASS LFA sonars are long-range systems operating in the LF band (below 1,000 Hz). These systems are composed of both active and passive components (Figure 2-1). SONAR is an acronym for SOund NAvigation and Ranging, and its definition includes any system that uses underwater sound, or acoustics, for observations and communications. Sonar systems are used for many purposes, ranging

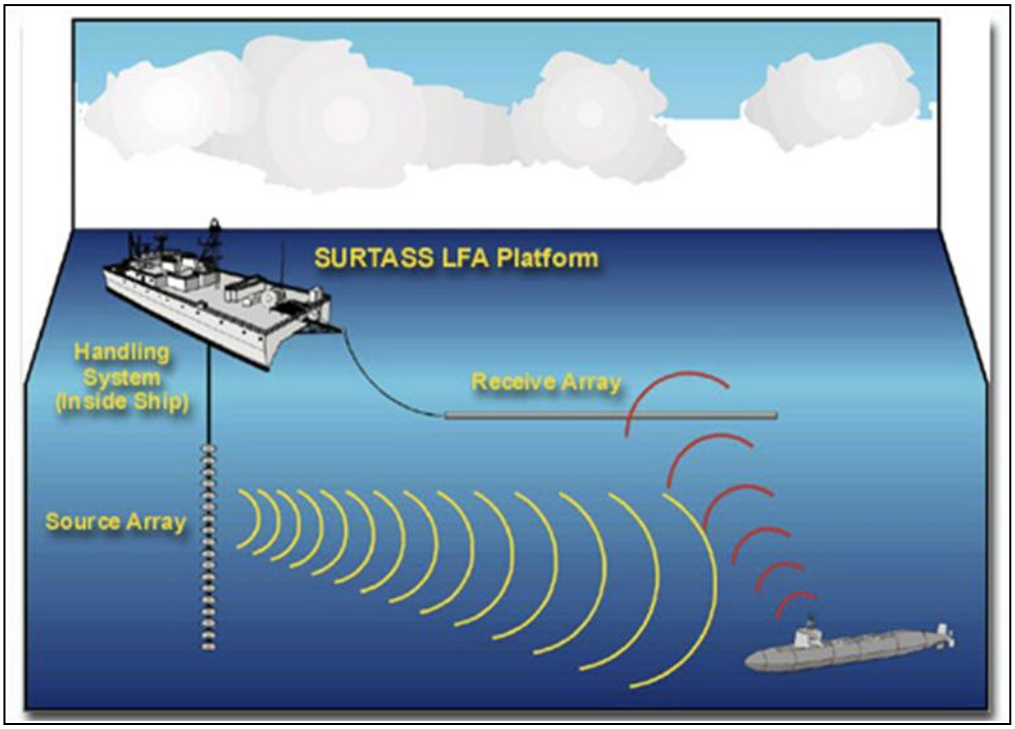

Figure 2-1. SURTASS LFA sonar systems.

from commercial off-the-shelf (COTS) “fish finders” to military ASW systems for detection and classification of submarines. There are two basic types of sonar:

- Passive sonar detects the sound created by an object (source) in the water. This is a one-way transmission of sound waves traveling through the water from the source to the receiver and is the same as people hearing sounds that are created by another source and transmitted through the air to the ear.
- Active sonar detects objects by creating a sound pulse, or “ping,” that is transmitted through the water and reflects off the target, returning in the form of an echo. This is a two-way transmission (source to reflector to receiver). Some marine mammals locate prey and navigate utilizing this form of echolocation.

LFA systems were initially installed on two SURTASS vessels: R/V *Cory Chouest*, which was retired in 2008, and USNS IMPECCABLE (T-AGOS 23). As future undersea warfare requirements continue to transition to littoral ocean regions, the introduction of a compact active system deployable on SURTASS ships was needed. This system upgrade is known as Compact LFA, or CLFA. CLFA consists of smaller, lighter-weight source elements than the current LFA system, and is compact enough to be installed on the VICTORIOUS Class platforms (T-AGOS 19). The initial CLFA installation was completed on the USNS ABLE (T-AGOS 20) in 2008 and at-sea-testing commenced in August 2008. CLFA improvements include:

- Operational frequency, within the 100 to 500 Hz range as stated in Chapter 1, matched to shallow water environments with little loss of detection performance in deep water environments.
- Improved reliability and ease of deployment.
- Lighter-weight design with mission weight of 64,410 kilograms (kg) (142,000 pounds [lb]) for CLFA vice 155,129 kg (324,000 lb) mission weight for LFA.

With the R/V *Cory Chouest's* retirement in FY 2008, two systems are currently operational. At present, there is one SURTASS LFA sonar system onboard USNS IMPECCABLE (T-AGOS 23) and one SURTASS CLFA sonar system onboard the USNS ABLE (T-AGOS 20). Two additional CLFA systems are planned for the T-AGOS 19 Class (Figure 2-2). Late in FY 2011, the CLFA system onboard the USNS EFFECTIVE (T-AGOS 21) commenced at sea testing and training. The CLFA system to be installed onboard the USNS VICTORIOUS (T-AGOS 19) is scheduled for at sea testing and training in FY2012. Therefore, no more than four systems are expected to be in use through FY 2017, and thus this SEIS/SOEIS considers the employment of up to four systems.

The operational characteristics of the compact system are comparable to the existing LFA systems as presented in Subchapter 2.1 of the FOEIS/EIS, FSEIS (DoN, 2007a), and this document. Therefore, the potential impacts from CLFA are expected to be similar to, and not greater than, the effects from the existing SURTASS LFA systems. Hence, for this analysis, the term low frequency active, or LFA, will be used to refer to both the existing LFA system and/or the compact (CLFA) system, unless otherwise specified.

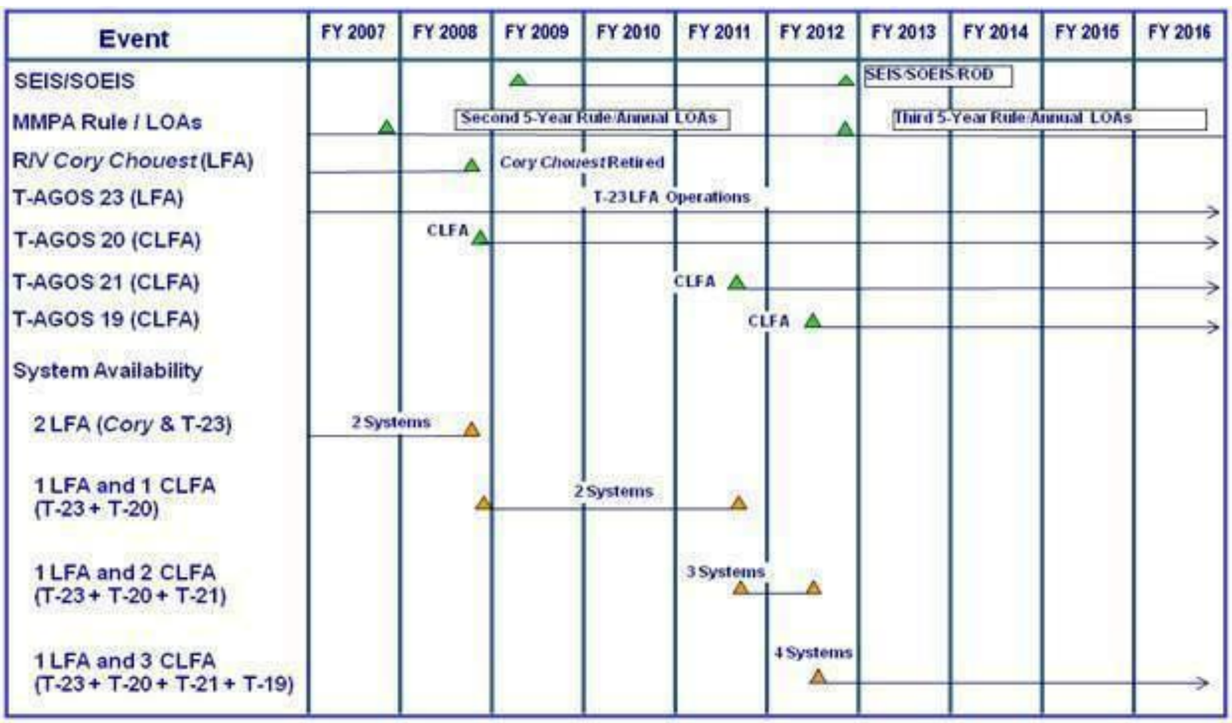

Figure 2-2. Projected LFA and CLFA sonar systems availability.

2.1.1 ACTIVE SYSTEM COMPONENT

The active component of the existing SURTASS LFA sonar system, LFA, is an active adjunct to the SURTASS passive capability and is planned for use when passive system performance is inadequate. LFA complements SURTASS passive operations by actively acquiring and tracking submarines when they are in quiet operating modes, measuring accurate target range, and re-acquiring lost contacts.

LFA is a set of acoustic transmitting source elements suspended by cable under an ocean surveillance vessel, such as the USNS IMPECCABLE (T-AGOS 23) and the VICTORIOUS Class (T-AGOS 19 Class) (see Figure 2-1). These elements, called projectors, are devices that produce the active sound pulse, or ping. The projectors transform electrical energy to mechanical energy that set up vibrations, or pressure disturbances, within the water to produce a ping.

The characteristics and operating features of the active component (LFA) are:

- The source is a vertical line array (VLA) of up to 18 source projectors suspended below the vessel. LFA's transmitted beam is omnidirectional (360 degrees) in the horizontal, with a narrow vertical beamwidth that can be steered above or below the horizontal.
- The source frequency is between 100 and 500 Hz. A variety of signal types can be used, including continuous wave (CW) and frequency-modulated (FM) signals.
- The source level (SL) of an individual source projector of the SURTASS LFA sonar array is approximately 215 dB re 1 µPa at 1 m (rms) or less. As measured by SPL, the sound field of the array can never be higher than the SL of an individual source projector.
- The typical LFA signal is not a constant tone, but rather a transmission of various waveforms that vary in frequency and duration. A complete sequence of sound transmissions is referred to as a wavetrain (also known as a ping). These wavetrains last between 6 and 100 seconds with an average length of 60 seconds. Within each wavetrain the duration of each continuous frequency sound transmission is no longer than 10 seconds.
- Average duty cycle (ratio of sound "on" time to total time) is less than 20%. The typical duty cycle, based on historical LFA operational parameters (2003 to 2009), is nominally 7.5 to 10%.
- The time between wavetrain transmissions is typically from 6 to 15 minutes.

2.1.2 PASSIVE SYSTEM COMPONENT

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

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

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

2.2 OPERATING PROFILE

Because of uncertainties in the world's political climate, a detailed account of future operating locations and conditions cannot be predicted. However, for analytical purposes, a nominal annual deployment schedule and operational concept were developed, based on actual LFA operations since January 2003 and projected Fleet requirements. This information, provided in subchapter 2.2 and Table 2-1 of the SURTASS LFA Sonar FSEIS (DoN, 2007a), remains valid; and the contents are incorporated herein by reference. The SURTASS LFA sonar vessels usually operate independently, but may operate in conjunction with other naval air, surface or submarine assets. The vessels generally travel in straight lines or racetrack patterns depending on the operational scenario.

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

2.3 FOCUS OF THE ANALYSIS

Due to recent concerns raised during litigation over employment of the SURTASS LFA sonar system, and to support issuance of a follow-on Final Rule under the MMPA for employment of SURTASS LFA sonar systems, the DASN(E) directed the development of a new supplement to the existing SURTASS LFA sonar FOEIS/EIS and FSEIS (DoN, 2001; 2007a). This SEIS/SOEIS will provide: 1) further analysis of potential additional OBIAs (located greater than 12 nmi [22.2 km]) in regions of the world where the Navy intends to use the SURTASS LFA sonar systems for routine training, testing, and military operations; 2) further analysis of whether using a greater coastal standoff range where the continental shelf extends further than current standoff range is practicable for SURTASS LFA sonar, at least in some locations; and 3) further analysis of cumulative impacts involving other active sonar sources.

Results from these analyses will be used to assist the Navy in determining how to employ SURTASS LFA sonar and meet the MMPA requirement for effecting the least practicable adverse impact on a species or stock of marine mammals and satisfy the purpose and need for SURTASS LFA sonar. This information will be considered in the selection of operating areas that the Navy requires for routine training and testing as well as for military operations in annual requests for MMPA LOAs submitted to the NFMS of the Department of Commerce’s (DoC) National Oceanic and Atmospheric Administration (NOAA).

2.3.1 ADDITIONAL OBIAS

Offshore biologically important areas are defined in the SURTASS LFA Sonar FOEIS/EIS Subchapter 2.3.2.1 as those areas of the world’s oceans outside the geographic stand-off range of a coastline where marine animals of concern (those animals listed under the ESA and/or marine mammals) congregate in high densities to carry out biologically important activities. These areas include migration corridors; breeding and calving grounds; and feeding grounds. This definition remains valid and will be used in this document for the purpose of considering any potential additional OBIAs associated with marine mammals that are low-frequency hearing specialists (i.e., marine species sensitive to SURTASS LFA sonar). The analysis of the OBIAs (for marine mammals and the potential for non-marine mammal OBIAs) is presented in Chapter 4 of this document.

2.3.2 COASTAL STANDOFF

Based on the analysis in the SURTASS LFA Sonar FSEIS (DoN, 2007a), it was determined that the best coastal standoff range for providing low overall risk to marine mammals was 22 km (12 nm). The Navy considered the practicability of SURTASS LFA sonar operations further offshore where the continental shelf break is greater than the current standoff range of 22 km (12 nmi). This analysis is presented in Chapter 4.

2.3.3 CUMULATIVE IMPACTS WITH OTHER ACTIVE SONAR SOURCES

This SEIS/SOEIS provides additional analysis on the question of whether, with multiple active sonar systems operating, some animals may be at a greater risk from exposure from the multiple sources than they would be if they were exposed to each source independently. The analysis of such a multiple exposure event must consider both the potential for injury and behavioral impact (i.e., Level A and B harassment, respectively, under the MMPA). The methodology and analyses to estimate the potential for Level A and B harassment from concurrent LFA and MFA sonar operations are presented in Chapter 4 and an associated appendix as part of the cumulative impacts analysis.

2.4 POTENTIAL OPERATIONAL AREAS

Because of uncertainties in the world's political climate and the time limits on NMFS' authority under the MMPA to issue a final rule for a period exceeding five years, future operating locations and conditions can only be projected over the next five years. Potential operations for SURTASS LFA sonar vessels over the next five years, based on current operational requirements, will most likely include areas located in the Pacific, Indian and Atlantic Oceans, and the Mediterranean Sea. SURTASS LFA sonar routine training and testing as well as military operations will potentially take place within any of the operational areas defined in Chapter 1 (see Figure 1-1). Polar Regions are excluded because of the inherent inclement weather conditions, including the danger of icebergs. To reduce adverse effects on the marine environment, areas will also be excluded as necessary to prevent 180-dB SPL or greater within 22 km (12 nmi) of land, in offshore biologically important areas during biologically important seasons, and in areas necessary to prevent greater than 145-dB SPL at known recreational and commercial dive sites.

As an integral part of the SEIS/SOEIS, the Navy must anticipate, or predict, where they may need to operate in the next five years or so. Naval forces are presently operating in several areas strategic to U.S national and international interests, including areas in the Mediterranean Sea, the Indian Ocean and Persian Gulf, and the Pacific Rim. National Security needs may dictate that many of these operational areas will be close to ports and choke points, such as straits, channels, and canals. It is anticipated that future naval conflicts are likely to occur within littoral or coastal areas. The Navy must balance National Security needs with environmental requirements and the potential for impacts, while protecting both our freedom and the world's natural resources.

2.4.1 OVERALL MARINE ENVIRONMENT ANALYSES

To predict the potential effects of SURTASS LFA sonar operations on marine species, the FOEIS/EIS (DoN, 2001) analyzed 31 worldwide sites for marine mammal stocks for multiple seasons. Because of the very conservative factors utilized in these analyses (see FOEIS/EIS page 4.2-3), the results of the FOEIS/EIS underwater acoustic modeling analyses for those 31 sites remain valid. In the first FSEIS (DoN, 2007a), the Navy analyzed an additional nine (9) sites in the Pacific Rim region. In addition to updating these nine (9) sites, this document analyzes an additional 10 sites in areas strategic to U.S. National Security interests. These are provided in subchapter 4.4. The total of 50 sites, for which underwater acoustic modeling for potential impacts to marine mammals has been performed, provide the foundation for the analysis of potential effects of SURTASS LFA sonar operations on the overall marine environment and for the annual LOA application process.

2.4.2 ANNUAL LOA APPLICATION PROCESS

The Navy is required to develop an annual process in consultation with NMFS that identifies, through LOA application procedures, the locations that the Navy intends to operate within that year. Additional analysis (including underwater acoustic modeling, if needed) is undertaken if it is deemed necessary (e.g., updated marine mammal distribution or density data available for potential operating areas). This analytical process is undertaken to identify marine areas for SURTASS LFA sonar routine testing, training, and military operations that would have the least practicable adverse impacts on marine mammals, while meeting National Security requirements.

2.4.2.1 Testing, Training, and Military Operations in Areas with the Least Practicable Adverse Impacts on Marine Mammals

The identification of SURTASS LFA sonar operating areas and seasons is based on the SURTASS LFA OBIA and coastal standoff analyses identified above, which support the goal of conducting SURTASS LFA sonar testing, training, and military operations in areas with the least practicable adverse impacts on marine mammals.

In the FSEIS, the methodology to meet this requirement involved the identification of areas of high marine life concentrations through a sensitivity/risk process and avoiding them when/where practicable**.** In order to ensure the least practicable adverse impact on marine mammals, the analysis in this document included the following factors:

- Designating and avoiding offshore (greater than 22 km [12 nmi]) biologically important areas (OBIAs); and
- Coastal zones with greater standoff ranges (greater than 22 km [12 nmi]) where practicable.

For the Navy to meet the MMPA requirements and satisfy the purpose and need for SURTASS LFA sonar, this analysis must:

- Determine areas of biologically important behavior for marine mammal species sensitive to SURTASS LFA sonar.
- Minimize risk to marine mammal species sensitive to SURTASS LFA sonar.
- Meet the criteria and conditions provided in the ROD, Final Rule, and LOAs.
- Meet National Security requirements.

The determination of operating areas that meets the MMPA requirement for least practicable adverse impacts on marine mammals must also support the section 7 consultation of the ESA and the biological opinion's jeopardy determination for listed species and destruction/adverse modification to critical habitat. This concurrent analysis must:

- Determine areas of biologically important behavior for listed species potentially sensitive to SURTASS LFA sonar.
- Minimize risk to listed species potentially sensitive to SURTASS LFA sonar.
- Meet the terms and conditions provided in the biological opinion and incidental take statement:
    - Take of any marine mammal stock cannot exceed allowable level B harassment limits for any LOA period;
    - Mitigation, monitoring, and reporting requirements; and
    - Coastal standoff ranges.
- Meet National Security requirements.

2.4.2.2 Risk Assessment Approach

Subchapter 4.4 of this document provides the risk assessment approach for addressing this issue, which starts with the Navy's ASW requirements to be met by SURTASS LFA sonar (Figure 2-3). Based on this information, mission areas are proposed by the CNO and Fleet commands. These mission areas are then reviewed to determine whether they are within or near OBIAs, as defined previously in this chapter and later in Chapter 4, or known dive sites. If they are, the proposed mission area is changed or revised, and the process is re-initiated. Then, available published data are collected, collated, reduced and analyzed with respect to marine mammal stocks, marine mammal habitat and seasonal activities, and marine mammal behavioral activities. These best scientific data are developed as part of the current NEPA and MMPA application processes that includes review of pertinent literature on small localized

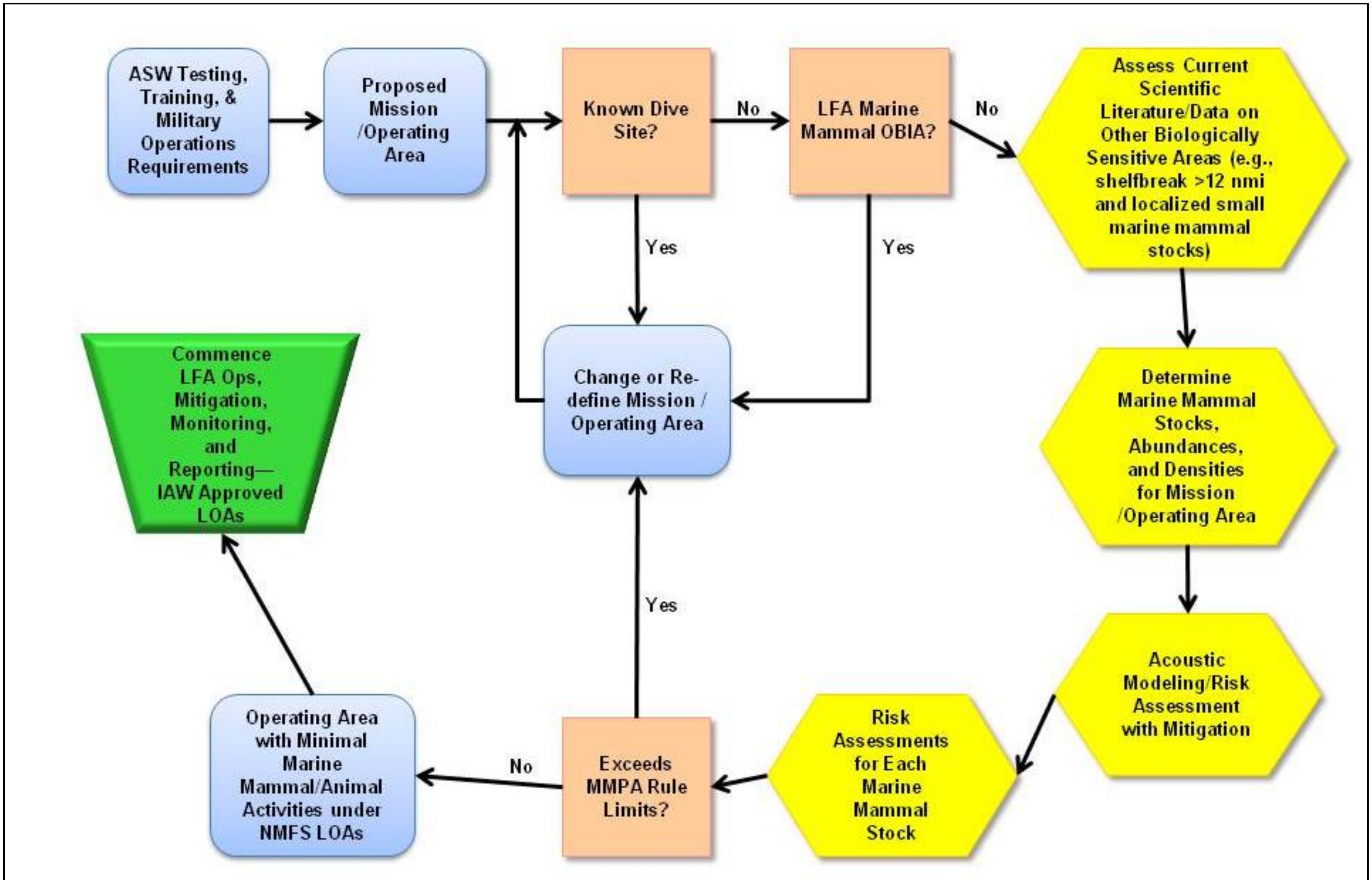

Figure 2-3. Overview of the SURTASS LFA sonar sensitivity/risk assessment approach.

marine mammal stocks. Where data are unavailable, scientific population estimates are made by highly-qualified marine biologists, based on known oceanic/biologic conditions and data for like species and/or geographic areas, and known marine mammal seasonal activity. Next, acoustic modeling and risk analysis are performed for the appropriate SURTASS LFA sonar operations area, including spatial, temporal, or operational restrictions. Then, mitigation is applied and risk estimates for each marine mammal stocks in the proposed mission area are calculated. Based on these risk estimates, a decision is made as to whether the proposed mission area meets the restrictions on marine mammal/animal impacts from SURTASS LFA sonar required under the current NMFS 5-year rule and ESA section 7 consultation. If not, the proposed mission area is changed or refined, and the process is re-initiated. If the mission area risk estimates are below the required restrictions, than the Navy has identified and selected the potential mission area with minimal marine mammal/animal activity based on the best available science and is consistent with regulations and its operational readiness requirements. Furthermore, because this determination of operating areas meets the MMPA rule and ESA section 7 consultation restrictions, this methodology assures that the selection of operating areas meets the MMPA requirement of least practicable adverse impacts on marine mammals and the ESA biological opinion's jeopardy determination for listed species and destruction/adverse modification to critical habitat. This process is discussed further in Chapter 4.

2.5 MITIGATION

Based on the results of the FSEIS (DoN, 2007a) and the review process for the SURTASS LFA sonar 2007 to 2012 Final Rule under the MMPA (NOAA, 2007c), the ASN(I&E) carefully weighed the operational, scientific, technical, and environmental implications of the alternatives considered. Based on this analysis, the Navy announced its decision to employ SURTASS LFA sonar systems with certain geographical restrictions and monitoring mitigation protocols designed to reduce potential adverse effects on the marine environment. This announcement, known as the Record of Decision (ROD) (DoN, 2007b), implemented Alternative 2, identified in the FSEIS for SURTASS LFA sonar. All practicable means to avoid or minimize environmental impacts were adopted through the incorporation of mitigation measures into operation of the SURTASS LFA sonar and the designation of the LFA mitigation zone.

LFA Mitigation Zone
The LFA mitigation zone covers a volume ensonified to a received level ≧180 dB re 1 µPa (rms) by the SURTASS LFA sonar transmit array. Under normal operating conditions, this zone will vary between the nominal ranges of 0.75 to 1.0 km (0.40 to 0.54 nmi) from the source array ranging over a depth of approximately 87 to 157 m (285 to 515 ft). (The center of the array is at a nominal depth of 122 m [400 ft]). Under rare conditions (e.g., strong acoustic duct) this range could be somewhat greater than 1 km (0.54 nmi). Knowledge of local environmental conditions (such as sound speed profiles [depth vs. temperature] and sea state) that affect sound propagation is critical to the successful operation of SURTASS LFA sonar and is monitored on a near-real-time basis. Therefore, the SURTASS LFA sonar operators would have foreknowledge of such anomalous acoustic conditions and would mitigate to the LFA mitigation zone even when this was beyond 1 km (0.54 nmi).

2.5.1 MITIGATION MEASURES UNDER THE 2007 TO 2012 FINAL RULE

The objectives of these mitigation measures are to avoid injury to marine mammals and sea turtles near the SURTASS LFA sonar source array, and to protect recreational and commercial divers in the marine environment, involving both geographic restrictions and operational measures.

These measures include:

- Geographic Restrictions to ensure that the sound field:
    - Is below 180 dB re 1 µPa (rms) received level within a specified distance of any coastline and in the offshore biologically important areas that exist outside 22-km (12-nmi) from any coastline during the biologically important season for that particular area; and
    - Does not exceed 145 dB re 1 µPa (rms) received level in the vicinity of known recreational and commercial dive sites.
- Monitoring to prevent injury to marine species by making every effort to detect animals within the LFA mitigation zone before and during transmissions. These monitoring techniques include:
    - Visual monitoring for marine mammals and sea turtles from the SURTASS LFA sonar vessel during daylight hours;
    - Use of the passive (low frequency) SURTASS towed array to listen for sounds generated by marine mammals as an indicator of their presence; and
    - Use of the high frequency marine mammal monitoring (HF/M3) active sonar to detect/locate/track potentially affected marine animals near the SURTASS LFA sonar vessel and the sound field that is produced by the SURTASS LFA sonar source array.

These mitigation measures are detailed in the FOEIS/EIS Subchapter 2.3.2 and Chapter 5, FSEIS Chapter 5, and in Chapter 5 of this document. Except as noted below, the contents of FOEIS/EIS Subchapter 2.3.2 and Chapter 5 and FSEIS Chapter 5 remain valid and are incorporated herein by reference.

2.5.2 INTERIM OPERATIONAL RESTRICTIONS

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

2.5.3 RESULTS OF MONITORING MITIGATION UNDER CURRENT RULE

During the first three LOAs under the current rule, there were 6 visual contacts (plus one non-operational sighting), 3 passive acoustic detections, and 24 active (HF/M3) detections (DoN, 2008; 2009a; 2010). These data sets involving marine species are too small to support any meaningful analyses, such as determining whether or not there are any differences in detection during the time when LFA is active and when it is not transmitting.

2.6 ALTERNATIVES

NEPA requires federal agencies to prepare an EIS that discusses the environmental effects of a reasonable range of alternatives (including the No Action Alternative). Reasonable alternatives are those that will accomplish the purpose and meet the need of the proposed action, and those that are practical and feasible from a technical and economic standpoint.

2.6.1 ALTERNATIVES CONSIDERED IN PREVIOUS ENVIRONMENTAL IMPACT STATEMENTS

There have been two previous NEPA/Executive Order 12114 environmental impact documents for the deployment of SURTASS LFA sonar systems, the initial FOEIS/EIS (DoN, 2001) and the first SEIS (DON, 2007a). The alternatives for these documents are summarized below.

2.6.1.1 SURTASS LFA Sonar FOEIS/EIS Alternatives

In the FOEIS/EIS, alternatives included the No Action Alternative, Alternative 1 (employment with geographic restrictions and monitoring mitigation), and Alternative 2 (unrestricted operation). Alternative 1 was the Navy's preferred alternative in the FOEIS/EIS.

The FOEIS/EIS also considered alternatives to SURTASS LFA sonar, such as other passive acoustic and non-acoustic technologies, as discussed in FOEIS/EIS Subchapters 1.1.2, 1.1.3, and 1.2.1; and Table 1-1 (DoN, 2001). These were also addressed in the NMFS Final Rule (NOAA, 2002b) and the ROD (DoN, 2002). These alternatives were eliminated from detailed study in the FOEIS/EIS in accordance with CEQ Regulation §1502.14 (a). These acoustic and non-acoustic detection methods included radar, laser, magnetic, infrared, electronic, electric, hydrodynamic, and biological technologies, and high- or mid-frequency sonar. The FOEIS/EIS concluded that these technologies did not meet the purpose and need of the proposed action to provide Naval forces with reliable long-range detection and, thus, did not provide adequate reaction time to counter potential threats. Furthermore, they were not considered practical and/or feasible for technical and economic reasons. These non-acoustic technologies were reexamined in Subchapter 1.1.4 of this document, and this evaluation reached the same conclusion as the FOEIS/EIS.

In 2002 and 2003 Opinions (U.S. District Court, Northern District of California [USDC-NDC], 2002 and 2003), the Court found that the Navy's alternatives analysis was arbitrary and capricious because the second alternative, full deployment with no mitigation or monitoring, was a phantom option. Moreover, the Court found that the Navy should have considered training in areas that presented a reduced risk of impacts to marine life and the marine environment when practicable.

2.6.1.2 SURTASS LFA Sonar FSEIS Alternatives

The 2007 SURTASS LFA Sonar FSEIS alternative analysis addressed the Court's 26 August 2003 Opinion and Order (USDC-NDC, 2003). The FSEIS provided an analysis of the proposed alternatives for the employment of SURTASS LFA sonar. In addition to the No Action Alternative, four alternatives were analyzed to address the issues raised by the Court and to determine the potential effects of changes to the proposed action. These alternatives incorporate coastline standoff restrictions of 22 and 46 km (12 and 25 nmi), seasonal variations, additional OBIAs, and the possibility of employing shutdown procedures for schools of fish. These alternatives include:

- No Action Alternative
- Alternative 1—Same as the FOEIS/EIS Alternative 1;
- Alternative 2—Alternative 1 with additional OBIAs;
- Alternative 3—Alternative 1 with extended coastal standoff range to 46 km (25 nmi); and
- Alternative 4—Alternative 1 with additional OBIAs, extended coastal standoff range to 46 km (25 nmi), and shutdown procedures for fish schools.

Alternative 2 was the Navy's preferred alternative.

2.6.2 ALTERNATIVES CONSIDERED

This subchapter provides a description of the proposed alternatives for the employment of SURTASS LFA sonar (Table 2-1); these alternatives are analyzed in Chapter 4 of this document. In addition to the No Action Alternative, analyses are provided for two alternatives. The analyses of these alternatives are intended to take into account the additional analysis contained in this SEIS/SOEIS on the issues of OBIA and coastal standoff ranges. Alternatives 1 and 2 also include the same mitigation measures presented in the 2007 FSEIS Subchapters 2.4, 5.1, 5.2, and 5.3, which are incorporated herein by reference.

The alternatives considered in this SEIS/SOEIS are:

- No Action Alternative;
- Alternative 1—Same as the 2007 FSEIS Preferred Alternative; and
- Alternative 2—Alternative 1 with updated OBIA list.

Table 2-1. Proposed alternatives and restrictions for employment of SURTASS LFA sonar.

PROPOSED RESTRICTIONS/MONITORING	NO ACTION ALTERNATIVE	ALTERNATIVE 1	ALTERNATIVE 2
Dive Sites	NA[18]	≤145 dB	≤145 dB
Coastline Restrictions	NA	<180 dB within 12 nmi of coast	<180 dB within 12 nmi of coast
FSEIS OBIAs	NA	Yes	No
Updated OBIAs	NA	No	Yes
Visual Monitoring	NA	Yes	Yes
Passive Acoustic Monitoring	NA	Yes	Yes
Active Acoustic Monitoring	NA	Yes	Yes
Reporting	NA	Yes	Yes

2.6.3 NO ACTION ALTERNATIVE

Under this alternative, operational deployment of the active component (LFA/CLFA) of SURTASS LFA sonar will not occur. The No Action Alternative is the same as the No Action Alternative presented in Subchapter 2.3.1 of the FOEIS/EIS and Subchapter 2.6.1 of the FSEIS; the contents of both are incorporated herein by reference. Under the No Action Alternative, SURTASS LFA systems would not be deployed and the U.S. Navy's ability to locate and defends against enemy submarines would be greatly impaired. Thus the purpose and need would not be met.

2.6.4 ALTERNATIVE 1

Alternative 1 is the same as Alternative 2 presented in Subchapter 2.6.3 of the FSEIS, which is incorporated herein by reference. This alternative proposes the employment of SURTASS LFA sonar technology with geographical restrictions to include maintaining SURTASS LFA sonar received levels below 180 dB re 1 µPa (rms) within 22 km (12 nmi) of any coastline and within the designated OBIAs (see Table 2-4 of the FSEIS and the Final Rule (50 CFR §216.184(f), 2007) that are outside of 22 km (12 nmi). Restrictions for OBIAs are year-round or seasonal, as dictated by marine animal abundances. SURTASS LFA sonar sound fields will not exceed received levels of 145 dB re 1 µPa (rms) within known recreational

[18] Not applicable.

and commercial dive sites. Monitoring mitigation includes visual, passive acoustic, and active acoustic (HF/M3 sonar) to prevent injury to marine animals when employing SURTASS LFA sonar by providing methods to detect these animals within the LFA mitigation zone.

2.6.5 ALTERNATIVE 2 (THE PREFERRED ALTERNATIVE)

Alternative 2 is the Navy's preferred alternative. This alternative is the same as Alternative 1 but with a comprehensive update of the OBIAs. OBIAs are discussed previously in this chapter and are analyzed in Chapter 4.

2.7 MONITORING AND RESEARCH

In order to increase knowledge of marine species, the Navy conducted monitoring and research to provide scientific data on the potential effects from SURTASS LFA sonar and other anthropogenic sources.

2.7.1 MONITORING

The Department of the Navy is committed to demonstrating environmental stewardship while executing its national defense mission, and is responsible for compliance with a suite of federal environmental and natural resources laws and regulations that apply to the marine environment. For example, the MMPA implementing regulations (216.104(a)(13)) require that an applicant for an MMPA authorization provide NMFS with a monitoring plan that will result in an increased understanding of the species and the impact that the proposed activity will have on those species.

NMFS recommended that the Navy conduct, or continue to conduct, the following types of monitoring/studies, which would be appropriate under the MMPA:

1. Systematically observe SURTASS LFA sonar training exercises for injured or disabled marine mammals;
2. Compare the effectiveness of the three forms of mitigation (visual, passive acoustic, HF/M3 sonar);
3. Conduct research on the responses of deep-diving odontocete whales to LF sonar signals;
4. Conduct research on the habitat preferences of beaked whales;
5. Conduct passive acoustic monitoring using bottom-mounted hydrophones before, during, and after LF sonar operations for the possible silencing of calls of large whales;
6. Continue to evaluate the HF/M3 mitigation sonar; and
7. Continue to evaluate improvements in passive sonar capabilities.

Under previous MMPA authorizations covering SURTASS LFA sonar, the Navy has conducted monitoring/studies pertinent to LFA (Table 2-2). Table 2-2 also addresses the monitoring/studies pertinent to LFA that the Navy is planning under the forthcoming MMPA authorization.

Table 2-2 Status of Navy-funded monitoring/studies regarding SURTASS LFA sonar.

NMFS Monitoring/Study Topics	Current Monitoring/Study Status	Monitoring/Study Plans Under New MMPA Authorization
<u>Injured/disabled Marine Animals</u> Systematically observe SURTASS LFA sonar training exercises for injured or disabled marine animals	This monitoring study is ongoing based on the mitigation and reporting requirements under the under the 2007 to 2012 Rule. As reported in the annual reports for the first three LOA periods (DoN, 2008, 2009b, 2010), post-operational incidental harassment assessments demonstrated that there were no known marine mammal exposures to RLs at or above 180 dB. These findings are supported by the results from the visual, passive acoustic and active acoustic monitoring efforts discussed in the first three annual reports for the period 16 August 2007 to 15 August 2010 under the current Rule. In addition, a review of recent marine mammal strandings did not indicate any stranding events associated with the times and locations of SURTASS LFA sonar operations (see Chapter 4).	Navy will continue this monitoring/study during the entire 5-year MMPA authorization, including annual reports and review of marine mammal strandings to determine if any may have been associated with the times and locations of SURTASS LFA sonar operations.
<u>Mitigation Effectiveness</u> Compare the effectiveness of the three forms of mitigation (visual, passive acoustic monitoring, HF/M3 sonar)	A summary of mitigation effectiveness was provided in Subchapter 4.1.8 of the Final Comprehensive Report (DoN, 2007c) for the 2002 to 2007 Rule. Under the current Rule, the Navy is also required to summarize the effectiveness of the mitigation in a final comprehensive report. Therefore, data collection and analyses are continuing as part of the reporting requirements of the Long Term Monitoring (LTM) Program.	Navy will continue to provide a summary of mitigation effectiveness in their Final Comprehensive Reports.

Table 2-2. Status of Navy-funded monitoring/studies regarding SURTASS LFA sonar.		
NMFS Monitoring/Study Topics	**Current Monitoring/Study Status**	**Monitoring/Study Plans Under New MMPA Authorization**
Passive Acoustic Monitoring Conduct passive acoustic monitoring using bottom-mounted hydrophones before, during, and after LF sonar operations for the possible silencing of calls of large whales	The Navy has and is continuing to sponsor multi-year studies regarding the acoustic monitoring of marine mammals using fixed passive acoustic monitoring systems in the North Atlantic Ocean (NORLANT). During four of these monitoring/study efforts (NORLANT 2004, 2005, 2006-01, 2006-02), no variations in normal behavior patterns for fin, blue, or humpback whales were noted in response to anthropogenic LF sounds. The fifth NORLANT monitoring/study effort was completed in 2007 (NORLANT 2007). During this period, seismic airguns were the most prevalent anthropogenic noise. The reports for these tasks are classified; unclassified summary reports have been produced. During the period of this report for the third year LOAs, the collection of cross spectral matrix (CSM) data from the arrays has continued. These data will be used to count fin and humpback whale calls and estimate their population. Observations of CSM data over time can also note the interaction and influence of noise sources (seismic profilers, storms, shipping, fishing activity, naval activities) on large whale behavior.	Navy will continue to sponsor multi-year studies regarding the acoustic monitoring of marine mammals using fixed passive acoustic monitoring systems in the North Atlantic Ocean; and will expand the acoustic monitoring studies to include fixed passive acoustic monitoring systems, and SURTASS in the North Pacific Ocean, as feasible.

TABLE 2-2. STATUS OF NAVY-FUNDED MONITORING/STUDIES REGARDING SURTASS LFA SONAR.		
NMFS MONITORING/STUDY TOPICS	**CURRENT MONITORING/STUDY STATUS**	**MONITORING/STUDY PLANS UNDER NEW MMPA AUTHORIZATION**
<u>Evaluate HF/M3</u> Continue to evaluate the HF/M3 sonar	The HF/M3 sonar has been upgraded for integration into the installations of Compact Low Frequency Active (CLFA) sonar on the T-AGOS 19 Class vessels. The first installation of the upgraded HF/M3 sonar was onboard the USNS ABLE (T-AGOS 20). The USNS EFFECTIVE (T-AGOS 21), which is currently undergoing initial at sea testing, is also equipped with the upgraded HF/M3 sonar. Evaluation of the HF/M3 sonar is part of the at sea testing and will be documented in the unclassified final comprehensive reports. The USNS VICTORIOUS (T-AGOS 19), which is scheduled to commence initial at sea testing in late FY 2012, will also be equipped with the upgraded HF/M3 sonar. Evaluation of the HF/M3 sonar will be part of the at sea testing and will be documented in the unclassified final comprehensive reports.	Navy will continue to evaluate the HF/M3 sonar, reporting its findings in the unclassified final comprehensive reports.

TABLE 2-2. STATUS OF NAVY-FUNDED MONITORING/STUDIES REGARDING SURTASS LFA SONAR.		
NMFS MONITORING/STUDY TOPICS	**CURRENT MONITORING/STUDY STATUS**	**MONITORING/STUDY PLANS UNDER NEW MMPA AUTHORIZATION**
Improvements in Passive Sonar Continue to evaluate improvements in passive sonar capabilities	Advances in the development of passive acoustic technology include the development of SURTASS Twin-Line (TL-29A), a shallow water variant of the SURTASS system, which provides improved littoral capability. The USNS ABLE (T-AGOS 20), USNS EFFECTIVE (T-AGOS 21), and USNS IMPECCABLE (T-AGOS 23) have the TL-29A twin-line passive arrays. The USNS VICTORIOUS (T-AGOS 19) will also have the TL-29A passive array. The integrated common processor (ICP) has been, or is scheduled to be, installed on the SURTASS LFA/CLFA sonar vessels. The ICP uses enhanced signal processing and automation to get accurate, actionable information on undersea threats to operational decision makers. The capability of passive acoustic sensors is also benefiting from increased processing power in computers and by networking, which is incorporating data from a variety of acoustic and non-acoustic sensors, and sources to construct a more complete battlefield picture (Friedman, 2007).	Navy will continue to evaluate improvements in passive sonar capabilities that relate to SURTASS performance capabilities which, in turn, could possibly equate to lower LFA transmission requirements.
Passive acoustic monitoring Before, during and after major fleet exercises in which SURTASS LFA sonar is participating	Not applicable.	Navy will, as feasible, use its SURTASS horizontal line arrays to collect marine mammal vocalizations before, during and after major fleet exercises that SURTASS LFA sonar is involved in, with the goal of determining the extent, if any, of changes in the marine mammal vocalizations that could have been caused by SURTASS LFA sonar operations.

2.7.2 RESEARCH

The Department of the Navy sponsors significant research and monitoring projects for marine living resources to study the potential effects of its activities on marine mammals. These funding levels have increased in recent years to $31M in FY 2009 and $32M in FY 2010 for marine mammal research and monitoring activities at universities, research institutions, federal laboratories, and private companies. Navy-funded research has produced, and is producing, many peer-reviewed articles in professional journals as demonstrated in Table 2-3. Publication in open professional literature thorough peer review is the benchmark for the quality of the research. This ongoing marine mammal research includes hearing and hearing sensitivity, auditory effects, dive and behavioral response models, noise impacts, beaked whale global distribution, modeling of beaked whale hearing and response, tagging of free-ranging marine animals at-sea, and radar-based detection of marine mammals from ships.

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

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

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

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

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

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

Table 2-3. Department of the Navy Sponsored Monitoring and Research

<u>Beaked Whale Habitat</u> Conduct research on characteristics of beaked whales habitat preferences, population structure, physiology, movements, bioacoustics, and behavior	The U.S. Navy/Office of Naval Research (ONR) has provided funding for research on beaked whales, which has resulted in the following published articles: • Baird, R.W., D.L. Webster, G.S. Schorr, D.J. McSweeney, and J. Barlow. 2008. Diel variation in beaked whale diving behavior. Marine Mammal Science 24(3):630-642. • Baumann-Pickering, S., S.M. Wiggins, E.H. Roth, M.A. Roch, H.-U. Schnitzler, and J.A. Hildebrand. 2010. Echolocation signals of a beaked whale at Palmyra Atoll. Journal of the Acoustical Society of America 127(6):3790-3799. • Claridge, D., and J. Durban. 2007. Distribution, Abundance and Population Structuring of Beaked Whales in the Great Bahama Canyon, Northern Bahamas. • Cranford, T.W., P. Krysl, and J.A. Hildebrand. 2008. Acoustic pathways revealed: simulated sound transmission and reception in Cuvier's beaked whale (*Ziphius cavirostris*). Bioinspiration & Biomimetics 3(1):016001. 10 pp. • Cranford, T.W., M.F. McKenna, M.S. Soldevilla, S.W. Wiggins, J.A. Goldbogen, R.E. Shadwick, P. Krysl, J.A. St. Leger, and J.A. Hildebrand. 2008. Anatomic geometry of sound transmission and reception in Cuvier's beaked whale (*Ziphius cavirostris*). The Anatomical Record 291:353–378. • D'Amico, A. R.C. Gisiner, D.R. Ketten, J.A. Hammock, C. Johnson, P.L. Tyack, and J. Mead. 2009. Beaked whale strandings and naval exercises. Aquatic Mammals 35(4):252-272. • DiMarzio, N., D. Moretti, J. Ward, R. Morrissey, S. Jarvis, A.M. Izzi, M. Johnson, P. Tyack, and A. Hansen. 2008. Passive acoustic measurement of dive vocal behavior and group size of Blainville's beaked whale (*Mesoplodon densirostris)* in the Tongue of the Ocean (TOTO). Canadian Acoustics 36(1):166-173. • Falcone, E.A., G.S. Schorr, A.B. Douglas, J. Calambokidis, E. Henderson, M.F. McKenna, J. Hildebrand, and D. Moretti. 2009. Sighting characteristics and photo-identification of Cuvier's beaked whales (*Ziphius cavirostris*) near San Clemente Island, California: A key area for beaked whales and the military? Marine Biology 156:2631-2640. • Filadelfo, R., J. Mintz, E. Michlovich, A. D'Amico, P.L. Tyack, and D.R. Ketten. 2009. Correlating military sonar use with beaked whale mass strandings: What do the historical data show? Aquatic Mammals 35(4):435-444. • Finneran, J.F., D.S. Houser, B. Mase-Guthrie, R.Y. Ewing, and R.G. Lingenfelser. 2009. Auditory evoked potentials in a stranded Gervais' beaked whale *(Mesoplodon europaeus*). Journal of the Acoustical Society of America 126(1):484-490. • Gillespie, D., C. Dunn, J. Gordon, D. Claridge, C. Embling, and I. Boyd. 2009. Field recordings of Gervais' beaked whales *Mesoplodon europaeus* from the Bahamas. Journal of the Acoustical Society 125(5):3428-3433. • Hooker, S.K., R.W. Baird, and A. Fahlman. 2009. Could beaked whales get the bends? Effect of diving behaviour and physiology on modelled gas exchange for three species: *Ziphius cavirostris, Mesoplodon densirostris,* and *Hyperoodon ampullatus*. Respiratory Physiology & Neurobiology 167(3):235-246. • Johnson, M., L.S. Hickmott, N. Aguilar Soto, and P.T Madsen. 2008. Echolocation behaviour adapted to prey in foraging Blainville's beaked whale (*Mesoplodon densirostris*). Proceedings of the Royal Society, B (Biological Sciences) 275:133-139. • Jones, B.A., T.K. Stanton, A.C. Lavery, M.P. Johnson, P.T. Madsen, and P.L. Tyack. 2008. Classification of broadband echoes from prey of a foraging Blainville's beaked whale. Journal of the Acoustical Society of America 123(3):1753-1762.

Table 2-3. Department of the Navy Sponsored Monitoring and Research

<u>Beaked Whale Habitat</u> Conduct research on characteristics of beaked whales habitat preferences, population structure, physiology, movements, bioacoustics, and behavior (Continued)	• MacLeod, C. W.F. Perrin, R. Pitman, J. Barlow, L. Ballance, A. D'amico, T. Gerrodette, G. Joyce, K.D. Mullin, D.L. Palka, and G.T. Waring. 2006. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). Journal of Cetacean Research and Management, 7(3): 271-286. • MacLeod, C. D., and G. Mitchell. 2006. Key areas for beaked whales worldwide. J. Cetacean Res. Manage. 7(3):309-322. • MacLeod, C.D., W.F. Perrin, R. Pitman, J. Barlow, L. Balance, A. D'Amico, T. Gerrodette, G. Joyce, K.D. Mullin, D.L. Palka, and G.T. Waring. 2006. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). J. Cetacean Res. Manage. 7(3):271-286. • McSweeney, D.J., R.W. Baird, and S.D. Mahaffy. 2007. Site fidelity, associations, and movements of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales off the island of Hawai'i. Marine Mammal Science 23(3):667-687. • Mellinger, D.K. 2008. A neural network for classifying clicks of Blainville's beaked whales (*Mesoplodon densirostris*). Canadian Acoustics 55(36):55-59. • Moretti, D., T.A. Marques, L. Thomas, N. DiMarzio, A. Dilley, R. Morrissey, E. McCarthy, J. Ward, and S. Jarvis. 2010. A dive counting density estimation method for Blainville's beaked whale (*Mesoplodon densirostris*) using a bottom-mounted hydrophone field as applied to a Mid-Frequency Active (MFA) sonar operation. Applied Acoustics 71**:**1036-1042. • Rankin, S. and J. Barlow. 2007. Sounds recorded in the presence of Blainville's beaked whales, *Mesoplodon densirostris*, near Hawai'i. Journal of the Acoustical Society of America 122(1)**:**42-45. • Schorr, G.S., R.W. Baird, M.B. Hanson, D.L. Webster, D.J. McSweeney, R.D. Andrews. 2009. Movements of satellite-tagged Blainville's beaked whales off the island of Hawai'i. Endangered Species Research 10:203-213. • von Benda-Beckmann, A.M., F.P.A. Lam, D.J. Moretti, K. Fulkerson, M.A. Ainslie, S.P. van IJsselmuide, J. Theriault, S.P. Beerens. 2010. Detection of Blainville's beaked whales with towed arrays. Applied Acoustics 71**:**1027-1035. • Ward, J., R. Morrissey, D. Moretti, N. DiMarzio, S. Jarvis, M. Johnson, P. Tyack, and C. White. 2008. Passive acoustic detection and localization of *Mesoplodon densirostris* (Blainville's beaked whale) vocalizations using distributed bottom-mounted hydrophones in conjunction with a digital tag (Dtag) recording. Canadian Acoustics 36(1):60-66. • Zimmer, W.M.X., J. Harwood, P.L. Tyack, M.P. Johnson, and P.T. Madsen. 2008. Passive acoustic detection of deep-diving beaked whales. Journal of the Acoustical Society of America 124(5):2823-2832. Other funded research that included beaked whale species: • Ferguson, M. C., J. Barlow, B., S. B. Reilly, and T. Gerrodette. 2006. Predicting Cuvier's (*Ziphius cavirostris*) and *Mesoplodon* beaked whale population density from habitat characteristics in the Eastern Tropical Pacific Ocean. JCRM 7(3):287-299. • Filadelfo, R., Y.K. Pinelis, S. Davis, R. Chase, J. Mintz, J. Wolfanger,. P.L. Tyack, D.R. Ketten, and A. D'Amico. 2009. Correlating whale strandings with navy exercises off southern California. Aquatic Mammals 35(4):445-451. • Redfern, J.V., M.C. Ferguson, E.A. Becker, K.D. Hyrenbach, C. Good, J. Barlow, K. Kaschner, M.F. Baumgartner, K.A. Forney, L.T. Ballance, P. Fauchald, P. Halpin, T. Hamazaki, A.J. Pershing, S.S. Qian, A. Read, S.B. Reilly, L. Torres, and F. Werner. 2006. Techniques for cetacean–habitat modeling. MEPS 310:271-295.

2.7.1.1 Research on Fish

The Navy has funded independent research to examine whether exposure to high-intensity, low frequency sonar, such as SURTASS LFA sonar, will affect fish, a prey species for marine mammals (Popper, et al. 2005a, 2007; Halvorsen et al., 2006; Kane et al., 2010). Dr. Arthur Popper (University of Maryland), an internationally recognized fish acoustics expert, investigated the effects of exposure to LFA sonar on hearing, the structure of the ear, and selected non-auditory systems of the rainbow trout (*Onchorynchus mykiss*) (a hearing non-specialist related to several endangered salmonids) and channel catfish (*Ictalurus punctatus*) (a hearing specialist) using an element of the standard SURTASS LFA source array (Popper et al., 2005a, 2007; Halvorsen et al., 2006). Hearing sensitivity was measured using auditory brainstem response (ABR), effects on inner ear structure were examined using scanning electron microscopy, effects on non-auditory tissues were analyzed using general pathology and histopathology, and behavior was observed with video monitoring. Additional studies on the immediate effects on inner ear and non-auditory tissues were done with a hybrid sunfish species (*Lepomis* sp.) (Kane et al., 2010).

Exposure to 193 dB re 1 µPa (rms) RL in the LFA frequency band for 324 seconds resulted in a TTS of 20 dB at 400 Hz in rainbow trout, with less TTS at 100 and 200 Hz (Popper et al, 2007). TTS in catfish ranged from 6 to 12 dB at frequencies from 200 to 1000 Hz (Popper et al., 2005a). Both species recovered from hearing loss in several days. Inner ear sensory tissues appeared unaffected by acoustic exposure. The sunfish showed no threshold shift (Halvorsen et al., 2006). The TTS results for catfish and sunfish are expected to be published within a year.

Gross pathology of the three fish species indicated no damage to non-auditory tissues, including the swim bladder. Histopathology was done on all major body tissues (brain, swim bladder, heart, liver, gonads, blood, etc.) and no differences were found among sound-exposed, control, or baseline fish (Kane et al., 2010). There was no fish mortality attributable to sound exposure, even up to four days post-exposure. Each species showed initial movement responses at sound onsets and changed position relative to the sound source during exposures. The sound levels (up to 193 dB re 1 µPa [rms] RL) used in these experiments approached those that fish would encounter very close to an active SURTASS LFA sonar source array (within approximately 200 m [656 ft]). However, the exposure during the experiments was very likely more substantial than any a fish would encounter in that the fish were exposed to multiple replicates of very intense sounds, whereas any fishes in the wild would encounter sounds from a moving source, and successive emissions from the source would decrease in intensity as the distance between the ship and exposed fish increased.

The conclusion from the SURTASS LFA sonar study demonstrated that LFA exposure to 193 dB re 1 µPa (rms) RL had no real adverse effects on the fish tested. These results support the conclusion in the FSEIS that the potential for a fish or schools of fish to be injured (thus impacting fish stocks) by exposure to SURTASS LFA sonar signals above 193 dB re 1 µPa (rms) RL (within approximately 200 m [656 ft] of the SURTASS LFA sonar operational array) is considered negligible.

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3.0 AFFECTED ENVIRONMENT

This chapter provides a generalized overview of the environments that could potentially be affected by Navy employment of the SURTASS LFA sonar system, including:

- **Marine Acoustic Environment**, including ambient noise in the oceans, physical environmental factors affecting acoustic propagation, and ocean acoustic regimes (Subchapter 3.1);
- **Marine Organisms,** including marine mammals and threatened and endangered species (Subchapter 3.2); and
- **Socioeconomic Conditions**, including commercial and recreational fishing, other recreational activities, research and development, and coastal zone management consistency (Subchapter 3.3).

To assist the reader in understanding the underwater sound units used when referencing sound levels in this chapter and document, the following definitions and suggested references are provided. Additionally, further background information on the basics of underwater sound may be found in the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001); Appendix B is recommended, which may be obtained online (http://www.surtass-lfa-eis.com/Download/index.htm).

References to Underwater Sound Levels
• **References to underwater sound pressure level (SPL) in this SEIS are values given in decibels (dBs), and are assumed to be standardized at 1 microPascal at 1 m (dB re 1 µPa at 1 m [rms]) for source level (SL) and dB re 1 µPa (rms) for received level (RL), unless otherwise stated (Urick, 1983; ANSI, 2006).**   • **In this SEIS, underwater sound exposure level (SEL) is a measure of energy, specifically the squared instantaneous pressure integrated over time and expressed as an equivalent one-second in duration signal, unless otherwise stated; the appropriate units for SEL are dB re 1 µPa^2-sec (Urick, 1983; ANSI, 2006; Southall et al., 2007).**   • **The term "Single Ping Equivalent" (SPE) (as defined in Chapter 4 and Appendix C of this SEIS) is an intermediate calculation for input to the risk continuum used in this document. SPE accounts for, or sums, the energy of all of the LFA acoustic transmissions that a modeled animal receives during an entire LFA mission (modeled for operations from 7 to 20 days). Calculating the potential risk from SURTASS LFA is a complex process and the reader is referred to Appendix C for all of the details. As discussed in Appendix C, SPE does not have a straightforward, identified unit. SPE levels will be expressed as "dB SPE" in this document, as they have been in the SURTASS LFA sonar FOEIS/FEIS and FSEIS documents (DoN, 2001 and 2007a).**

3.1 MARINE ENVIRONMENT

Except as noted below, there have been no significant changes to the knowledge or understanding in the marine environment, acoustic propagation, or propagation modeling. The information in Subchapters 3.1 (Marine Environment) in the FOEIS/EIS and the Final SEIS (DoN, 2001; 2007a) remains valid, and their contents are incorporated herein by reference.

Sound energy unlike light and other stimuli travels very efficiently through water (Richardson et al., 1995). Electromagnetic, thermal, light, and other forms of energy are severely attenuated in water at a much greater rate than sound (Au and Hastings, 2008). This makes sound, or acoustics, the medium of choice for sensing the ocean environment for both marine organisms and humans. Marine animals use underwater sound as the most effective method to perform their life cycle functions such as communications, navigation, obstacle avoidance, predator avoidance, and prey detection by the use of both active echolocation and passive listening (Au and Hastings, 2008). Dolphins, and other toothed whales, utilize echoes from sounds that they produce (echolocation) to locate prey and navigate (NRC, 2000a). Humans use acoustics to detect underwater objects, such as submarines or sunken vessels, to conduct depth measurements, and for communications.

The ability to use sound as an effective sensing medium in the ocean is dependent on the level of background noise (ambient noise) as it is related to the signal, or sound, being received, the physical factors of the ocean that affect the speed at which sound travels through water, and the rate at which sound energy is lost. Sound power or intensity loss by the acoustic signal is a result of spreading and absorption. This is referred to as propagation or transmission loss. Water temperature, salinity, and depth/pressure are all factors that affect the density of the water and, therefore, the speed of sound through the water, and thus the water's propagation characteristics.

3.1.1 AMBIENT NOISE

Subchapter 3.1.1 of the FOEIS/EIS (DoN, 2001) provided a summary and discussion of LF ambient noise within the ocean as it relates to the frequency at which SURTASS LFA sonar would operate (i.e., between 100 and 500 Hz). Ambient noise is the typical or persistent background noise that is present in an environment. Ambient noise is broadband in all frequencies and directional both horizontally and vertically, meaning that it does not come at equal sound levels from all directions. For more detailed information on oceanic ambient (or background) noise, Urick (1983), Richardson et al. (1995), and Au and Hastings (2008) provide an excellent and a more comprehensive discussion than can be presented herein.

Ambient noise has both natural and anthropogenic (man-made) components. Many of these sources are comparable in frequency to SURTASS LFA sonar. Distant shipping noise has been reported by Urick (1983) to be from 50 to 500 Hz and by Richardson et al. (1995) to be between 20 and 300 Hz. Biological noise can also be a major contributor of LF noise in the ocean. Several species of baleen whales, toothed whales, and seals are known to produce underwater sounds between 100 and 500 Hz.

3.1.1.1 Natural Sources of Ambient Noise

Natural sources include breaking waves and surf, wind, precipitation, ice, earthquakes, and biological noises. Wind and waves are common and interrelated sources of ambient noise in all of the world’s oceans. All other factors being equal, ambient noise levels tend to increase with increasing wind speed and wave height (Richardson et al., 1995). Noise generated by surface wave activity and biological sounds is the primary contributor over the frequency range from 300 Hz to 5 kHz. The wind-generated noise level decreases smoothly with increasing acoustic frequency (i.e., there are no spikes at any given frequency).

At some frequencies, rain and hail will increase ambient noise levels. Significant noise is produced by rainsqualls over a range of frequencies from 500 Hz to 15 kHz. Large storms with heavy precipitation can generate noise at frequencies as low as 100 Hz and significantly affect ambient noise levels at a considerable distance from a storm’s center. Lightning strikes associated with storms are loud, explosive events that deliver an average of 100 kilojoules per meter (kJ/m) of energy (Considine, 1995). Hill (1985) estimated the source level for cloud-to-water pulse to be 260.5 dB re 1 µPa (rms) @ 1 m. It has been estimated that over the earth's oceans the frequency of lightning averages about 10 flashes per second, or 314 million strikes per year (Kraght, 1995).

Biological noises are sounds created by animals in the sea and may contribute significantly to ambient noise in many areas of the oceans. Because of the habits, distribution, and acoustic characteristics of these sound producers, certain areas of the oceans are louder than others. Three groups of marine animals are known to produce sounds (Urick, 1983):

- Crustaceans, such as snapping shrimp;
- Fish, such as the drumfish; and
- Marine mammals, including whales, dolphins, and porpoises.

The most widespread, broadband noises from animal sources (in shallow water) are those produced by croakers (representative of a variety of fish classified as drumfish) (100 Hz to 10 kHz) and snapping shrimp (500 Hz to 20 kHz). Sound-producing fishes and crustaceans are restricted almost entirely to bays, reefs, and other coastal waters, although there are some pelagic, sound-producing fish. In oceanic waters, whales and other marine mammals are principal contributors to biological noise.

3.1.1.2 Anthropogenic Component of Ambient Noise

Anthropogenic noises that could affect ambient noise levels arise from the following general types of activities in and near the sea, any combination of which can contribute to the total noise at any one place and time. These noises include:

- Transportation (ship-generated noise);
- Dredging;
- Construction;
- Hydrocarbon and mineral exploration and recovery;
- Geophysical (seismic) surveys;
- Sonars;
- Explosions; and
- Ocean science studies.

The dominate source of anthropogenic sound in the sea stems from the propulsion of ships (Tyack, 2008). At the lower frequencies, the dominant source of this noise is the cumulative effect 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 21^{st} 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 (Andrews et al., 2002). McDonald et al. (2006a) compared data sets from 1964 to 1966 and 2003 to 2004 for continuous measurements west of San Nicolas Island, California and found an increase in ambient noise levels of 10 to 12 dB at 30 to 50 Hz.

3.1.2 ENVIRONMENTAL FACTORS AFFECTING SOUND PROPAGATION

Sound propagation in water is influenced by various physical characteristics, including water temperature, depth, salinity, and surface and bottom properties that cause refraction, reflection, absorption, and scattering of sound waves. Except for the discussion of ocean acidification below, there have been no significant changes to the knowledge or understanding of how geology and bottom topography, sedimentation, temperature, salinity, winds and sea state can affect LF sound transmission.

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

3.1.3 OCEAN ACOUSTIC REGIMES

The oceans are not homogeneous, that is, they do not have the same physical characteristics throughout their four-dimensional structure (the fourth dimension being time or season). Sound speed in water varies with water density. Water density is affected primarily by depth, temperature, and to a lesser degree, by salinity. Thus, the speed of sound in water varies with depth (a plot of sound speed versus water depth is known as a sound speed profile [SSP]). As sound speed changes due to environmental conditions of the water, the sound rays bend, or refract, either toward or away from the surface. Under certain conditions sound rays may become trapped in a duct and create a sound channel (i.e., surface duct or deep sound channel). It is this refraction, coupled with the reflection from the surface and interaction with the bottom that makes it difficult to predict how sound travels in water. There have been no significant changes to the knowledge or understanding concerning the general conditions of sound speed in the oceans. For more details on this topic see Appendix B of the SURTASS LFA FOEIS/EIS (DoN, 2001).

Based on the characteristics of the SSPs for specific areas of the oceans, sound propagation for those areas can be predicted. These predictions are generally grouped by the physical effects that the SSP has on acoustic propagation. Despite the complexity of the ocean environment these effects can be organized into the following three groups, which are referred to as ocean acoustic regimes:

- Deep water convergence zone (CZ);
- Surface duct/sound channels; and
- Shallow water bottom interaction.

3.2 MARINE ORGANISMS

Because the SURTASS LFA sonar system operates in an ocean environment, there is the potential for it to interact with marine species and their environments. Marine species have been screened to determine whether or not they may potentially be affected by LF sounds produced by SURTASS LFA sonar. Those marine species as well as their habitats, and the process by which they could potentially be affected, are discussed in detail in this subchapter.

3.2.1 SPECIES SCREENING

Marine species must be able to hear LF sound and/or have some organ or tissue capable of changing sound energy into mechanical effects to be affected by LF sound. In order for there to be an effect by LF sound, the organ or tissue must have an acoustic impedance different from water, where impedance is the product of density (kg/m^3 [lb/yd^3]) and sound speed (m/sec [ft/sec]). Thus, many organisms would be unaffected, even if they were in areas of LF sound, because they do not have an organ or tissue with acoustic impedance different from water. These factors immediately limit the types of organisms that could be adversely affected by LF sound. In other words, to be evaluated for potential impact in this SEIS/SOEIS, the marine species must: 1) occur within the same ocean region and during the same time of year as the SURTASS LFA sonar operation, and 2) possess some sensory mechanism that allows it to perceive the LF sounds, and/or 3) possess tissue with sufficient acoustic impedance mismatch to be affected by LF sounds. Species that did not meet these criteria were excluded from consideration.

The process by which a marine species' potential to be affected by SURTASS LFA sonar is discussed in detail in Subchapter 3.2.1 of the SURTASS LFA Sonar SEIS (DoN, 2007a). Except as noted below, there have been no significant changes to the knowledge or understanding relating to species screening. The information in Subchapter 3.2.1 (Species Screening) in the Final SEIS (DoN, 2007a) remains valid, and the contents are incorporated herein by reference. The screening information is summarized and updated, as necessary, in the remainder of this section.

3.2.1.1 Invertebrates

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

Among invertebrates, only cephalopods (octopus and squid) and decapods (lobsters, shrimps, and crabs) are known to sense LF sound (Packard et al., 1990; Budelmann and Williamson, 1994; Lovell et al., 2005; Mooney et al., 2010). Limited data have begun to emerge on the hearing mechanism and potential hearing thresholds on these few invertebrate species. Budelmann and Williamson (1994) demonstrated that the hair cells of cephalopod statocysts are directionally sensitive in a way that is similar to the responses of hair cells on vertebrate vestibular and lateral line systems. Packard et al. (1990) showed that three species of cephalopods were sensitive to particle motion, not pressure, with the lowest thresholds of 2 to 3 x 10^{-3} m/sec^2 at 1 to 2 Hz. This type of hearing mechanism was confirmed by Mooney et al. (2010) who demonstrated that the statocyst of squid acts as an accelerometer through which particle motion of the sound field can be detected. They measured acceleration thresholds of -26 dB re 1 m/sec^2 between 100 and 300 Hz and a pressure threshold of 110 dB re 1 μPa at 200 Hz. Lovell et al. (2005) found a similar sensitivity for prawn, 106 dB re 1 μPa at 100 Hz, noting that this was the lowest frequency at which they tested and animals might be more sensitive at lower frequencies. Thresholds at higher frequencies have been reported, i.e., 134.4 dB re 1 μPa and 139.0 dB re 1 μPa at 1,000 Hz for the oval squid (*Sepioteuthis lessoniana*) and the octopus (*Octopus vulgaris*), respectively (Hu et al., 2009). However, Mooney et al. (2010) suggested that the measurement techniques of Hu et al. (2009) placed the animals close to the air-sea interface and introduced particle motion to which animals were responding rather than the pressure measurements reported. Popper et al. (2003) also reviewed behavioral, physiological, anatomical, and ecological aspects of sound and vibration detection by decapod crustaceans. Many decapods also have an array of hair-like receptors within and upon the body surface that potentially respond to water- or substrate-borne displacements as well as proprioceptive organs that could serve secondarily to perceive vibrations. However, the acoustic sensory system of decapod crustaceans remains under-studied (Popper, et al., 2003).

Popper and Schilt (2008) stated that, like fish, some invertebrate species produce sound, possibly using it for communications, territorial behavior, predator deterrence, and mating. Well known sound producers include lobster (*Panulirus* sp.) (Latha et al., 2005) and the snapping shrimp (*Alpheus heterochaelis*) (Herberholtz and Schmitz, 2001). Snapping shrimp are found worldwide and make up a significant portion of the ambient noise budget between 500 Hz and to 20 kHz.

McCauley et al. (2000) reported that exposure of caged squid to seismic airguns showed behavioral response including inking. Wilson et al. (2007) played back killer whale echolocation clicks to two groups of squid (*Loligo pealeii*) in a tank. With signals of up to 199 to 226 dB, there were no apparent behavioral effects or any acoustic debilitation. Both of these experiments were with caged squid, and it is unclear how unconfined animals would have reacted.

André et al. (2011) exposed four cephalopod species (*Loligo vulgaris, Sepia officinalis, Octopus vulgaris,* and *Ilex coindetii*) to two hours of continuous sound from 50 to 400 Hz at 157 ± 5 dB re 1 μPa. They reported lesions to the sensory hair cells of the statocysts of the exposed animals that increased in severity with time, suggesting that cephalopods are particularly sensitive to low-frequency sound in a manner incompatible with life. However, scientists have expressed concern that this study contains flaws. The two most egregious errors include the experimental design and lack of controls. First, exposure was produced by an in-air loudspeaker to animals in two different tanks, resulting in highly complex and unpredictable sound fields. There was limited description of the experiment set-up, calibration procedures, or sound field measurement techniques, and no reference to the particle motion sound field to which these animals would actually be sensitive. Second, there was a lack of proper controls, with different numbers of animals of each species used in the noise exposure part of the study and no indication if the controls were of the same species as the exposed animals. The paper also implies that the controls were not placed in the same experimental setup as the exposed animals, but rather were captured and then sacrificed immediately. The difference in tissue degradation observed between the experimental and control animals could have resulted from poor tissue fixation techniques, degradation prior to fixation, handling of the animals, feeding regime, water quality, exposure to chemicals in the holding tanks, or differences in how tissue was taken from the animals. Without further details on how the experiment was conducted and statistics on comparing the damage of exposed to control animals, the results and accompanying interpretation are questionable. One final flaw of the study is that it states that "if the relatively low levels and short exposure applied in this study can induce severe acoustic trauma in cephalopods, the effects of similar noise sources on these species in natural conditions over longer time periods may be considerable" (André et al., 2011). However, the authors fail to elaborate that, in fact, there are no anthropogenic sources to which animals might be exposed with characteristics similar to those used in their study. The time sequence of exposure from low-frequency sources in the open ocean would be about once every 10 sec for seismic airguns and once every 10 to 15 min for SURTASS LFA. Ships, such as large tankers, tugs, and barges, which when operated produce continuous, low-frequency sound, would require a cephalopod to be at least within 100 m to receive the sound level used in the study. Therefore, the sound exposures are far longer in duration and higher in energy than any exposure a wild animal would likely ever receive and acoustically very different than a free field sound to which animals would be exposed in the real world.

While data are still very limited, they do suggest that some of the major cephalopods and decapods may not hear well. Given the data on hearing thresholds of cephalopods, SURTASS LFA sonar operations could only have a lasting impact on these animals if they are within a few tens of meters from the source. Therefore, the fraction of the cephalopod and decapod stocks that could possibly be found in the water column near a vessel using SURTASS LFA sonar would be negligible. Cephalopods and decapods, therefore, have been eliminated from further consideration because of their distribution in the water column.

3.2.1.2 Vertebrates

Vertebrates offer an acoustic impedance contrast with water and have specialized organs for hearing; hence, they are potentially susceptible to the operation of SURTASS LFA sonar.

Fish

Fish are able to detect sound, although there is remarkable variation in hearing capabilities in different species. While it is not easy to generalize about hearing capabilities due to this diversity, most all fish known to detect sound can at least hear frequencies from below 50 Hz up to 800 Hz, while a large subset of fish can detect sounds to over 1,000 Hz, and another subset can detect sounds to over 2,000 Hz. Of the estimated 29,000 extant fish species (Nelson, 2006) only a small percentage have been studied in terms of audition or sound production (Popper et al., 2003). Of the 100 or more species on which hearing studies have been done, all are able to detect sound. While only a relatively small number of species have been studied, it is apparent that many bony fish (but apparently no sharks and rays) are able to produce vocalizations and use these sounds in various behaviors. Hearing or sound production is documented in well over 240 fish species comprising at least 58 families and 19 orders, although it is likely that with additional study it will be found that many more species produce sounds. Potential SURTASS LFA sonar effects are considered by fish taxonomic order for this analysis, except for the Perciformes, which is analyzed by family, although it must be recognized that even within a taxonomic order or family, different species may have different hearing capabilities or uses of sound. Of the 19 orders of fish currently known with sound production, those that would be found inshore in shallow waters (within 22 km [12 nmi] of the coast) have been eliminated from evaluation because they would not occur where the SURTASS LFA sonar would be operating. The fish orders with known sound production that do occur in pelagic (oceanic) waters where they might encounter SURTASS LFA sonar are Heterodontiformes, Orectolobiformes, Lamniformes, Rajiformes, Anguilliformes, Albutleiformes, Clupeiformes, Salmoniformes, Gadiformes, Pleuronectiformes, Beryciformes, Batrachoidiformes, Scorpaeniformes, Siluriformes, and the Perciformes families Pomacentridae, Labridae, Lutjanidae, Serranidae, Sciaenidae, and Scombridae; these fish families also occur pelagically: Haemulidae, Sparidae, Carangidae, Eleotridae, Mullidae, Mugilidae, Gobiidae. These are the fish groups evaluated for potential impacts in this SEIS/SOEIS.

Seabirds

There are more than 270 species of seabirds in five orders, and each order has species that dive to depths exceeding 25 m (82 ft). There are few data on hearing in seabirds and even less on underwater hearing. Studies with bird species have shown that birds are sensitive to LF sounds in air. While it is likely that many diving seabirds can hear underwater LF sound, there is no evidence that seabirds use sound underwater.

There is a considerable amount of knowledge about seabird foraging ecology in terms of foraging habitat, behavior, and strategy. Foraging habitat features include water masses, environmental gradients, fronts, topographical features, and sea ice. Seabird foraging behavior mostly involves taking prey within a half meter of the sea surface. However, some species take prey within 20 m (66 ft) or deeper, feed on dead prey at the surface, or take prey from other birds. Foraging behaviors involve such things as locating physical oceanic features, relying on subsurface predators (marine mammals and large fish) to drive prey to the surface, feeding in flocks, feeding at night, and maximizing surface area surveillance (Ballance et al., 2001). None of these foraging behaviors appear to require the use of underwater sound.

Ballance et al. (2001) states that seabirds spend 90% of their life at sea foraging over hundreds to thousands of kilometers. Some dive to several hundred meters below the sea surface. Ballance et al. (2001) further state, however, that most seabirds take their prey within a half meter of the sea surface and that prey on a global scale is patchier in oceanic waters than shelf and slope waters. There are several factors that reduce the exposure of seabirds to LFA when they are diving. First, the free surface effects (reduction of sound levels at the air-water interface) will effectively reduce the LF sound levels near the surface (within 2 m [6.6 ft]) by 20 to 30 dB. Second, the air bubbles that are created due to the impact will further reduce any potential effects from LFA sound transmissions. Finally, for any possible interaction between a diving seabird and LFA, the animal would need to be at least 2 m (6.6 ft) below the water surface near a transmitting LFA source, even more unlikely given that LFA transmits only 7.5% of the time (active transmission duty cycle based on actual operations). Seabirds are not expected to be impacted by LFA because they are generally shallow divers, spend a small fraction of their time in the water at depths where LFA might affect them, and can rapidly disperse to other areas if disturbed (Croll et al., 1999). However, because as stated above possible interaction between seabirds and LFA would be minimal, the possibility of dispersal due to LFA sound exposure should also be considered minimal. For these reasons, significant impacts to seabirds, including those that may be threatened or endangered, are highly unlikely. Therefore, seabirds have been excluded from further evaluation.

Sea Snakes

There is no available research regarding the potential effects on sea snakes of LF sounds or other anthropogenic underwater noises. Research on hearing ability in snakes is also limited, 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). They possess no external ear and lack many of the interior auditory components that facilitate hearing; but in water the inner ear may receive signals via the lungs, which would work like the swim bladder in fish.

Sea snakes primarily inhabit coastal areas in tropical oceans, notably the Indian Ocean and western Pacific Ocean (Kharin, 2004). Additionally, sea snakes need to surface to breathe and are thus relatively shallow divers, rarely descending deeper than 100 m (328 ft) (Heatwole, 1999).

Sea snakes would not be at any greater risk than fish for potential injury from SURTASS LFA sonar transmissions and would not be subject to behavioral reactions because of their poor sensitivity to LF sound. Because they are predominately shallow diving, coastal creatures, it is unlikely that sea snakes would be exposed to LFA signals at all, much less at levels high enough to affect them adversely. Therefore, sea snakes are excluded from further considerations.

Sea Turtles

There are seven species of marine turtles, six of which are listed as either threatened and/or endangered under the ESA. The flatback turtle (*Natator depressus*) is not listed under the ESA as its distribution is restricted largely to the tropical, continental shelf waters of Australia; Papua New Guinea; and Papua, Indonesia (Limpus, 2007). Since it is likely that all species of sea turtles hear LF sound as adults (Ridgway et al., 1969; O'Hara and Wilcox, 1990), all species of sea turtles (Table 3-1) are considered for evaluation in this document.

Table 3-1. Sea turtle species considered for further evaluation of the potential effects from exposure to SURTASS LFA sonar.

FAMILY	SPECIES	ESA STATUS
Cheloniidae	Green turtle (*Chelonia mydas)*	Threatened[19]
	Hawksbill turtle (*Eretmochelys imbricata)*	Endangered
	Loggerhead turtle (*Caretta caretta*)	Threatened
	Olive ridley turtle (*Lepidochelys olivacea)*	Threatened[20]
	Kemp's ridley turtle (*Lepidochelys kempii)*	Endangered
	Flatback turtle (*Natador depressus*)	
Dermochelyidae	Leatherback turtle (*Dermochelys coriacea)*	Endangered

Marine Mammals

- **Baleen whales (Mysticetes)**

[19] As a species, the green turtle is listed as threatened. However, the Florida and Mexican Pacific coast nesting populations are listed as endangered under the ESA.

[20] As a species, the olive ridley is listed as threatened, but the Pacific nesting population in Mexico is listed as endangered under the ESA.

All 12 species of baleen whales (mysticetes) produce LF sounds. Sounds may be used as contact calls, for courtship displays and possibly for navigation and food finding. Although there are no direct data on auditory thresholds for any mysticete species, anatomical evidence strongly suggests that their inner ears are well adapted for LF hearing. Therefore, sound perception and production are assumed to be critical for mysticete survival. For this reason all mysticete species are considered sensitive to LF sound. All 12 species of baleen whales occur within the latitudes of proposed SURTASS LFA sonar operations and as such, all are considered for further evaluation (Table 3-2).

➢ **Toothed whales (Odontocetes)**

There are at least 72 species of odontocetes (some species classifications are under study and the exact number of beaked whales is not known). Many odontocete species are known to use high-frequency (HF) clicks for echolocation. All odontocete species studied to date hear best in the mid- to high-frequency range, and as a consequence, are less likely to be affected by exposure to LF sounds than mysticetes. Odontocetes also depend upon acoustic perception and sound production for communication, prey location, and probably for navigation and orientation as well. Although most odontocete species inhabit ocean areas where SURTASS LFA sonar might operate, at least 14 toothed whale species are found in nearshore or inshore waters where SURTASS LFA cannot operate and have been eliminated from further evaluation:

- Narwhal (*Monodon monoceros*)—occurrence principally only in high Arctic waters, where SURTASS LFA sonar will not be operated.
- Coastal Porpoises—Porpoise species, including Burmeister's porpoise *(Phocoena spinipinnis*), vaquita (*P. sinus)*, and finless porpoise (*Neophocaena phocaenoides),* are excluded due to their distribution in nearshore, shallow coastal waters well inside of the 12 nmi shoreward limit where SURTASS LFA sonar would not be operated.
- River Dolphins—Dolphin species, such as the Chinese river dolphin (*Lipotes vexillifer)*, franciscana (*Pontoporia blainvillei*), boto/Amazon River dolphin (*Inia geoffrensis*), and the South Asia river dolphins (Ganges River dolphin [*Platanista gangetica gangetica]* and Indus River dolphin [*Platanista gangetica minor*]), are excluded as their distribution is restricted to riverine waters of Asia and South America. Although occasionally river dolphins may enter coastal waters, they occur well inshore of the areas where SURTASS LFA sonar would be employed.
- Coastal Dolphins—Delphinid species, including the Tucuxi/boto (*Sotalia fluviatilis)*, Irrawaddy dolphin (*Oracella brevirostris),* Australian snubfin dolphin (*Oracella heinsohni*), Indo-Pacific humpbacked dolphin (*Sousa chinensis)*, costero (*Sousa guianensis*), Atlantic humpbacked dolphin (S*ousa teuszii)*, and humpback dolphin (*Sousa plumbea)* all occur in shallow, coastal waters well shoreward of the 12 nmi extent where SURTASS LFA sonar could be employed. Also, these dolphins are not known to hear sounds in the range of the SURTASS LFA sonar system.

The remaining 58 species (Table 3-3) of globally occurring odontocetes further analyzed in this document are found in deeper waters away from the coast where SURTASS LFA sonar might operate.

➢ **Seals, sea lions, and walruses (Pinnipeds)**

The suborder Pinnipedia consists of eared seals (family Otariidae), earless or true seals (family Phocidae), and walruses (family Odobenidae). There are 16 species of otariids, including sea lions and fur seals, which are found in temperate to sub-polar waters. All but two of the otariid species (Table 3-4), the Antarctic fur seal (*Arctocephalus gazella),* which is restricted to Antarctic waters where SURTASS LFA sonar will not be operated, and the Japanese sea lion, which is considered by most scientists to be extinct, are analyzed in this document.

Table 3-2. Mysticete or baleen whale species considered for further evaluation of the potential effects from exposure to SURTASS LFA sonar.

FAMILY	SPECIES	ESA STATUS
Balaenopteridae	Blue whale (*Balaenoptera musculus)*	Endangered
	Fin whale (*Balaenoptera physalus)*	Endangered
	Sei whale (*Balaenoptera borealis*)	Endangered
	Bryde's whale (*Balaenoptera edeni)*	
	Minke whale (*Balaenoptera acutorostrata)*	
	Humpback whale (*Megaptera novaeangliae*)	Endangered
Balaenidae	Bowhead whale (*Balaena mysticetus*)	Endangered
	North Atlantic right whale (*Eubalaena glacialis*)	Endangered
	North Pacific right whale (*Eubalaena japonica*)	Endangered
	Southern right whale (*Eubalaena australis*)	Endangered (foreign)
Neobalaenidae	Pygmy right whale (*Caperea marginata*)	
Eschrictiidae	Gray whale (*Eschrichtius robustus*)	Endangered (Only Western Pacific population)

Walruses are found discontinuously only in the Northern Hemisphere in Arctic and subarctic waters. The Pacific walrus subspecies is generally found in the Bering Sea of Alaska and north towards the Chukchi Sea, East Siberian Sea, and western Beaufort Sea (Jefferson et al., 2008). The Atlantic walrus subspecies occurs in the eastern Canadian Arctic and Hudson Bay to Greenland, Svalbard, and the Barents and Kara Sea (Jefferson et al., 2008; Kastelein, 2009). An additional isolated population occurs in the Laptev Sea off northern Russia (Jefferson et al., 2008; Kastelein, 2009). Walruses are generally found in shallow, continental shelf waters (up to 80 m [263 ft]) since they feed on benthic invertebrates and rarely are found in deeper waters. Walruses inhabit drifting ice covered regions with numerous leads and polynas (Kastelein, 2009). Due to the restricted polar distribution of all subspecies of the walrus, this species has been excluded from further analysis.

Eight of the 18 species of phocids occur in polar regions of both hemispheres and inland lakes and can, therefore, be excluded from further analysis in this document. These excluded phocid seals include the ringed seal (*Phoca hispida*), Baikal seal (*Pusa sibirica*), Caspian seal (*Pusa caspica*), bearded seal (*Erignathus barbatus*), crabeater seal (*Lobodon carcinophaga*), Ross seal (*Ommatophoca rossii*), leopard seal (*Hydrurga leptonyx*), and Weddell seal (*Leptonychotes weddellii*). The remaining 10 phocid species (Table 3-5), including two endangered monk seal and one threatened spotted seal species, merit further evaluation.

- **Ursids and mustelids**

The polar bear (*Ursus maritimus*) is a marine mammal that can be excluded from further analysis since it only occurs in shallow Arctic regions. Two additional species of marine mammals, the sea otter (*Enhydra lutris*) and the marine otter (chungungo) (*Lontra felina*), will not be further considered in this document because they occur almost exclusively in shallow waters less than 12 nmi from shore.

Table 3-3. Odontocete or toothed whale species considered for further evaluation of the potential effects from exposure to SURTASS LFA sonar.

FAMILY	SPECIES	ESA STATUS
Physeteridae	Sperm whale (*Physeter macrocephalus*)	Endangered
Kogiidae	Pygmy sperm whale (*Kogia breviceps*)	
	Dwarf sperm whale (*Kogia sima*)	
Ziphiidae	Baird's beaked whale (*Berardius bairdii)*	
	Arnoux's beaked whale (*Berardius arnuxii)*	
	Shepherd's beaked whale (*Tasmacetus sheperdii*)	
	Cuvier's beaked whale (*Ziphius cavirostris*)	
	Northern bottlenose whale (*Hyperodon ampullatus*)	
	Southern bottlenose whale (*Hyperodon planifrons)*	
	Longman's beaked whale (*Indopacetus pacificus*)	
	Andrew's beaked whale (*Mesoplodon bowdoini*)	
	Blainville's beaked whale (*Mesoplodon densirostris)*	
	Gervais' beaked whale (*Mesoplodon europaeus)*	
	Ginkgo-toothed beaked whale (*Mesoplodon ginkgodens)*	
	Gray's beaked whale (*Mesoplodon grayi)*	
	Hector's beaked whale (*Mesoplodon hectori)*	
	Hubbs beaked whale (*Mesoplodon carhubbsi)*	
	Perrin's beaked whale (*Mesoplodon perrini)*	
	Pygmy beaked whale (*Mesoplodon peruvianus)*	
	Sowerby's beaked whale (*Mesoplodon bidens)*	
	Spade-toothed beaked whale (*Mesoplodon traversii)*	
	Stejneger's beaked whale (*Mesoplodon stejnegeri)*	
	Strap-toothed beaked whale (*Mesoplodon layardii)*	
	True's beaked whale (*Mesoplodon mirus)*	
Monodontidae	Beluga (*Delphinapterus leucas*)	Endangered (Only Cook Inlet stock)
Delphinidae	Killer whale (*Orca orcinus*)	Endangered (Only Southern Resident population)
	False killer whale (*Pseudorca crassidens*)	
	Pygmy killer whale (*Feresa attenuata*)	
	Melon-headed whale (*Peponocephala electra*)	
	Long-finned pilot whale (*Globicephala melas*)	
	Short-finned pilot whale (*Globicephala macrorhynchus)*	
	Risso's dolphin (*Grampus griseus*)	
	Short-beaked common dolphin (*Delphinus delphis*)	
	Long-beaked common dolphin (*Delphinus capensis)*	
	Fraser's dolphin (*Lagenodelphis hosei*)	
	Common bottlenose dolphin (*Tursiops truncatus*)	

Table 3-3. Odontocete or toothed whale species considered for further evaluation of the potential effects from exposure to SURTASS LFA sonar.

FAMILY	SPECIES	ESA STATUS
Delphinidae (Continued)	Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)	
	Pantropical spotted dolphin (*Stenella attenuata*)	
	Striped dolphin (*Stenella coeruleoalba)*	
	Atlantic spotted dolphin (*Stenella frontalis)*	
	Spinner dolphin (*Stenella longirostris)*	
	Clymene dolphin (*Stenella clymene)*	
	Peale's dolphin (*Lagenorhynchus australis*)	
	Dusky dolphin (*Lagenorhynchus obscurus)*	
	Atlantic white-sided dolphin (*Lagenorhynchus acutus)*	
	White-beaked dolphin (*Lagenorhynchus albirostris)*	
	Hourglass dolphin (*Lagenorhynchus cruciger)*	
	Pacific white-sided dolphin (*Lagenorhynchus obliquidens)*	
	Rough-toothed dolphin (*Steno bredanensis*)	
	Northern right whale dolphin (*Lissodelphis borealis*)	
	Southern right whale dolphin (*Lissodelphis peronii)*	
	Commerson's dolphin (*Cephalorhynchus commersonii*)	
	Chilean dolphin (*Cephalorhynchus eutropia)*	
	Heaviside's dolphin (*Cephalorhynchus heavisidii)*	
	Hector's dolphin (*Cephalorhynchus hectori)*	
Phocoenidae	Dall's porpoise (*Phocoenoides dalli*)	
	Harbor porpoise (*Phocoena phocoena*)	
	Spectacled porpoise (*Phocoena dioptrica)*	

➢

➢ **Sirenians**

Globally, four sirenian species exist including three manatee species, the West Indian (*Trichechus manatus*), Amazonian (*T. inunguis*), and West African (*T. senegalensis*) manatees, and one dugong species (*Dugong dugon*). The West Indian and West African manatees occur in coastal and inshore tropical to subtropical marine, brackish, and freshwater waters while the Amazonian manatee is restricted solely to the freshwater river habitats of the Amazon River and its tributaries (Jefferson et al., 2008).

Although manatees can travel great distances, with occasional sightings of sole individuals of the Florida subspecies of the West Indian manatee (*T. m. latirostris*) having been recorded as far north as Cape Cod, MA (Wynne and Schwartz, 1999; DoN, 2005b) and individuals also very occasionally traveling into offshore waters (Reid et al., 1991; Fertl et al., 2005), these are considered to be atypical and rare occurrences. Virtually all documented sightings of sirenians have occurred in nearshore and inshore waters, well excluded from the LFA vessel operational area and depth. For these reasons, the manatee species are excluded from further analysis.

Dugongs are widely but discontinuously distributed in the northern Indian and western North Pacific Oceans in coastal and estuarine tropical and subtropical waters that are typically less than 5m (16.4 ft)

Table 3-4. Pinniped species in the Otariidae family considered for further evaluation of the potential effects from exposure to SURTASS LFA sonar.

SPECIES	ESA STATUS
South American fur seal (*Arctocephalus australis*)	
New Zealand fur seal (*Arctocephalus forsteri*)	
Galapagos fur seal (*Arctocephalus galapagoensis*)	
Juan Fernadez fur seal (*Arctocephalus philippi*)	
South African and Australian fur seals (*Arctocephalus pusillus*)	
Guadalupe fur seal (*Arctocephalus townsendi*)	Threatened (foreign)
Subantarctic fur seal (*Arctocephalus tropicalis*)	
Northern fur seal (*Callorhinus ursinus*)	
Steller sea lion (*Eumetopias jubatus*)	Endangered (Western DPS); Threatened (Eastern DPS)
California sea lion (*Zalophus californianus*)	
Galapagos sea lion (*Zalophus wollebaeki*)	
Australian sea lion (*Neophoca cinerea*)	
New Zealand fur seal (*Phocarctos hookeri*)	
South American sea lion (*Otaria flavescens*)	

Table 3-5. Pinniped species in the Phocidae family considered for further evaluation of the potential effects from exposure to SURTASS LFA sonar.

SPECIES	ESA STATUS
Mediterranean monk seal (*Monachus monachus*)	Endangered (foreign)
Hawaiian monk seal (*Monachus schauinslandi*)	Endangered
Northern elephant seal (*Mirounga angustirostris*)	
Southern elephant seal (*Mirounga leonina*)	
Ribbon seal (*Phoca fasciata*)	
Spotted seal (*Phoca largha*)	Threatened (Southern DPS)
Harbor seal (*Phoca vitulina*)	
Gray seal (*Halichoerus grypus*)	
Hooded seal (*Cystophora cristata*)	
Harp seal (*Pagophilus groenlandicus*)	

deep (Jefferson et al., 2008). Although principally coastal dwellers, dugongs have been sighted near reefs up to 80 km (43.2 nmi) from shore in waters up to 23 m (75 ft) deep (Reeves et al., 2002). Although the distance dugongs may potentially travel from shore exceeds the 12 nmi exclusion distance from land in which SURTASS LFA sonar will not operate, the water depth of these more offshore reefs where dugongs uncommonly travel are so shallow that the operation of the sonar is precluded. As a result, the dugong was eliminated from further evaluation.

3.2.2 FISH

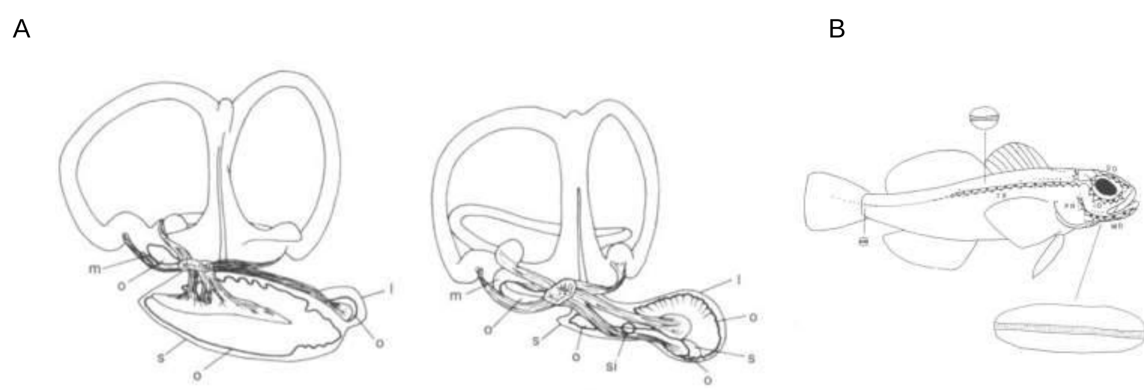
Two taxonomic classes of fish are considered for this SEIS: Chondrichthyes (cartilaginous fish including sharks and rays) and Osteichthyes (bony fish). The bony fish comprise the largest of all vertebrate groups with over 29,000 extant species (Nelson, 2006). The ecological distribution of fish is extraordinarily wide, with different species being adapted to a diverse range of abiotic and biotic conditions.

Pelagic fish live in the water column, while demersal fish live near the bottom and both types of fishes may potentially be exposed to LF sounds. Additionally, many fish species are protected and are commercially important. It is likely that all species of fish can hear, and that many fish species produce and/or use sound for communication (Appendix B). However, data on hearing and/or sound production are not available for many species beyond those shown in the table. For example, there is reason to suggest that a number of deep-sea species that live where there is little or no light, such as myctophids (lanternfish) (Popper, 1980a; Mann and Jarvis, 2004), macrourids (rattails—relatives of cod) (Deng et al., 2009), and deep sea eels (Buran et al., 2005) hear well and/or use sound for communication, but this cannot be confirmed without far more extensive data.

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

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

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



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

Figure 3-1. Octavolateralis system of fish including the inner ear and lateral line system (Coombs et al., 1989).

The ear and the lateral line overlap in the frequency range to which they respond. The lateral line appears to be most responsive to signals ranging from below 1 Hz to between 150 and 200 Hz (Coombs et al., 1992; Webb et al., 2008), while the ear responds to frequencies from about 20 Hz to several thousand Hz in some species (Popper and Fay, 1993; Popper et al., 2003; Popper and Schilt, 2008).[21] The specific frequency response characteristics of the ear and lateral line varies among different species and is probably related, at least in part, to the life style of the particular species.

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

Hearing is better understood for bony fish than for cartilaginous fish like sharks and jawless fish (class Agnatha) (Popper and Fay, 1993; Ladich and Popper, 2004). Bony fish with specializations that enhance their hearing sensitivity have been referred to as hearing “specialists”, whereas, those that do not posses

[21] As discussed below, some fish species are now known to detect sounds well below 20 Hz and others sounds that are in the ultrasound range.

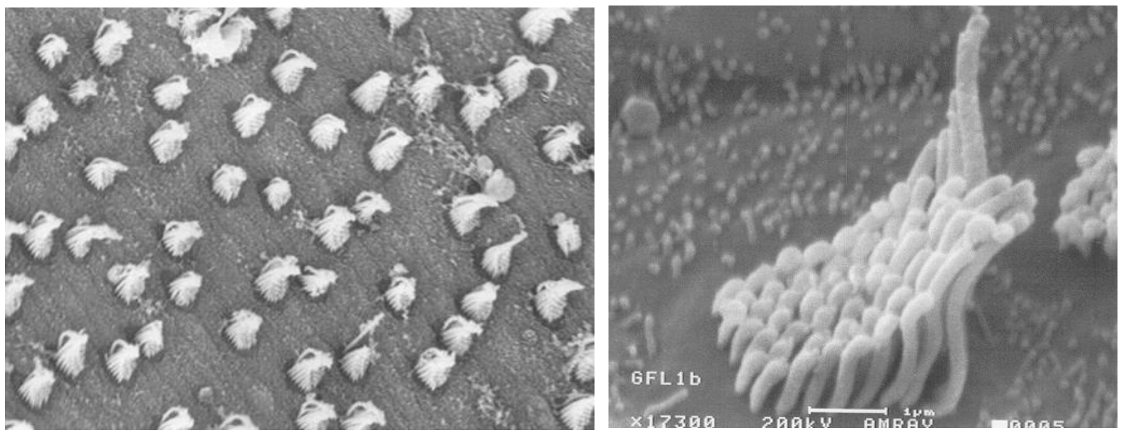


Figure 3-2. Scanning electron micrographs of the ciliary bundles of hair cells from a goldfish (*Carassius auratus*) lagena (unpublished photographs by M.E. Smith). The hair cell on the right is magnified (17,300x) from the general area shown on the left. The scale bar represents 1 µm).

such capabilities are called “nonspecialists” (or “generalists”). However, in a recent review, Popper and Fay (2009a) have argued that the terms hearing “generalist” and “specialist” should be dropped, since there is so much overlap in hearing capabilities and mechanisms among different species. Instead, Popper and Fay (2009a) suggest that different hearing capabilities should be treated on a “continuum” of capabilities.

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

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

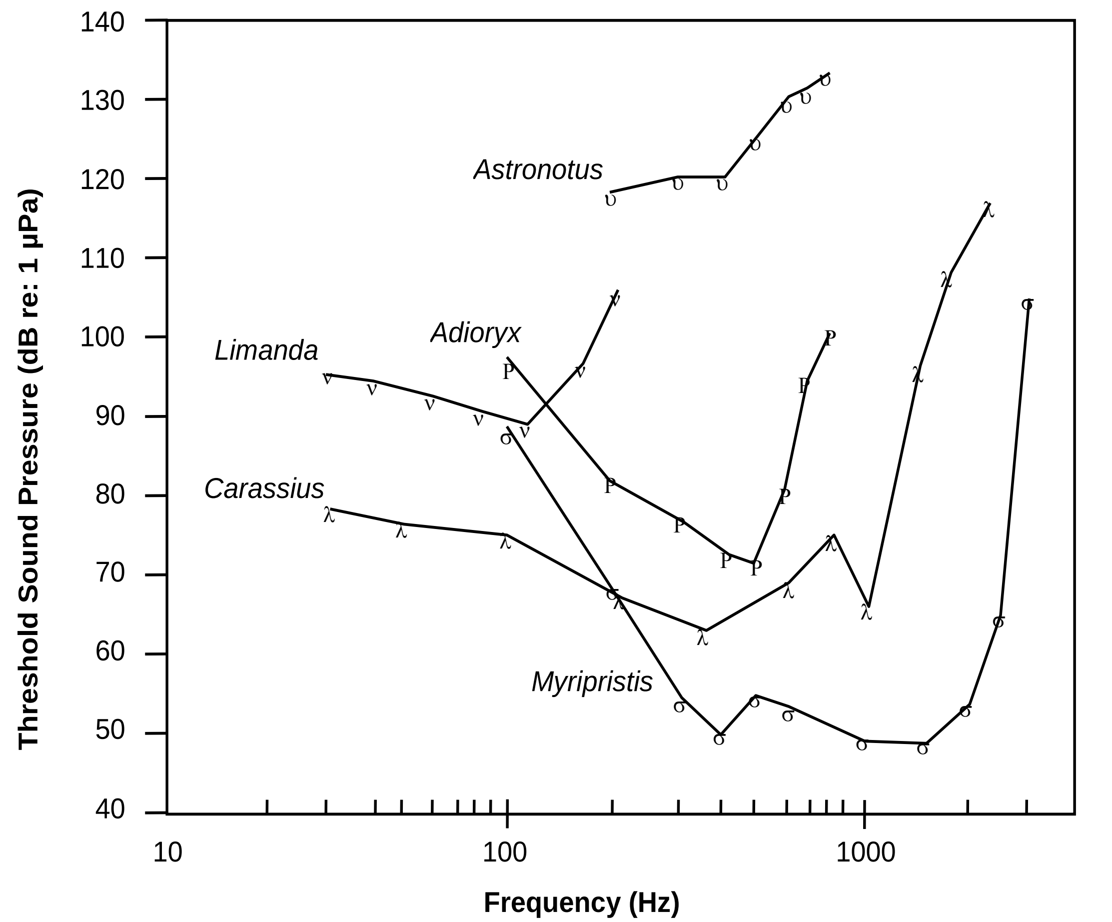
Audiograms (measures of hearing sensitivity) have been determined for over 50 fish (mostly fresh water) and several elasmobranch species (Fay, 1988a; Casper et al., 2003; Casper et al., 2006; Casper and Mann, 2006) (Figures 3-3 and 3-4). An audiogram plots auditory thresholds (minimum detectable levels) at different frequencies and depicts the hearing sensitivity of the species. It is difficult to interpret audiograms because it is not known whether sound pressure or particle motion is the appropriate stimulus and whether background noise determines threshold. The general pattern that is emerging indicates that the those species with hearing specializations detect sound pressure with greater sensitivity over a wider bandwidth (to 3 kHz or above) than those species with no hearing specializations. Also, the limited behavioral data available suggest that frequency and intensity discrimination performance may not be as acute in those species with no hearing specializations (Fay, 1988a).

Popper and Fay (1993) point out that threshold values are expressed as sound pressure levels because that quantity is easily measured, although this value is strictly correct only for the fish that respond in proportion to sound pressure. It is uncertain if the thresholds for the oscar and lemon sole should be expressed in terms of sound pressure or particle motion amplitude. In comparing best hearing thresholds, fishes with hearing specializations are similar to most other vertebrates, when thresholds determined in water and air are expressed in units of acoustic intensity (i.e., Watts/cm^2) (Popper and Fay, 1993) (Figure 3-4).

Those fish species with hearing specializations whose best hearing is below about 1000 Hz appear well adapted to this particular range of frequencies, possibly because of the characteristics of the signals they produce and use for communication, or the dominant frequencies that are found in the general underwater acoustic environment to which fish listen (Schellart and Popper, 1992; Popper and Fay, 1997, 1999; Popper et al., 2003). The region of best hearing in the majority of fish for which there are data is from 100 to 200 Hz up to 800 Hz. Most species, however, are able to detect sounds to below 100 Hz, and often there is good detection in the LF range of sounds. It is likely that as data are accumulated for additional species, investigators will find that more species are able to detect low frequency sounds fairly well.

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

Many species of fish produce sounds for communication. Myrberg (1980) states that members of more than 50 fish families produce some kind of sound using special muscles or other structures that have evolved for this role, or by grinding teeth, rasping spines and fin rays, burping, expelling gas, or gulping air. Sounds are often produced by fish when they are alarmed or presented with noxious stimuli (Myrberg, 1981; Zelick et al., 1999; Bass and Ladich, 2008). Some of these sounds may involve the use of the swim bladder as an underwater resonator. Sounds produced by vibrating the swim bladder may be at a higher frequency (400 Hz) than the sounds produced by moving body parts against one another. The swim bladder drumming muscles are correspondingly specialized for rapid contractions (Zelick et al., 1999; Bass and Ladich, 2008). Sounds are known to be used in reproductive behavior by a number of fish species, and the current data lead to the suggestion that males are the most active producers. Sound activity often accompanies aggressive behavior in fish, usually peaking during the reproductive season.



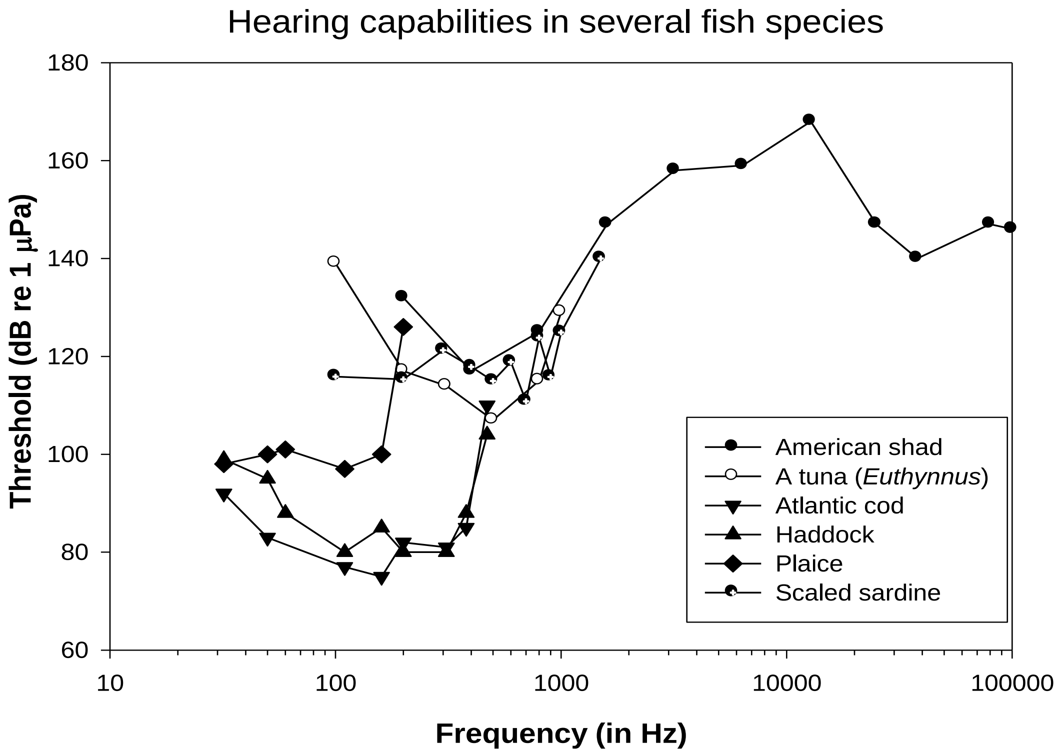
Two fish species with hearing specializations—*Carassius auratus* (goldfish) (Fay, 1969) and *Myripristis kuntee* (squirrelfish) (Coombs and Popper, 1979); two fishes with no hearing specializations but possessing a swimbladder—*Adioryx xantherythrus* (another squirrelfish) (Coombs and Popper, 1979)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

Figure 3-3. Behavioral audiograms for selected freshwater fish species.

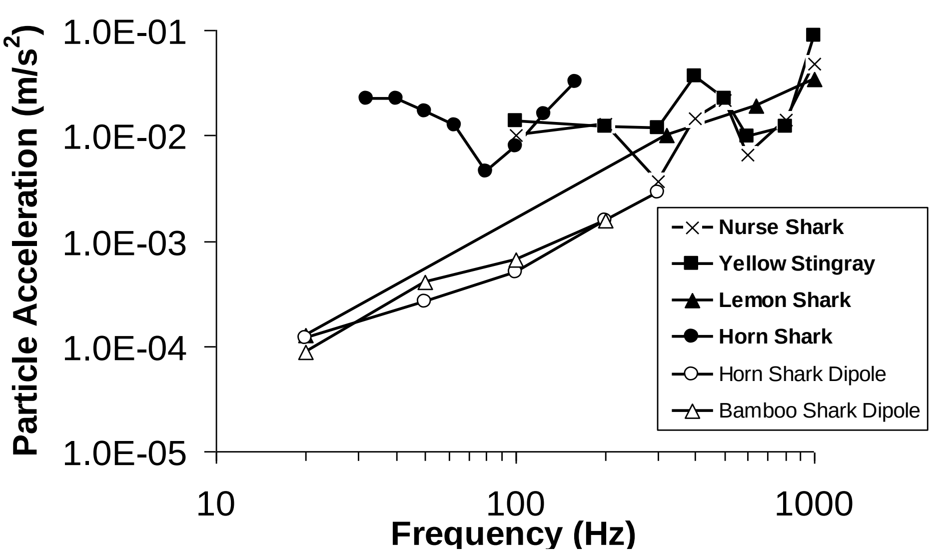
Those benthic fish species that are territorial in nature often produce sounds regardless of season but particularly during periods of high-level aggression (Myrberg, 1981).

3.2.2.2 Chondrichthyes (Cartilagenous Fish)—Hearing Capabilities, Sound Production, and Detection

Sharks are also of interest because of their low frequency sound detection ability, a capability that is particularly important for detecting sounds that are produced by potential prey (Nelson and Gruber, 1963; Myrberg et al., 1976; Nelson and Johnson, 1976; Myrberg, 1978). There are hearing data on very few species, and it is not yet clear whether sharks and rays respond to sound pressure or to particle velocity (or displacement), or to both. In general, sharks appear to only detect frequencies that are in a range that is similar to that of fish that are classified as hearing generalists, and hearing sensitivity (the lowest sound levels detectable) is probably poorer than hearing generalist fish (Banner, 1967; Nelson, 1967; Kelly and



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



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

Figure 3-4. Behavioral audiograms for selected marine fish species.

Nelson, 1975; Casper et al., 2003). The function of the lateral line system of sharks is likely, as in fish, to respond to low frequency hydrodynamic stimuli.

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

The most recent studies of several elasmobranch species show hearing ranges that are comparable to those of earlier studies, but were measured in terms of particle motion, the stimulus parameter that is most likely the most important to animals without a swim bladder, such as elasmobranchs (Casper et al., 2003; Casper and Mann, 2006, 2007), and unlike that done in earlier studies (see van den Berg and Schuijf, 1983). Casper et al. (2003) showed that the little skate, *Raja erinacea* is able to detect sounds from 100 to over 800 Hz, with best hearing up to and possibly slightly greater than 500 Hz. Similar thresholds and hearing range have been reported for the nurse shark (*Ginglymostoma cirratum*) and the yellow stingray (*Urobatis jamaicensis*) (Casper and Mann, 2006) and the horn shark *Heterodontus francisci* and the white-spotted bamboo shark *Chiloscyllium plagiosum* (Casper and Mann, 2007) (Figure 3.2-3).

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

The effects of pulse intermittency and pulse-rate variability on the attraction of five species of reef sharks to low frequency pulsed sounds were studied at Eniwetok Atoll, Marshall Islands in 1971 (Nelson and Johnson, 1972). The species tested were gray reef, blacktip reef, silvertip, lemon, and reef white tip. Nelson and Johnson (1972) concluded from these tests that the attractive value of 25 to 500 Hz pulsed sounds is enhanced by intermittent presentation, and that such intermittency contributes more to attractiveness than does pulse-rate variability. All tested sharks exhibited habituation to the sounds during the course of the experiment.

One caveat with all data collected with sharks is that the earlier work was all based on studies of single animals, which means the data do not reflect inter-animal variability in sensitivity and bandwidth within a single species, something widely known to occur in all animal groups. While more recent studies (e.g., Casper et al. 2003; Casper and Mann 2006, 2007) used multiple animals, there is still the issue that hearing ability changes with age, health, and many other variables. While the thresholds reported for sharks give an indication of the sounds they can detect, it would be of great value to replicate these analyses using modern methods and several animals. A similar observation may be made for some fish studies, but generally those are done with several animals and are replicated far more than is possible with the larger and more difficult-to-handle sharks. It is important to note that in virtually all fish studies there is some variation in hearing sensitivity among fish, reflecting the normal variation found in hearing in all vertebrates.

A second issue with earlier shark work (but much less so with the recent studies) is that hearing was measured in terms of sound pressure levels. However, we now know that elasmobranchs are very likely detectors of particle motion rather than pressure (e.g., Casper and Mann, 2007), and so interpretation of thresholds and even bandwidth from earlier studies need to be taken with some caution. However, what is certainly clear is that elasmobranchs do not detect sounds much above 1,000 Hz, and it is possible that the usable upper limit for hearing is not much higher than 500 Hz.

3.2.2.3 Threatened and Endangered Fish Species

The following marine and anadromous fish species have been listed as threatened (T) or endangered (E) under the ESA, often for specific geographic locations known as distinct population segment (DPS) or evolutionary significant unit (ESU):

- Atlantic salmon (*Salmo salar) (E, Gulf of Maine DPS): Maine coastal rivers and northwestern Atlantic Ocean from Gulf of Maine to Labrador, Canada;*
- Coho salmon (*Oncorhynchus kisutch*) (E, one ESU; T, three ESUs): North Pacific Ocean basin;
- Chinook salmon (*Oncorhynchus tshawytscha*) (E; two ESUs; T; seven ESUs): North Pacific Ocean basin;
- Sockeye salmon (*Oncorhynchus nerka*) (E, one ESU; T, one ESU): North Pacific Ocean basin;
- Chum salmon (*Oncorhynchus keta) (T, two ESUs):* North Pacific Ocean basin*;*
- Steelhead trout (*Oncorhynchus mykiss*) (T, 11 DPSs): inland and coastal waters of North Pacific Ocean;
- Shortnose sturgeon (*Acipenser brevirostrum*) (E): nearshore waters and coastal rivers of U.S. northwestern Atlantic Ocean;
- Gulf sturgeon (*Acipenser oxyrinchus desotoi*) (T): coastal waters of U.S. Gulf of Mexico from Mississippi River to Tampa Bay;
- Green sturgeon (*Acipenser medirostris) (T; Southern DPS): Coastal rivers of California;*
- Smalltooth sawfish (*Pristis pectinata) (E, U.S. DPS): primarily nearshore and inshore Florida but may be also found in shelf waters of southeastern U.S.;*
- *Largetooth sawfish* (*Pristis perotteti*) (E): shallow near-shore estuarine and lagoonal areas of the Gulf of Mexico;
- Totoaba (*Cynoscion macdonaldi*) (E, foreign): Gulf of California;
- Bocaccio (*Sebastes paucispinis*) (E; Puget Sound/Georgia Basin DPS): inshore waters of Puget Sound and the Georgia Basin;
- Canary rockfish (*Sebastes pinniger)* (T; Puget Sound/Georgia Basin DPS): inshore waters of Puget Sound and the Georgia Basin;
- Yelloweye rockfish (*Sebastes ruberrimus*) (T; Puget Sound/Georgia Basin DPS): inshore waters of Puget Sound and the Georgia Basin; and
- Pacific euchalon/smelt (*Thaleichthys pacificus)* (T): Northeastern Pacific Ocean.

Anadromous fish species, such as salmon and trout, live in the ocean as juveniles and adults but return to the freshwater streams or lakes of their birth to spawn as adults; all of the Pacific salmon species and a number of Atlantic salmon die after spawning. Many of these ESA-listed species, such as the sturgeons, are found only in nearshore waters of the marine environment and also migrate into freshwater rivers and streams. While principally found in nearshore waters, large adult smalltooth sawfish have been captured in continental shelf and deeper waters off the southeastern U.S. (DoN, 2007d).

3.2.3 SEA TURTLES

Seven species of living marine turtles are distributed circumglobally in the Atlantic, Pacific, and Indian Oceans and throughout the Caribbean and Mediterranean Seas. The distributions of these species span tropical and temperate waters and, in the case of the leatherback turtle (*Dermochelys coriacea*), extends northward to the subArtic and as far south as New Zealand and the Southern Ocean. All sea turtles are protected under Appendix I of the Convention on International Trade in Endangered Species of Flora and Fauna (CITES), which prohibits international trade to and from signatory countries. Six of the seven sea turtle species are listed under the ESA as threatened and/or endangered (Table 3-1). The seventh sea turtle species, the flatback turtle (*Natator depressus*), is not listed under the ESA as its distribution is restricted to coastal waters off Australia, Papua New Guinea, and Guinea. In addition, the International Union for the Conservation of Nature and Natural Resources (IUCN) considers the Kemp's ridley and hawksbill turtles to be critically endangered, the loggerhead and green turtles to be endangered, the olive ridley to be vulnerable, and the flatback turtle to be data deficient (IUCN, 2010).

3.2.3.1 Natural History and Behavior

Sea turtles are marine reptiles well adapted for life in the sea. Their streamlined bodies and flipper-like limbs make them strong swimmers, able to navigate across oceans. Marine turtles inhabit the world's oceans except the Arctic and Antarctic and range from the northern and southern reaches of the Atlantic and Pacific Oceans to the tropics and into the Mediterranean Sea. Sea turtles go ashore to lay their eggs on beaches and isolated shores and eat a wide-ranging diet, from sea grasses to jellyfish, algae, clams, crabs, and sponges (Spotila, 2004). In addition, sea turtles are the only reptiles that exhibit long-distance migrations that rival those of terrestrial and avian vertebrates. Data accumulated from several decades of mark-recapture and telemetry studies demonstrate that adult sea turtle migrations are resource-driven, with migrants traveling hundreds to thousands of kilometers between established feeding and breeding areas at regular or seasonal intervals (Plotkin, 2003).

Marine turtles are capable of making deep, repetitive dives to search for food and can remain submerged for long periods of time, such as when resting on the ocean bottom. In fact, most sea turtles spend as little as 3 to 6% of their time at the surface—often just long enough to take a breath of air. In addition to their distinctive anatomical traits, sea turtles have interesting physiological adaptations that allow them to exploit the marine environment in unique ways, and interesting parallels can be made with the aquatic adaptations exhibited by marine mammals (Lutcavage and Lutz, 1997).

Sea turtles show a wide range in diving ability. The leatherback turtle, the deepest diving turtle, has been recorded diving to a maximum water depth of 1,230 m (4,035 ft) (Hays et al., 2004), while the green turtle typically only dives no deeper than 20 m (65.6 ft) (Hays et al. 2000). Olive ridley turtles are exceptional in their ability to remain underwater for very long stretches of time, with turtles tagged in waters >20°C by McMahon et al. (2007) remaining underwater for up to 3 hrs and 30 min. This is unlike the overwintering behavior of loggerhead turtles, during which the longest dive of any marine vertebrate was recorded. A tagged loggerhead dove for 6.8 hrs during winter when low (<15°C) water temperatures result in reduced metabolic rates that allow these animals to remain submerged for extensive periods on the sea floor (Hochscheid et al., 2005).

Sea turtle diving and surface behavior patterns may be a reflection more of the turtle's ecology and environment and less of their size and physiological attributes. For example, sea turtles such as hawksbills have been observed resting on the ocean bottom, wedged under a coral ledge for a prolonged period of time, which would be recorded as a long dive-duration. In contrast, some sea turtles can spend as much as 19 to 26% of their time at the surface engaged in basking, feeding, orientation, and mating (Lutcavage and Lutz, 1997).

The biology of sea turtles is intimately tied to the temperature of their environment. Like other reptiles, sea turtles are ectothermic[22], with no physiological regulation of their body temperature. However, marine turtles are unusual among reptiles because their large body size allows adults to use insulation and blood flow to maintain body temperature above that of the surrounding water. In general, the body temperature of inactive green, loggerhead, and olive ridley turtles is 1 to 2°C higher than the temperature of the surrounding water, and when active, their body temperature is 2 to 3°C higher than the water. The body temperature of leatherbacks is also 1 to 2°C higher than ambient tropical waters while their body temperature in cold temperate/subarctic waters is much warmer than the ambient waters due to their large body size and thermoregulatory capabilities (Spotila et al., 1997; Wallace et al., 2005). Leatherback turtles can remain active even in very cold water, down to at least 0.4°C (33°F) (James et al., 2006).

The distribution of many sea turtle species is also dependent upon (and often restricted by) water temperature (Coles and Musick, 2000). Most sea turtles become lethargic at temperatures below 10°C and above 40°C (Spotila et al., 1997). The normal range of sea surface temperatures (SST) in which sea turtles predominantly occur is from 13.3° to 28°C (Coles and Musick, 2000); these preferred water temperature ranges vary across age classes and species as well as seasons.

Despite some thermoregulatory and behavioral adaptations that sea turtles have evolved, green, loggerhead, and Kemp's ridley turtles are susceptible to a phenomenon called "cold stunning." Cold stunning occurs in late fall through early winter, when water temperatures suddenly drop to 7 to 10°C (45 to 50°F). In late fall, a small %age of primarily juvenile turtles remain in the nearshore waters and embayments, where they have spent the summer feeding. As the water temperatures precipitously drop, the young turtles become "stunned" by the suddenly much cooler waters. Cold stunned turtles become lethargic and more buoyant, floating on the surface, and often cease eating (Milton and Lutz, 2003). Death often ensues when most sea turtle species are exposed to water temperatures below 5° to 6°C since the animals can no longer swim or dive (Milton and Lutz, 2003). Cold stunning is a major cause of sea turtle stranding along the New England, Florida, and Gulf of Mexico coasts and along the shores of Western Europe in late fall and early winter (Spotila et al., 1997; Spotila, 2004). Alternatively, in some geographic regions (such as the Mediterranean and Florida), some green and loggerhead turtles escape cold temperature conditions by resting on the seabed or burying themselves in the bottom sediments to brumate (Ogren and McVea, 1995; Hochscheid et al., 2005) or by conducting very long dives, sometimes of more than five hours in duration (Hochscheid et al., 2005; Hawkes et al., 2007).

One strategy to avoid cold water temperatures is for animals to migrate to warmer waters. Sea turtles migrate, sometimes extremely long distances, from foraging grounds to shallow-water nesting grounds to mate, nest, and lay their eggs. Depending on the species, sea turtles reach sexual maturity at five to 15 years (leatherback) to 35 years (green turtle) of age (Spotila, 2004). After the nesting season, turtles migrate back to the foraging grounds. In most species of sea turtles, mature females do not nest every year, remaining instead at the foraging grounds in non-nesting years (Wynne and Schwartz, 1999).

Following an 8- to 10-week incubation period, sea turtle eggs hatch. Hatchlings dig their way out of the nest to typically emerge at night. The hatchlings enter the water and swim rapidly in a "swimming frenzy" (Wyneken, 1997) until they reach the open ocean, where many species spend the "lost years" living and feeding in floating *Sargassum*. Juvenile sea turtles share feeding grounds with adults or, in some cases, migrate to developmental feeding grounds (Wynne and Schwartz, 1999). Bolten (2003) has described this life history pattern as a Type 2 pattern, characterized by early development in the oceanic zone followed

[22] An ectotherm is an animal that obtains most of its body heat from the surrounding environment, does not have the physiologic means to regulate its internal temperature, and maintains its body temperature within a fairly narrow temperature range by behavioral means (e.g., basking or burrowing in sediments).

by later development in the neritic zone[23]. In contrast, some species, such as the leatherback and olive ridley (east Pacific populations), spend their entire lives in a pelagic existence, coming inshore only to mate and nest and are described as a Type 3 life history pattern, characterized by both developmental and adult stages occurring completely in the oceanic zone (Bolten, 2003).

3.2.3.2 Species Descriptions of Potentially Affected Sea Turtles

Population sizes or abundances of sea turtles are generally derived worldwide from estimates of breeding females as they return to shore to nest, when they are more visible and easily counted. Unless otherwise noted, sea turtle abundances are counts of nesting females. Although these abundances represent underestimations of the sea turtle populations as they do not include counts of male or juvenile turtles, they are the best available abundance data available.

- **Green turtle (*Chelonia mydas*)**

There is still considerable controversy regarding the taxonomic status of the east Pacific green turtle, or black turtle, and whether it is a separate species or subspecies from the green turtle. Recent reviews of available data, including morphological, phylogenetic, geographic, and genetic information, have left researchers to conclude that while it is possible that the east Pacific green turtle populations are undergoing speciation, not enough evidence exists at this time to warrant species or subspecies status (Parham and Zug, 1996; Bowen and Karl, 2000). Therefore, for the purposes of this analysis, the black turtle will be considered as eastern Pacific populations of the green turtle, *C. mydas.*

The green turtle is protected under CITES and is listed as endangered by the IUCN. The breeding colonies of Florida and Mexico's Pacific coast are listed as endangered under the ESA while the species is listed as threatened in the rest of the Pacific and Atlantic Oceans. Once abundant, green turtles have been hunted for their meat, green fat (where the common name derives), and eggs.

Green turtles nest in about 80 countries around the world. The NMFS and USFWS (2007) estimate that between 108,761 to 150,521 female turtles nest per year at the 46 worldwide sites for which data were collected. Raine Island, off eastern Australia is reputed to be the largest nesting concentration of female green turtles in the world, even though no reliable abundance estimates of nesting females are available (NMFS and USFWS, 2007). The most recent estimate of nesting females is 25,000 females, but in some years this number is estimated to reach 80,000 (NMFS and USFWS, 2007). The largest rookery in the Atlantic Ocean is located at Tortuguero, Costa Rica, where 17,402 to 37,290 females are estimated to nest each year (NMFS and USFWS, 2007).

Green turtles are widespread throughout tropical and subtropical waters of the Atlantic, Pacific, and Indian Oceans but have been recorded as far north as the temperate waters of Cape Cod and Georges Bank in the northwestern Atlantic Ocean (Lazell, 1980; DoN, 2005b). These turtles inhabit the neritic zone, typically occurring in nearshore and inshore waters where they forage primarily on sea grasses and algae (Mortimer, 1982). Green turtles primarily occur in coastal regions as juveniles and adults but make long pelagic migrations, swimming thousands of kilometers across the open ocean, between foraging and nesting grounds (Bjorndal, 1997; Pritchard, 1997). Green turtles typically make shallow dive to no more than 30 m (Hochscheid et al., 1999; Hays et al., 2000) with a maximum recorded dive to 110 m (65.6 ft) in the Pacific Ocean (Berkson, 1967). Most dives of green turtles are typically 9 to 23 min in duration with a maximum dive having been recorded at 66 min (Brill et al., 1995).

- **Hawksbill turtle *(Eretmochelys imbricate)***

The hawksbill turtle is listed as critically endangered under the IUCN, endangered throughout its range under the ESA, and is protected by CITES. Nearly hunted to extinction, hawksbills were heavily exploited

[23] The neritic zone is the marine environmental zone that is closest to shore and that extends from the low-tide mark to the edge of the continental shelf or to a water depth of about 200 m (656 ft).

for their shells—the real “tortoiseshell,” which was made into jewelry, combs, hairbrushes, and decorative inlays in fine furniture. Although there is a lack of data to determine good population estimates, the best estimate of the number of annual nesting females worldwide is 21,212 to 28,138 turtles, which represents about 83 nesting areas (NMFS and USFWS, 2007a). The largest nesting populations in the Pacific Ocean occurs in eastern Australia with some 6,500 females nesting per year, in the Atlantic Ocean Yucatan Peninsula, Mexico and Cuba have 534 to 891 and 400 to 833 females nesting, respectively, and in the Indian Ocean, about 2,000 females nest in western Australia and 1,000 nest in Madagascar annually (NMFS and USFWS, 2007a). Although very few hawksbills nest in U.S. waters, nesting does occur on four Puerto Rico locations (120 to 200 female turtles annually), U.S. Virgin Islands (56 to 222 females annually), Hawaii (5 to 10 females annually), and fewer than 10 females annually in the north Pacific U.S. territories (Spotila, 2004; NMFS and USFWS, 2007a).

Hawksbill turtles occur in coastal tropical and subtropical waters in the Atlantic, Pacific, and Indian Oceans (NMFS and USFWS, 1998a), and are especially in often encountered in shallow lagoons and coral reefs. The largest populations live in the Caribbean Sea, the Seychelles, Indonesia, and Australia. There are no hawksbills in the Mediterranean Sea (Spotila, 2004). In the western Atlantic, they range from Brazil to Massachusetts, but are considered rare north of Virginia (Wynne and Schwartz, 1999). They tend to remain in shallow water of 20 to 50 m (66 to 164 ft) but make the longest routine dives of all sea turtles, with routine dives ranging from 34 to 74 min (Starbird et al., 1999).

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

- **Loggerhead turtle (*Caretta caretta*)**

The loggerhead turtle is listed as endangered under the IUCN, threatened under the ESA, and is protected under CITES. Although Spotila (2004) estimated that 44,560 adult female loggerheads nest annually worldwide, this is likely an underestimate. One of the three major loggerhead populations occurs in southeastern U.S. and northern Gulf of Mexico waters, where 32,000 to 56,000 adult female turtles are estimated to occur (Ehrhart et al., 2003). Formerly the largest worldwide nesting aggregation, the number of females nesting annually in eastern Australia has substantially declined to less than 500, while the only nesting in the North Pacific Ocean, occurs in Japan where more than 4,000 females have been documented nesting recently (NMFS and USFWS, 2007b). The largest nesting aggregation of loggerheads in the Indian Ocean occurs in Masirah, Oman where 20,000 to 40,000 females nest annually (Baldwin et al., 2003).

Loggerhead turtles are found in temperate, tropical, and subtropical waters, coastal and pelagic habitats, and in both the northern and the southern hemispheres. They are found in the Atlantic, Pacific, and Indian Oceans, including the Mediterranean Sea (Dodd, 1988). The greatest concentrations of loggerheads live along the coast of the western Atlantic Ocean, including Mexico, Cuba, the Bahamas, along the coast of North America from the Mississippi River along the Gulf coast and up the U.S. East Coast, and as far north as Newfoundland. Very few loggerheads forage along the European or African coasts (Spotila, 2004). Loggerheads are highly migratory, capable of traveling hundreds to thousands of kilometers between feeding and nesting grounds. Although loggerheads forage in the Mediterranean Sea, 45% migrate between the Atlantic Ocean and Mediterranean Sea. Indian Ocean loggerheads occupy foraging grounds along the coasts of southern Africa, Madagascar, Yemen, and Oman, and in the Arabian Gulf, as well as along Western Australia into Indonesian waters. In the Pacific, loggerheads feed in the Gulf of California and along Baja California, but none nest in the eastern Pacific. Hatchlings from nests in eastern Australia and Japan migrate to Mexico and then return to the western Pacific as large juveniles.

Polovina et al. (2003) found that loggerhead turtles spent about 40% of their time at the water surface and 70% of their dives were to no more than 5 m. Even as larger juveniles and adults, loggerheads' routine dives are only nine to 22 m (30 to 72 ft), but adult female loggerheads have recorded dives to 233 m (764 ft), lasting 15 to 30 min (Lutcavage and Lutz, 1997).

- **Olive ridley turtle (*Lepidochelys olivacea*)**

Although the olive ridley turtle is the most abundant sea turtle worldwide, it has declined or disappeared from many of its historic nesting areas. The turtles were hunted for their meat and eggs well into the 1990s. The global population is protected by CITES, classified as vulnerable under the IUCN, and listed as threatened under the ESA everywhere except the Mexican breeding stocks, which are listed as endangered. Accurate abundance estimates are difficult to obtain, as most olive ridley females nest in mass aggregations of hundreds to thousands of turtles, called *arribadas*, making counts of individual turtles difficult. In addition, solitary-nesting females are often too spread out to ensure accurate data collection. Chaloupka et al. (2004) reported abundances for 1999 and 2000, respectively, of 2 and 1.1 million nesting females for two (Ostional, Costa Rica and Escobilla, Mexico) of the major olive ridley nesting populations in the eastern Pacific stock. From data collected at sea, Eguchi et al. (2007) estimated the juvenile and adult olive ridley population in the eastern tropical Pacific Ocean (area encompasses major arribada[24] beaches in Mexico and Central America) as 1.39 million turtles.

Olive ridleys are found in the tropical to warm-temperate Pacific and Indian oceans, but are uncommon in the western Pacific and eastern Indian Ocean. They can also be found in the Atlantic along the west coast of Africa and northeastern coast of South America. Individuals are rarely sighted further into the Caribbean than Trinidad and the West Indies (NMFS, 1995; Plotkin 2003; Spotila, 2004). Unlike their other hard-shelled counterparts, olive ridleys favor an oceanic existence, rarely coming inshore except to nest. Even during the breeding season, males will often remain in the open ocean, intercepting females on their way to the nesting beaches. Copulating pairs have been seen at distances over 1,000 km (540 nmi) from the nearest nesting beach. Olive ridleys are highly migratory and spend most of their non-breeding life cycle in the oceanic zone. Their migratory paths vary annually and no apparent migration corridors exist. Instead, they appear to wander over vast stretches of ocean in search of food, possibly using water temperature as an environmental cue and seeking oceanographic features, such as thermal fronts and convergence zones, to locate suitable feeding areas (Plotkin, 2003; Spotila, 2004).

Olive ridley turtles are capable of deep dives, having been recorded diving to 290 m (951 ft), although routine feeding dives of 80 to 110 m (262 to 361 ft) are most common (Bjorndal, 1997; Lutcavage and Lutz, 1997). Polovina et al., 2003 reported that olive ridley turtles only remained at the surface for 20% of the time, with about 75% of their dives to 100 m and 10% of total dive time spent at depths of 150 m. Inter-nesting females make routine dives of 54.3 min while breeding and post-breeding males apparently make shorter duration dives of 28.6 and 20.5 min, respectively (Lutcavage and Lutz, 1997).

Little is known about the early life stages of the olive ridley turtle. Based on data from the Kemp's ridley sea turtle (discussed below), it is thought that olive ridleys mature in 11 to 16 years at a size of 56 to 78 cm (22 to 31 in) (NMFS, 1995; Spotila, 2004). As stated previously, olive ridleys nest in mass aggregations, called *arribadas*, with thousands of females emerging from the water to nest on a given

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[24] 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).

stretch of beach at the same time, often in daytime. This nesting technique is thought to be a strategy that evolved to overwhelm predators by providing safety in numbers (Spotila, 2004). Major arribada nesting beaches include Ostional (500,000 females) and Nancite (100,000) on Costa Rica's Pacific coast, La Escobilla (450,000) in Pacific Mexico, and Gahirmatha (135,000) in India. Minor *arribada* beaches are found in Nicaragua (12,000 to 25,000 females), India (2,000 to 10,000), Mexico (2,000), and Panama (2,000). Solitary nesting occurs on the beaches of 32 countries (Spotila, 2004).

➢ **Kemp's ridley turtle *(Lepidochelys kempii)***

The Kemp's ridley turtle is the rarest sea turtle worldwide and has the most restricted distribution. The Kemp's ridley is classified as critically endangered under the IUCN, as endangered throughout their range under the ESA, and are protected by CITES. When its primary nesting beach was first discovered in 1947, approximately 40,000 female Kemp's ridleys were nesting in an arribada at Rancho Nuevo in Tamaulipas, Mexico (NMFS and USFWS, 2007c). Due to hunting of adults and eggs, these numbers were reduced to an estimated 2,000 females by the mid-1960s. At the same time, the shrimp trawling fishery in the Gulf of Mexico was incidentally drowning ridley turtles along with other species of sea turtles. By 1985, only 234 females nested at Rancho Nuevo (NMFS and USFWS, 2007c). In 1977, tentative steps toward protection and recovery began with a bi-national recovery plan was established between the United States and Mexico to protect Kemp's ridley turtles both on the beach and in the water. Available data from 2006 indicate an abundance of 7,000 to 8,000 nesting females (NMFS and USFWS, 2007c).

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

Unlike their olive ridley cousins, Kemp's ridleys make shallow dives (<50 m; 164 ft) of short duration (12 to 18 min) (Lutcavage and Lutz, 1997). Few data are available on Kemp's ridley diving but routine dives have durations ranging from 16.7 to 33.7 min (Mendonca and Pritchard, 1986; Renaud, 1995).

➢ **Flatback turtle (*Natador depressus*)**

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

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

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

- **Leatherback turtle (*Dermochelys coriacea*)**

The leatherback turtle is the largest turtle in the world and one of the largest living reptiles. It is listed as critically endangered under the IUCN, endangered throughout its range under the ESA, and is protected under CITES. As of 2004, roughly 35,800 adult female leatherbacks were estimated in the world, but fewer than 1,000 in the eastern Pacific (Spotila, 2004). Spotila et al. (2000) reported the possible extirpation of leatherbacks from key nesting beaches in the eastern Pacific. The most recent worldwide population estimate of leatherback turtles is 34,000 to 94,000 (NMFS and USFWS, 2007d). Most turtle authorities consider the leatherback to be the most endangered of all sea turtles due to the rapid decline in global population during the last 15 years (Ferraroli et al., 2004).

Leatherbacks are the most pelagic and most widely distributed of any sea turtle and can be found circumglobally in temperate and tropical oceans, ranging as far north as the waters off Newfoundland and as far south as New Zealand and the Southern Ocean (NMFS, 1995; Spotila, 2004). Highly migratory, they make yearly long-distance excursions from their nesting beaches to their feeding grounds, following their primary food source, jellyfish. In the western Atlantic, leatherbacks travel north in the spring, following the Gulf Stream and feeding opportunistically on the spring blooms of jellyfish they find en route. These turtles continue northward, arriving in waters corresponding to the continental slope by April, and finally, continuing on to continental shelf and coastal waters off New England and Atlantic Canada where they remain through October. In the fall, some leatherbacks head south essentially retracing the offshore route from which they came, while others cross the Atlantic to Great Britain and migrate south along the eastern Atlantic (James et al., 2005). Similarly, populations that nest in the eastern Atlantic and Indian oceans make annual transoceanic migrations between breeding grounds and feeding grounds (Spotila, 2004). During their migratory phases, leatherbacks rarely stop swimming, and individuals have been documented to swim greater than 13,000 km (7,015 nmi) per year (Eckert, 1998; Eckert, 1999).

Leatherback nesting beaches are found around the world, with the largest nesting colony in South America along the coast of French Guiana (Ferraroli et al., 2004). Here, roughly 6,000 adult females nest on beaches from Trinidad to French Guiana each year. The second largest nesting colony is in Gabon, West Africa with 4,300 females per year (Spotila, 2004). The eastern Pacific coast of Mexico, particularly Michoacan, Guerrero, and Oaxaca, were once the largest nesting grounds in the Pacific. Today, however, sea turtles do not nest there regularly (NMFS and USFWS, 1998b). The largest colony of eastern Pacific leatherbacks nests in Guanacaste, Costa Rica, where up to 435 females have been recorded in a given year. Western Pacific colonies in Irian Jaya, Papua New Guinea and the Solomon Islands document 1,052 females per year. And the Andaman and Nicobar islands off Thailand in the Indian Ocean see about 1,000 nesting females per year. Small colonies of leatherbacks nest in U.S. waters, primarily on St. Croix in the U.S. Virgin Islands and in Puerto Rico and Florida (Spotila, 2004).

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

Leatherback turtles make the deepest dives—the deepest dive recorded was to 1,230 m (4,035 ft) (Hays et al., 2004). Dives of 4 to 78 m (13 to 256 ft) and 78 to 252 m (256 to 827 ft) of longer duration (28 to 48 min) characterize the migratory phases of the leatherback, while shallower dives (<50 m [164 ft]) of shorter duration (<12 min) were typical on the feeding grounds (James et al., 2005). Leatherbacks have been recorded diving for as long as 70 to 80 min, but most dives are no more than 40 min (Sale et al., 2006).

3.2.3.3 Sea Turtle Hearing Capabilities

There are only very limited data on sea turtle sound production and hearing. A few data are available about the mechanism of sound detection by sea turtles, including the pathway by which sound gets to the inner ear and the structure and function of the inner ear (Bartol et al., 1999; Bartol and Musick, 2003; Bartol, 2008; Ketten, 2008). Additional assumptions have been made about sea turtle hearing based on research on terrestrial species. Based on the structure of the inner ear, there is some evidence to suggest that marine turtles primarily hear low frequency sounds, and this hypothesis is supported by the limited amount of physiological data on turtle hearing (e.g., Ketten and Bartol, 2006; Bartol, 2008). A description of the ear and hearing mechanisms can be found in Bartol and Musick (2003) (see also Ketten, 2008). The few studies completed on the auditory capabilities of sea turtles suggest that they could be capable of hearing LF sounds, particularly as adults. These investigations examined adult green, loggerhead, and Kemp's ridley sea turtles (Ridgway et al., 1969; Mrosovsky, 1972; O'Hara and Wilcox, 1990; Bartol et al., 1999). There have been no published studies to date of olive ridley, hawksbill, or leatherback sea turtles (Ridgway et al., 1969; O'Hara and Wilcox, 1990; Bartol et al., 1999).

Ridgway et al. (1969) used airborne and direct mechanical stimulation to measure the cochlear response in three juvenile green sea turtles in air. The study concluded that the maximum sensitivity for one animal was 300 Hz, and for another 400 Hz. At 400 Hz, the turtle's hearing threshold was about 64 dB (re: 20 µPa). At 70 Hz, it was about 70 dB (re: 20 µPa). Sensitivity decreased rapidly in the lower and higher frequencies. From 30 to 80 Hz, the rate of sensitivity declined approximately 35 dB. However, these studies were done in air, up to a maximum of 1 kHz, and thresholds were not meaningful since they only measured responses of the ear; moreover, they were not calibrated in terms of pressure levels.

Perhaps the most important recent work comes from Saryoa Bartol and her colleagues. Bartol et al. (1999) measured the hearing of juvenile loggerhead sea turtles using auditory evoked potentials to LF tone bursts; they found the range of hearing via auditory evoked potentials[25,26] (AEP) to be from at least 250 to 750 Hz. The lowest frequency tested was 250 Hz and the highest was 1,000 Hz.

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[25] Auditory evoked potentials (AEP) are often referred to with the less accurate term "auditory brainstem response" or ABR.

[26] AEP is a method in which recordings are made, non-invasively, of the brain response to sound. It is widely used to rapidly assess hearing in new-born humans, and is now being used extensively in studies of animal hearing, including fish, turtles, and marine mammals. The advantages of AEP are that the animal does not have to be trained to make a response (which can take days or weeks) and it can be done on an animal that is not able to move. It is also very rapid and results can be obtained within a few minutes of exposure to noise. The disadvantages are primarily that the AEP only reflects the signal that is in the ear and

However, a recent unpublished ONR-funded study provides the underwater hearing range and hearing sensitivity for loggerhead, green, and Kemp's ridley turtles of different ages (Figure 3-5) (Ketten and Bartol, 2006). The investigators found that all three turtle species detected sounds to as low as 100 Hz (the lower limit of hearing tested but not necessarily the lowest frequency that the animals could hear) while maximum hearing was to 900 Hz. These data support the earlier results of in-air studies cited above. Interestingly, the widest hearing range (to 900 Hz) was in the hatchling loggerheads, the smallest animals tested. There is some evidence from this study that older animals did not detect higher frequencies as well as the hatchlings, a loss that is found in many terrestrial animals and marine mammals as they age. In older animals, the authors found that two year old loggerheads responded (with AEP responses) to sounds from 100 to 700 Hz, while three year old animals responded to sounds from 100 to 400 Hz. Similar age/size range changes were encountered in green sea turtles (Figure 3-5). The juvenile Kemp's ridley had the narrowest hearing range, from 100 to 500 Hz, with best hearing from 100 to 200 Hz.

Although yet to be published in the peer-review scientific literature, these data are important since they indicate that marine turtles, as suggested by the earlier data, best detect low frequency sounds. There are several caveats on the Ketten and Bartol (2006) data, however. First, as with all AEP-derived data, these data do not necessarily represent the full hearing range or hearing sensitivity of the animals, as would be obtained in behavioral tests where animals are "asked" to respond to a sound and where the complete nervous system is used to process signals. Second, the data on changes with age suggest that results for older and larger animals may be rather different than the younger animals and this may have important consequences for detection, or non-detection, of anthropogenic sounds. Third, while the AEP data are of importance, more comprehensive data on turtle hearing, such as ability to detect signals in the presence of noise and ability to detect signal direction, are of great importance in understanding the behavioral effects of sound on turtles.

One critical question to ask is whether there are sufficient anthropogenic sounds in the normal environment of sea turtles to suggest that hearing might be masked. While there are no masking studies on marine turtles, an indirect study looked at the potential for masking by examining sounds in an area known to be inhabited by turtles. These underwater sound recordings were made in one of the major coastal foraging areas for juvenile sea turtles (mostly loggerhead, Kemp's ridley and green sea turtles) in the Peconic Bay Estuary system in Long Island, NY (Samuel et al., 2005). The recording season of the underwater environment coincided with the sea turtle activity season in an inshore area where there is considerable boating and recreational activity, especially during the July to September timeframe. During this time period, RLs at the data collection hydrophone system in the 200 to 700 Hz band ranged from 83 dB (night) up to 113 dB (weekend day). Therefore, during much of the season when sea turtles are

brain and does not reflect effects of signal processing in the brain that may result in detection of lower signal levels than apparent from measures of AEP. In other words, in a behavioral study the investigator measures the hearing response of animals that have used their brains to process and analyze sounds, and therefore potentially extract more of the signal even in the presence of noise. With AEP, the measure is strictly of the sound that is detectable by the ear, without any of the sophisticated processing provided by the nervous system of any vertebrate. At the same time, AEP does give an excellent indication of basic hearing loss, and is an ideal method to quickly determine if there is hearing loss right after sound exposure when results are compared with those from controls that were not exposed to loud sounds.

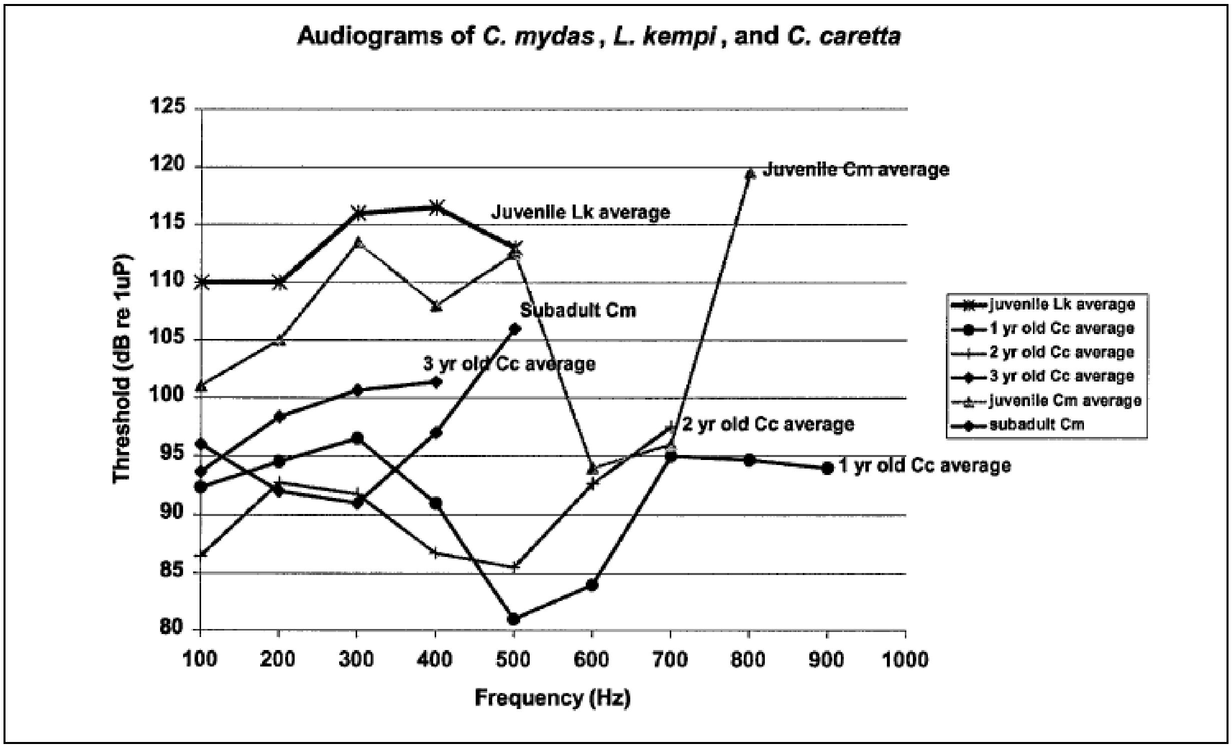

Figure 3-5. Auditory evoked potential audiograms of juvenile Kemp's ridley (Lk), juvenile and subadult green (Cm), and hatchling and juvenile loggerhead (Cc) turtles (Ketten and Bartol, 2006).

actively foraging in New York waters, they are undoubtedly exposed to these levels of noise, most of which is anthropogenic in origin. However, there were no data collected on any behavioral changes in the sea turtles as a consequence of anthropogenic noise or otherwise during this study and so it cannot be stated whether this level of ambient sound would have any physiological and/or behavioral impacts on the turtles.

3.2.3.4 Sea Turtle Sound Production and Acoustic Communication

Very little is known about sound production or use of sound in communication by marine turtles (reviewed in Giles et al., 2009; also see Giles 2005). There is evidence that some species produce sounds when they come onto a beach to mate, but there apparently is no clear evidence for the biological importance of such sounds. More importantly, there are no data on underwater sound production by marine turtles, or use of sound by marine turtles to communicate. The most germane data comes from a recent study of the long-necked freshwater turtle, *Chelodina oblonga* (Giles et al., 2009), and it is not clear if the results of this study have relevance to marine species.

In the study, Giles et al. (2009) found that *Chelodina* produces at least 17 different sounds, and concludes that this species uses sound to communicate since the range of visibility in their aquatic habitats is very limited. The investigators found that call length ranged from less than a tenth of a second to several seconds. All calls contained broad band energy, some starting at 100 Hz and some going to 3.5 kHz. The authors noted some energy in clicks to over 20 kHz (the upper limit of their recording equipment).

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

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

3.2.4 Marine Mammals—Cetaceans

The most abundant order of marine mammals found in the world's oceans is cetaceans (whales, dolphins, and porpoises). Cetaceans spend their entire lives in the aquatic environment and never return to land purposefully. This group varies in distribution and is found in widely diverse variety of aquatic habitats from freshwater rivers to deep ocean waters. Cetaceans are ecologically diverse and range in size from approximately 1 to 33 m (3.3 to 108 ft) in length (Ballance, 2009).

Cetaceans include over 80 species that are classified in two suborders: baleen or mysticete whales and toothed or odontocete whales (also including dolphins and porpoises) (Balance, 2009). Mysticetes are distinguished by their large body size and specialized baleen feeding structures, which are keratinous plates that replace teeth and are used to filter zooplankton (e.g., krill) and small fishes from seawater. In contrast, odontocetes have teeth for feeding and exhibit greater foraging diversity. Both cetacean groups are capable of emitting sound, but only odontocetes emit sound signals, called echolocation, used for locating prey and objects as well as navigating.

The status of cetacean populations is impacted by their biological characteristics and interaction with anthropogenic activity. Many cetacean populations have been reduced by commercial whaling exploitation, incidental mortality, and habitat destruction over the last centuries. The reduction in some cetacean populations has led to the risk of extinction. The ESA, along with the international organizations of CITES and the IUCN, designate a protected status when species at risk of extinction, generally based on natural or manmade factors affecting the continued existence of species. In addition, in the U.S., all marine mammals are protected by the MMPA.

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

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

3.2.4.1 Mysticete Species

The mysticetes that potentially could be affected by SURTASS LFA sonar include four families containing 12 species (Table 3-2). Mysticetes can be distinguished by their large baleen plates and paired blowholes. Baleen whales include the largest animal ever to live on Earth, the blue whale, which can grow to over 30 m (100 ft) in length and 170 tons (154,221 kg) in weight (Bannister, 2009). The status of many mysticete species is considered to be imperiled throughout their worldwide ranges.

All mysticetes produce low frequency sounds, although no direct measurements of auditory (hearing) thresholds have been made for the majority of species as most tests for auditory measurements are impractical in such large animals (Clark, 1990; Richardson et al., 1995; Edds-Walton, 1997; Tyack, 2000; Evans and Raga, 2001). A few species' vocalizations are known to be communication signals but the function of other mysticete low-frequency sounds are not fully understood but likely are used for functions such as orientation, navigation, or detection of predators and prey. Several mysticete species, including the humpback, fin, bowhead, and blue whales, sing or emit repetitous patterned signals or vocalizations (Frankel, 2009). Based on a study of the morphology of cetacean auditory mechanisms, Ketten (1994) hypothesized that mysticete hearing is in the low to infrasonic range. It is generally believed that baleen whales have frequencies of best hearing where their calls have the greatest energy—below 5,000 Hz (Ketten, 2000).

Balaenopteridae (Rorquals)

The family Balaenopteridae contains six whales in two genera: *Balaenoptera* and *Megaptera.* The genus *Balaenoptera* includes the blue, fin, Bryde's, sei, and minke whale species. The genus *Megaptera* includes only one species, the humpback whale. Balaenopterids are also known as "rorquals" because of the large ventral folds or pleats of skin along their throat region that distend when feeding (Bannister, 2009).

- **Blue whale (*Balaenoptera musculus*)**

The blue whale is currently listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and as endangered (Antarctic), vulnerable (North Atlantic), and lower risk/conservation dependent (North Pacific) by the IUCN. The global population is estimated between 8,000 to 9,000 individuals (Jefferson et al., 2008), while 1,368 blue whales are estimated to occur in the eastern North Pacific (Carretta et al., 2009), 1,700 blue whales are estimated for the Southern Ocean (Branch et al., 2007), and 424 whales are estimated for the Madagascar Plateau region in the austral summer (Best, 2003).

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

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

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

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

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

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

- **Fin whale (*Balaenoptera physalus*)**

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

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

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

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

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

- **Sei whale (*Balaenoptera borealis*)**

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

Sei whales are primarily found in temperate zones of the world's oceans. Like other members of the family *Balaenopteridae*, sei whales are assumed to migrate to subpolar higher latitudes where they feed during the late spring through early fall, followed by movements to lower latitudes where they breed and calve during the fall through winter (Jefferson et al., 2008). In the North Atlantic, sei whales are located off Nova Scotia and Labrador during the summer and as far south as Florida during the winter (Leatherwood and Reeves, 1983). In the North Pacific, they range from the Gulf of Alaska to California in the east and from Japan to the Bering Sea in the west. Specific breeding grounds are not known for this species.

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

There is no direct measurement of the hearing sensitivity of sei whales (Ketten, 2000; 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 frequency of 433 Hz.

- **Bryde's whale (*Balaenoptera edeni*)**

The Bryde's whale is currently protected under CITES and classified as a data deficient species by the IUCN. There are no global estimates for Bryde's whale. In the western North Pacific, the population of Bryde's whales is estimated by the IWC (2009) as 20,501 whales, while 10,000 whales are estimated in the eastern tropical Pacific (Jefferson et al., 2008). In Hawaiian waters, 493 Bryde's whales have been estimated (Carretta et al., 2009), and in the waters of the Gulf of Mexico, only 15 Bryde's whales are estimated to occur (Waring et al., 2009).

Bryde's whales occur roughly between 40°N and 40°S throughout tropical and warm temperate (>16.3°C [61.3°F]) waters of the Atlantic, Pacific, and Indian Oceans year round (Omura, 1959; Kato and Perrin, 2009). Bryde's whales occur in some semi-enclosed waters such as the Gulf of California, Gulf of Mexico, and East China Sea (Kato and Perrin, 2009). Bryde's whales migrate seasonally toward the lower latitudes near the equator in winter and to high latitudes in summer (Kato and Perrin, 2009). There is some evidence that Bryde's whales remain resident in areas off South Africa and California throughout the year, migrating only short distances (Best, 1960; Tershy, 1992). Bryde's whales are known to breed off South Africa (Best, 1960 and 1975). Foraging grounds are not well known for this species.

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

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

➢ **Minke whale (*Balaenoptera acutorostrata*)**

The minke whale is protected under CITES and classified by the IUCN as a least concern (lower risk) species. Populations are estimated at 180,000 in the Northern Hemisphere (Jefferson et al., 2008). Regional stock assessments report approximately 3,312 animals off the Canadian east coast and 806 animals of the coasts of California, Oregon, and Washington (Waring et al., 2009; Carretta et al., 2009). Three stocks of minke whales are recognized in the North Pacific by the International Whaling Commission (IWC). The first stock is the Sea of Japan/East China Sea stock, the second is the western Pacific stock, west of 180°W longitude, and the third is referred to as the "remainder" stock which consists of whales east of 180°W longitude. The NMFS reports that in this remainder area, minke whales are common in the Bering Sea, the Chukchi Sea, and in the Gulf of Alaska, but they are not considered abundant in any other part of the eastern Pacific Ocean. Minke whales are generally found over continental shelf waters; and in the far north, they are believed to be migratory, but appear to have home ranges in the inland waters of Washington and central California (Dorsey et al., 1990). Similar to other balaenopterids, minke whales migrate during late spring through early fall to higher latitudes where they feed, and to lower latitudes where they breed during the fall and winter. Lockyer (1981) recorded average swimming speeds of 6.1 km/hr (3.3 kts). Maximum dive duration in minke whales is 15 min, with an average dive time of 6 to 12 min.

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

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

- **Humpback whale (*Megaptera novaeangliae*)**

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

Humpback whales are distributed throughout the world's oceans, and are only absent from high Arctic and some parts of the equatorial region. They are a highly migratory species that can travel over 8,047 km (4,345 nmi) one way, which is the longest known migration of any mammal (Jefferson et al., 2008). The whales travel to high latitudes in the spring for feeding and to the tropics in the winter for calving and breeding. Humpback whales are found in coastal shelf waters when feeding and close to islands and reefs when breeding (Clapham, 2009). Data indicate that not all animals migrate during the fall from summer feeding to winter breeding sites and that some whales remain year round at high latitudes (Christensen et al., 1992; Clapham et al., 1993).

Barco et al. (2002) reported on humpback whale population site fidelity in the waters off the U.S. Mid-Atlantic States. Individual whales have shown a strong fidelity to specific feeding grounds, including the Gulf of Maine, Newfoundland/Labrador, the Gulf of Saint Lawrence, Greenland, Iceland, and Norway. Humpback whales migrate from their feeding grounds to a winter breeding range in the West Indies. The majority of whales engage in this seasonal migration, but some whales have also been observed in the high latitudes during winter (Barco et al., 2002).

Humpback whales have well-defined breeding areas in tropical waters that are usually located near isolated islands. In the North Atlantic, there are breeding areas near the West Indies and Trinidad in the west, and the Cape Verde Islands and off northwest Africa in the east. In the North Pacific, there are breeding grounds around the Mariana Islands, Bonin, Ogasawara, Okinawa, Ryukyu Island, and Taiwan (Clapham, 2009). In the eastern North Pacific, breeding grounds occur around the Hawaiian Islands, off the tip of Baja California, and off the Revillagigedo Islands (Clapham, 2009).

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

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

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

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

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

Balaenidae (Right and Bowhead Whales)

The family Balaenidae is comprised of four species that are classified in two genera. Three species are included in the genus *Eubalaena*: North Atlantic right whale (*Eubalaena glacialis*), North Pacific right whale (*E. japonica*), and southern right whale (*E. australis*), while only one species, the bowhead whale, is included in the genus *Balaena*. These large baleen whales lack a dorsal fin or ridge, move more slowly than other whales, and are found in cold temperate to arctic waters.

- **Bowhead whale (*Balaena mysticetus*)**

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

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

Bowhead whales are distributed in arctic to sub-arctic waters of the northern hemisphere roughly between 55° and 85°N (Jefferson et al., 2008). Bowheads typically occur in or near sea/pack ice, with their seasonal distribution being strongly influenced by the location of pack ice (Moore and Reeves, 1993). Typically, bowheads move southward in autumn and winter with the advancing ice edge and remain near the ice edge, in polynyas[27], or areas of unconsolidated pack ice. Moving northward in spring and summer, bowheads concentrate on feeding in areas of high zooplankton abundance.

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

Dive behavior of bowhead whales varies widely by season, feeding depth, and life history stage (age and reproductive status) but exhibits no diel pattern (Krutzikowsky and Mate, 2000; Thomas et al., 2003; Heide-Jorgensen et al., 2003). Bowheads are excellent divers, capable of remaining submerged for 61 minutes and diving to depths as deep as 416 m (1,365 ft) (Krutzikowsky and Mate, 2000; Heide-Jorgensen et al., 2003). The majority of bowhead dives appear to be shallow and short dives, at depths ≤16 m (53 ft) for a mean duration of 6.9 to 14.1 minutes (Krutzikowsky and Mate, 2000). Heide-Jorgensen et al. (2003) reported that fewer than 15% of all recorded bowhead dives were to depths greater than 152 m and only 5% of the dives lasted more than 24 minutes. Averaging about 1.1 to 5.8 km/hr (0.6 to 3 kts), bowhead whales are fairly slow swimmers (Mate et al., 2000). They can, however, travel vast distances, with one tagged bowhead whale having traveled 3,386 km (1,828 nmi) in 33 days at an overall swim speed of 5 km/hr (2.7 kts) (Mate et al. 2000).

Knowledge of mysticete hearing is very limited. No direct physiological or behavioral measurements of bowhead whale hearing have been made (Ketten, 1997). Norris and Leatherwood (1981) described the unique auditory morphology of the bowhead whale and determined that bowhead whales are adapted to hear frequencies ranging from high infrasonic to low ultrasonic. Mysticete hearing sensitivity is often inferred from behavioral responses to sound and from the vocalization ranges a species uses.

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

Richardson (1995) estimated from observations of behavioral reactions that mysticete whales likely hear sounds predominantly in the 50 to 500 Hz range, while Ketten (2000) reported that baleen whales likely have best hearing in the frequency range where their vocalizations have the greatest energy, below 5 kHz.

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

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

➢ **North Atlantic right whale (*Eubalaena glacialis*)**

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

North Atlantic right whales are found in temperate to subpolar waters of the North Atlantic Ocean (Jefferson et al., 2008). They are most commonly found around coastal and continental shelf waters of the western North Atlantic from Florida to Nova Scotia (Kenney, 2009). From late fall to early spring, right whales breed and give birth in temperate shallow areas, and then migrate into higher latitudes where they feed in coastal waters during the late spring and summer. Right whales have been known to occasionally move offshore into deep water, presumably for feeding (Mate et al., 1997). North Atlantic right whales calve between the northeast coast of Florida and southeastern Georgia and forage in the Bay of Fundy (IFAW, 2001; Vanderlaan et al., 2003).

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

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

- **North Pacific right whale (*Eubalaena japonica*)**

The North Pacific right whale is listed as endangered under the ESA, depleted under the MMPA, and protected under CITES. The North Pacific right whale is also classified as endangered under the IUCN. There are no reliable population estimates for the North Pacific right whale, but it is estimated that there are no more than a few hundred North Pacific right whales in the North Pacific Ocean (Angliss and Allen, 2009).

The North Pacific right whale is not a very well known species because there are so few left. This whale population is primarily sighted in the Sea of Okhotsk and the eastern Bering Sea (Jefferson et al., 2008). Passive acoustics and satellite tracking led to the observation of 17 individuals in the eastern Bering Sea in 2004 (Wade et al., 2006). They are often found in continental shelf waters to oceanic waters. Breeding grounds for this species are unknown. From historic records, North Pacific right whales were recorded in offshore waters with a northward migration in the spring and southward migration in autumn (Jefferson et al., 2008). There is no swim speed or dive information available for the North Pacific right whale.

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

- **Southern right whale (*Eubalaena australis*)**

The southern right whale is listed as endangered under the ESA, depleted under the MMPA, and protected under CITES. The southern right whale is also classified as a least concern (lower risk) species under the IUCN. The population size is estimated to be around 8,000 whales (Jefferson, et al., 2008).

Southern right whales have a circumpolar distribution in the Southern Hemisphere, predominately found off Argentina, South Africa, and Australia (Kenney, 2009). Major breeding areas include southern Australia, southern South America along the Argentine coast, and along the southern coast of South Africa (Croll et al., 1999). There is no swimming or diving information available for the southern right whale.

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

Neobalaenidae

The family Neobalaenidae includes a single known genus and species, the pygmy right whale (*Caperea marginata)*, which is one of the least known baleen whales and the smallest species of all the mysticetes (Kemper, 2009).

- **Pygmy right whale (*Caperea marginata*)**

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

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

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

Eschrichtiidae

The family Eschrichtiidae includes a single known genus and species, the gray whale. A highly distinctive species, the gray whale is known to be the most coastal of all the mysticetes (Jones and Swartz, 2002).

- **Gray whale (*Eschrichtius robustus*)**

The gray whale population is divided into two different stocks. The eastern North Pacific stock of gray whales was listed as endangered under the ESA, but was de-listed in 1994. The western North Pacific stock is extremely small and is still listed as endangered by the ESA. Gray whales are protected under CITES and classified as a least concern (lower risk) species under IUCN. The western North Pacific stock was thought to be extinct, but a small group of less than 100 gray whales still remain (Jefferson et al., 2008). The eastern North Pacific stock of gray whales is estimated to be 18,178 whales along the west coast of the United States (Angliss and Allen, 2009).

Gray whales are confined to the shallow coastal waters of the North Pacific and adjacent seas. They are found as far south as the Baja of California in the eastern North Pacific, and to southern China in the western North Pacific (Jefferson et al., 2008). Every year most of the population makes a large north-south migration from high latitude feeding grounds to low latitude breeding grounds. Most gray whales in the eastern Pacific breed or calve during the winter in lagoons of Baja California (Jones and Swartz, 2009). There is no available information on breeding and calving areas of the western North Pacific gray whale.

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

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

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

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

3.2.4.2 Odontocete Species

The odontocetes evaluated for this SEIS include six families containing over 54 species (Table 3-3). Odontocetes can be distinguished from mysticetes by the presence of functional teeth and a single blowhole. They range in size from the sperm whale at 16 m (52 ft) and 40,823 kg (45 tons) to the harbor porpoise at 1.4 m (4.8 ft) and 50 kg (110 lbs) (Whitehead, 2009; Bjorge and Tolley, 2009).

Odontocetes have a broad acoustic range, with recent hearing thresholds measuring between 400 Hz and 100 kHz (Finneran et al., 2002). Many odontocetes produce a variety of click and tonal sounds for communication and echolocation purposes (Au, 1993). Odontocetes communicate mainly above 1,000 Hz and echolocation signals as high as 150 kHz (Würsig and Richardson, 2009). Little is known about the details of most sound production and auditory thresholds for many species (Frankel, 2009).

Physeteridae

The family Physeteridae includes a single known genus and species, the sperm whale (*Physeter macrocephalus)*, which is the largest of all the odontocete species (Whitehead, 2009).

- **Sperm whale (*Physeter macrocephalus*)**

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

Sperm whales are primarily found in deeper (>1000 m [3,280 ft]) ocean waters and distributed in polar, temperate, and tropical zones of the world (Reeves and Whitehead, 1997). They have the largest range of all cetaceans, except killer whales (Rice, 1989), but are commonly found near the equator and in the North Pacific (Whitehead, 2009). The migration patterns of sperm whales are not well understood, as some whales show seasonal north-south migrations, and some whales show no clear seasonal migration, especially in the equatorial areas (Whitehead, 2009). The sperm whale has a prolonged breeding season extending from late winter through early summer. In the Southern Hemisphere, the calving season is between November and March (Simmonds and Hutchinson, 1996), although specific breeding and foraging grounds are not well known for this species.

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

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

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

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

Kogiidae

The family Kogiidae includes two species, the pygmy (*Kogia breviceps*) and dwarf (*Kogia sima*) sperm whales (McAlpine, 2009).

- **Pygmy sperm whale *(Kogia breviceps)* and Dwarf sperm whale *(Kogia sima)***

Both the pygmy sperm whale and dwarf sperm whale are listed as data deficient under the IUCN. Abundance estimates of the global population sizes for these species are unknown. However, there are estimates for specific geographic regions. Jefferson et al. (2008) stated that there are an estimated 3,000 pygmy sperm whales off the coast of California, and an estimated 11,000 dwarf sperm whales in the ETP. In the Atlantic, there is an estimated 395 pygmy and dwarf sperm whales, and 453 in the Gulf of Mexico (Waring et al., 2009). Pygmy and dwarf sperm whales are distributed worldwide, primarily in temperate to tropical deep waters. They are especially common along continental shelf breaks (Evans, 1987); Jefferson et al., 2008). Dwarf sperm whales seem to prefer warmer water than the pygmy sperm whale (Caldwell and Caldwell, 1989). Breeding areas for both species include waters off Florida (Evans, 1987). There is little evidence that pygmy and dwarf sperm whales have a seasonal migration pattern (McAlpine, 2009).

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

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

Ziphiidae (Beaked Whales)

The family Ziphiidae contains 21 species of whales in five genera (Mead, 2009a) (Table 3-3). Ziphiidae are protected under the MMPA. The northern and southern bottlenose whales are the only two species in the Ziphiidae family protected under Appendix I of CITES. All species of beaked whales are considered data deficient by the IUCN except the southern bottlenose whale and Cuvier's beaked whale, which are classified as least concern.

- **Baird's beaked whale *(Berardius bairdii)* and Arnoux's beaked whale *(Berardius arnuxii)***

Both the Baird's and Arnoux's beaked whales are currently classified as data deficient under the IUCN. Abundance estimates of the global population size for either species are unknown. The abundance of both species has been estimated as 5,029 whales off the Pacific coast of Japan, 1,260 whales in the eastern Sea of Japan, and 660 in the southern Sea of Okhotsk (Kasuya, 2009). Baird's beaked whale population numbers are estimated at 1,100 in the eastern North Pacific, including 540 Baird's beaked whales in the waters of Washington, Oregon, and California (Jefferson et al., 2008; Caretta et al., 2009).

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

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

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

- **Shepherd's beaked whale (*Tasmacetus shepherdi*)**

The Shepherd's beaked whale is currently classified as a data deficient species by IUCN. Abundance estimates of this species are not available. Shepherd's beaked whales are distributed in cold temperate to polar seas of the Southern Hemisphere including the waters of Antarctica, Brazil, Galapagos Islands, New Zealand, Argentina, Australia, and the South Sandwich Islands (Mead, 2009b). No data are available to confirm seasonal migration patterns for Shepherd's beaked whales, and there are no known breeding or calving grounds.

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

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

Cuvier's beaked whale is currently classified as a least concern (lower risk) species by the IUCN. Global population estimates for this species are unknown. Abundances of Cuvier's beaked whales are estimated for the ETP as 20,000 individuals while 90,000 whales are estimated in the eastern North Pacific (Barlow, 1995). Off the U.S. West Coast (CA/OR/WA), 2,830 Cuvier's have been estimated to occur while 12,728 individuals are estimated for Hawaiian EEZ waters (Caretta et al., 2009). The best abundance estimate for pooled beaked whales in the western North Atlantic is 3,513 individuals while 65 Cuvier's are estimated in the northern Gulf of Mexico (Waring et al., 2009).

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

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

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

- **Northern bottlenose whale *(Hyperoodon ampullatus)* and Southern bottlenose whale *(Hyperoodon planifrons)***

The IUCN classifies the status of northern bottlenose whales as data deficient while southern bottlenose whales are currently classified as least concern (lower risk). Both species are also protected under CITES. Abundance estimates of the global populations are unknown. There are an estimated 40,000 northern bottlenose whales in the North Atlantic Ocean, including the Gully, the region southeast of Sable Island, Nova Scotia with an estimated 130 whales, and the Faroe Islands, with over 5,000 northern bottlenose whales estimated (Whitehead et al., 1997). The Scotian Shelf population of northern bottlenose whales was listed as endangered under Canada's Species at Risk Act (SARA). There are an estimated 500,000 southern bottlenose whales south of the Antarctic Convergence, making them the most common beaked whale sighted in Antarctic waters (Jefferson et al., 2008).

The northern bottlenose whale is found only in the cold temperate to subarctic waters of the North Atlantic from New England to southern Greenland and the Strait of Gibraltar to Svalbard (Jefferson et al., 2008). This oceanic species occurs seaward of the continental shelf in waters deeper than 500 m (1,640 ft) (Leatherwood and Reeves, 1983; Jefferson et al., 2008). Northern bottlenose whales are commonly found foraging in the Gully, off the coast of Nova Scotia, Canada (Gowans, 2009). The Scotian Shelf population appears to be non-migratory, unlike other northern bottlenose whale populations. The Labrador population migrates to the southern portion of their range, between New York and the Mediterranean, for the winter months. Calving and breeding grounds are unknown.

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

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

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

- **Longman's beaked whale (*Indopacetus pacificus*)**

Longman's beaked whale, also known as the Indo-Pacific beaked whale, is currently classified as data deficient by IUCN. Global abundance estimates of this species are not available but 760 animals have been estimated in Hawaiian waters (Jefferson et al., 2008).

The distribution of Longman's beaked whale is limited to the Indo-Pacific region (Leatherwood and Reeves, 1983; Jefferson et al., 2008). Recent whale groups sighted in the equatorial Indian and Pacific Oceans off Mexico and Africa have tentatively been identified as Longman's beaked whales (Ballance and Pitman, 1998; Pitman et al., 1998; Pitman, 2009a). No data are available to confirm seasonal migration patterns for Longman's beaked whales. No data on breeding and calving grounds are available.

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

- ***Mesoplodon* species**

Species in the genus *Mesoplodon* are currently classified with a data deficient status by IUCN. The worldwide population sizes for all species of *Mesoplodon* spp. are unknown. However, estimates of 25,300 in the ETP and 250 *Mesoplodon* whales off California have been documented (Wade and Gerrodette, 1993; Barlow, 1995). In addition, minimum population estimates for undifferentiated beaked whales in the western North Atlantic was 3,531 whales (Waring et al, 2009), and an estimate of 1,024 whales was reported in the eastern North Pacific (Carretta et al., 2009).

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

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

Hubb's beaked whale has been recorded producing whistles between 2.6 and 10.7 kHz, and pulsed sounds from 300 Hz to 80 kHz and higher with dominant frequencies from 300 Hz to 2 kHz (Buerki et al., 1989; Lynn and Reiss, 1992). A stranded Gervais' beaked whale had an upper limit for effective hearing at 80 to 90 kHz (Finnernan et al., 2009).

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

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

Monodontidae

The family Monodontidae includes the beluga whale, also known as the “white whale” (O'Corry-Crowe, 2002).

- **Beluga whale (*Delphinapterus leucas*)**

The beluga is classified as a near threatened species by the IUCN, and the Cook Inlet stock is a listed as endangered under the ESA (Jefferson et al., 2008; NMFS, 2008). Worldwide abundance is estimated near 150,000, with 39,258 in the Beaufort Sea, 3,710 in the eastern Chukchi Sea, 7,986 in the eastern Bering Sea, 18,142 in Norton Sound, 2,877 in Bristol Bay, 375 in Cook Inlet, 28,000 in Baffin Bay, 25,000 in western Hudson Bay, 10,000 in eastern Canada, and over 21,000 in Russian waters, including the Sea of Okhotsk (Jefferson et al., 2008; Angliss and Allen, 2009).

Beluga habitat is found in both shallow and deep water of the north circumpolar region ranging into the subarctic. Belugas inhabit the east and west coasts of Greenland, and their distribution in North America extends from Alaska across the Canadian western arctic to the Hudson Bay (Jefferson et al., 2008). Occasional sightings and strandings occur as far south as the Bay of Fundy in the Atlantic. Belugas tend to summer in large groups in bays, shallow inlets, and estuaries. Possible reasons include warmer water in the shallow areas, and availability of anadromous fish, such as salmon, capelin, and smelt which are highly abundant in those areas during the summer months (O’Corry-Crowe, 2009). In the Pacific, migratory belugas summer in the Okhotsk, Chukchi, Bering, and Beaufort seas, the Anadyr Gulf, and waters off Alaska (Jefferson et al., 2008; Waring et al., 2009). Other beluga populations reside in Cook Inlet year round (Hansen and Hubbard, 1998; Rugh et al., 1998). Little is known about beluga whales in the winter, but it is believed that the whales migrate in the direction of the advancing ice front, and overwinter near holes in the ice called “polynyas” (O’Corry-Crowe, 2009).

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

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

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

(Au, 1993; Au et al., 1987). There is supportive evidence of geographical variation from distinctive calls used for individual recognition among beluga whales (Belkovich and Shekotov, 1990).

Delphinidae

- **Killer whale (*Orcinus orca*)**

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

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

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

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

Killer whales hear underwater sounds in the range of <500 Hz to 120 kHz (Bain et al., 1993; Szymanski et al., 1999). Their best underwater hearing occurs between 15 and 42 kHz, where the threshold level is near 34 to 36 dB RL (Hall and Johnson, 1972; Szymanski et al., 1999). Killer whales produce sounds as low as 80 Hz and as high as 85 kHz with dominant frequencies at 1 to 20 kHz (Schevill and Watkins, 1966; Diercks et al., 1971, 1973; Evans, 1973; Steiner et al., 1979; Awbrey et al., 1982; Ford and Fisher, 1983; Ford, 1989; Miller and Bain, 2000). An average of 12 different call types (range 7 to 17)—mostly repetitive discrete calls—exist for each pod (Ford, 2009). Pulsed calls and whistles, called dialects, carry information hypothesized as geographic origin, individual identity, pod membership, and activity level. Vocalizations tend to be in the range between 500 Hz and 10 kHz and may be used for group cohesion and identity (Ford, 2009; Frankel, 2009). Whistles and echolocation clicks are also included in killer whale repertoires, but are not a dominant signal type of the vocal repertoire in comparison to pulsed calls (Miller and Bain, 2000). Erbe (2002) recorded received broadband sound pressure levels of orca burst-pulse calls ranging between 105 and 124 dB RL at an estimated distance of 100 m (328 ft).

➢ **False killer whale (*Pseudorca crassidens*)**

False killer whales are classified as least concern (lower risk) by the IUCN. The global population for this species is unknown. Estimates of 39,800 have been documented in the ETP (Wade and Gerrodette, 1993). In the northwestern Pacific, an estimate of near 17,000 has been documented (Miyashita, 1993). In the Gulf of Mexico, there is an estimated 777 false killer whales (Waring et al., 2009).

False killer whales are found in tropical to warm temperate zones in deep, offshore waters (Stacey et al., 1994; Odell and McClune, 1999; Baird, 2002a). Although typically a pelagic species, they approach close to the shores of oceanic islands and regularly mass strand (Baird, 2009a). False killer whales have a poorly known ecology. Breeding grounds and seasonality in breeding are unknown; however, one population does have a breeding peak in late winter (Jefferson et al., 2008). These whales do not have specific feeding grounds but feed opportunistically (Jefferson et al., 2008). False killer whales have an approximate swim speed of 3 km/hr (1.6 kts), although a maximum swim speed has been documented at 28.8 km/hr (11.9 kts) (Brown et al. 1966; Rohr et al., 2002).

False killer whales hear underwater sounds in the range of less than 1 to 115 kHz (Johnson, 1967; Au, 1993). Their best underwater hearing occurs at 17 kHz, where the threshold level ranges between 39 to 49 dB RL. In a study by Yuen et al. (2005), false killer whales' hearing was measured using both behavioral and AEP audiograms. The behavioral data show that this species is most sensitive between 16 and 24 kHz, with peak sensitivity at 20 kHz. The AEP data 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 produce a wide variety of sounds from 4 to 130 kHz, with dominant frequencies between 25 to 30 kHz and 95 to 130 kHz (Busnel and Dziedzic, 1968; Kamminga and van Velden, 1987; Thomas and Turl, 1990; Murray et al., 1998). Most signal types vary among whistles, burst-pulse sounds and click trains (Murray et al. 1998). Whistles generally range between 4.7 and 6.1 kHz. False killer whales echolocate highly directional clicks ranging between 20 and 60 kHz and 100 and 130 kHz (Kamminga and van Velden, 1987; Thomas and Turl, 1990). There are no available data regarding seasonal or geographical variation in the sound production of false killer whales. Estimated SL of clicks are near 228 dB (Thomas and Turl, 1990).

➢ **Pygmy killer whale (*Feresa attenuata*)**

Pygmy killer whales are one of the least known cetacean species. They are classified as data deficient by the IUCN. The global population for this species is unknown. Estimates of 39,000 have been documented in the ETP (Jefferson et al., 2008). An estimated 323 pygmy killer whales were reported in the Gulf of Mexico (Waring et al., 2009).

Pygmy killer whales have been recorded in oceanic tropical and subtropical waters (Caldwell and Caldwell, 1971; Donahue and Perryman, 2009). It is sighted relatively frequently in the ETP, the Hawaiian archipelago and off Japan (Leatherwood et al., 1988; Donahue and Perryman, 2009). No data are available to confirm seasonal migration patterns for pygmy killer whales. No data on breeding and calving grounds are available. General swim speeds for this species are not available, and no dive data are available.

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

Little is known of the sound production of this species. One document describes pygmy killer whales producing LF “growl” sounds (Pryor et al., 1965).

- **Melon-headed whale (*Peponocephala electra*)**

Melon-headed whales are classified as a lower risk (least concern) species by the IUCN. The global population for this species is unknown. Estimates of 45,000 have been documented in the ETP (Jefferson et al., 2008). An estimate of 2,283 whales was reported for the northern Gulf of Mexico (Waring et al., 2009).

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

There is no direct measurement of hearing sensitivity for melon-headed whales (Ketten, 2000; Thewissen, 2002). Melon-headed whales produce sounds between 8 and 40 kHz. Individual click bursts have frequency emphases between 20 and 40 kHz. Dominant frequencies of whistles are 8 to 12 kHz, with both upsweeps and downsweeps in frequency modulation (Watkins et al., 1997). There are no available data regarding seasonal or geographical variation in the sound production of this species. Maximum SLs are estimated at 155 dB for whistles and 165 dB re 1 µPa at 1 m for click bursts (Watkins et al., 1997).

- **Long-finned pilot whale (*Globicephala melas*)**

The long-finned pilot whale is classified as data deficient by the IUCN. The global population for the long-finned pilot whale is unknown. An estimated 200,000 exist in the Antarctic Convergence (Jefferson et al., 2008). An estimate of 31,139 long-finned pilot whales was reported for the western North Atlantic and 780,000 in the eastern North Atlantic (Jefferson et al., 2008; Waring et al., 2009).

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

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

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

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

The short-finned pilot whale is classified as data deficient by the IUCN. A global population estimate for short-finned pilot whales is unknown. Off the U.S. west coast, abundance estimates are approximately 1,000 animals (Jefferson et al., 2008). Estimates of 500,000 have been documented in the ETP, 7,700 have been estimated in Philippine waters, and 60,000 in Japanese waters (Jefferson et al., 2008). Estimates of 716 and 31,139 short-finned pilot whales were reported for the Gulf of Mexico and western North Atlantic, respectively (Waring et al., 2009).

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

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

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

- **Risso's dolphin (*Grampus griseus*)**

Risso's dolphins are classified as a least concern (lower risk) species by the IUCN. Although no global population abundance exists for the Risso's dolphin, in the waters of the ETP, Japan, the Philippines, and off Sri Lanka abundances have been estimated at 175,000; 83,000; 950; and 5,550 to 13,000 dolphins, respectively (Jefferson et al., 2008). In the U.S. Pacific Ocean waters, an estimated 11,621 Risso's dolphins occur in the California/Oregon/Washington stock while 2,351 dolphins occur in the Hawaiian stock (Carretta et al., 2009). An abundance of 20,479 Risso's dolphins has been estimated for the western North Atlantic stock and 1,589 Risso's dolphins in the northern Gulf of Mexico stock (Waring et al., 2009).

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

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

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

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

- **Short-beaked common dolphin (*Delphinus delphis)* and Long-beaked common dolphin (*Delphinus capensis)***

The two common dolphin species are the short-beaked and long-beaked common dolphin. In addition, a geographic form of the long-beaked common dolphin is recognized—the Indo-Pacific common dolphin (*Delphinus capensis tropicalis*). The short-beaked dolphin is classified as a least concern (lower risk) species, and the long-beaked common dolphin is classified as a data deficient species by the IUCN. The global population for all common dolphin species is unknown. Short-beaked common dolphins are the most abundant species at an estimate of 3,000,000 in the ETP (Jefferson et al., 2008). In the California/Oregon/Washington stock, there are an estimated 392,733 dolphins while an estimated 120,743 short-beaked common dolphins are estimated for the western North Atlantic stock (Carretta et al., 2009; Waring et al., 2009). There are also an estimated 61,000 in the eastern Atlantic, 96,000 in the Black Sea, and 75,000 in the Celtic Sea (Jefferson et al., 2008). There are little data available on abundance estimates of long-beaked common dolphins. The abundance of long-beaked common dolphins in the California/Oregon/Washington waters is 15,335 animals while 15,000 to 20,000 long-beaked dolphins are estimated to occur in South African waters (Jefferson et al., 2008; Carretta et al., 2009).

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

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

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

- **Fraser's dolphin (*Lagenodelphis hosei*)**

Fraser's dolphin is classified as a data deficient species by the IUCN. The global population for this species is unknown. Abundances or densities of Fraser's dolphins only exist for a limited number of regions: in the ETP, the Fraser's abundance has been estimated as 289,300 Fraser's dolphins; in the eastern Sulu Sea the abundance is estimated as 13,518 dolphins; and in Hawaiian waters, the Fraser's abundance is estimated as 16,836 dolphins (Carretta et al., 2009; Dolar, 2009). Although the Fraser's dolphin is known to occur rarely in the U.S. Gulf of Mexico, no current abundance estimate is available for this dolphin in the northern Gulf (Waring et al., 2009).

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

Swim speeds of Fraser's dolphin have been recorded between 4 and 7 km/hr (2.2 and 3.8 kts) with swim speeds up to 28 km/hr (15 kts) when escaping predators (Croll et al., 1999). Several foraging depths have been recorded. Based on prey composition, it is believed that Fraser's dolphins feed at two depth horizons in the ETP. The shallowest depth in this region is no less than 250 m (820 ft) and the deepest is no less than 500 m (1640 ft). In the Sulu Sea, they appear to feed near the surface to at least 600 m (1,968 ft). In South Africa and in the Caribbean, they were observed feeding near the surface (Dolar et al., 2003). According to Watkins et al. (1994), Fraser's dolphins herd when they feed, swimming rapidly to an area, diving for 15 seconds or more, surfacing and splashing in a coordinated effort to surround the school of fish. Dive durations are not available.

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

- **Common bottlenose dolphin *(Tursiops truncatus)***

The bottlenose dolphin is classified as least concern (lower risk) by the IUCN. The global population for the bottlenose dolphin is unknown. Estimates of 243,500 have been documented in the ETP, and an estimated 317,000 inhabit the waters of Japan (Jefferson et al., 2008). Off the Pacific coast of the U.S., 3,495 bottlenose dolphins were estimated (Carretta et al., 2009). A total of 7,000 bottlenose dolphins were estimated in the Black Sea and a minimum of 2,000 to 3,000 animals have been estimated for Shark Bay, Australia (Jefferson et al., 2008). The abundance of the western North Atlantic offshore and coastal stocks stock of bottlenose dolphins are 81,588 and 39,977, respectively, with 39,087 bottlenose dolphins found in the northern Gulf of Mexico (Waring et al., 2009).

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

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

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

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

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

- **Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)**

Only in the last ten years has this species' taxonomy been clearly differentiated from that of the common bottlenose dolphin. Indo-Pacific bottlenose dolphins are considered data deficient by the IUCN. No global abundance estimates exist for the species and even regional abundance estimates are few, even though it is the most commonly observed marine mammal species in some coastal regions of the world. Estimates of Indo-Pacific bottlenose dolphins include 218 animals in Japanese waters; 1,634 to 1,934 in Australian waters; and 136 to 179 dolphins off Zanzibar, Tanzania (Wang and Yang, 2009).

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

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

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

➢ **Pantropical spotted dolphin *(Stenella attenuata)***

The pantropical spotted dolphin is one of the most abundant dolphin species in the world. This species is listed as a least concern (lower risk) species by the IUCN. In the ETP, 640,000 northeastern offshore spotted dolphins have been estimated, while an estimated 4,439 occur in the western North Atlantic, and 29,311 dolphins are estimated in the northern Gulf of Mexico (Perrin, 2009a; Waring et al., 2009). In the Hawaiian EEZ, there are an estimated 10,260 pantropical spotted dolphins (Carretta et al., 2009). In the early 1990s, about 438,000 were estimated to occur in Japanese waters (Jefferson et al., 2008).

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

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

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

➢ **Striped dolphin (*Stenella coeruleoalba*)**

Striped dolphins are a lower risk (least concern) species classified by the IUCN. Striped dolphins are known to be the most abundant species in the Mediterranean Sea, with an estimated 225,000 individuals (Jefferson et al., 2008; Archer, 2009). In the ETP, there is an estimated 1 million striped dolphins (Jefferson et al., 2008). In the western North Atlantic, there is an estimated 94,462, and in the northern Gulf of Mexico there is an estimated 3,325 (Waring et al., 2009). Off the Pacific coast of the U.S., there are an estimated 17,925, and in the Hawaiian EEZ there is an estimated 10, 385 striped dolphins (Carretta et al., 2009).

Striped dolphins are common in tropical and warm-temperate waters. Their full range is unknown, but they are known to range from the Atlantic coast of northern South America up to the eastern seaboard of North America, with a northern limit following the Gulf Stream. They are found in the eastern North Atlantic, south of the United Kingdom, and are the most frequently observed dolphin in the Mediterranean Sea. Striped dolphins have also been documented off the coast of several countries bordering the Indian Ocean. Striped dolphins are found outside the continental shelf, over the continental shelf, and are associated with convergence zones and waters influenced by upwelling. Temperature ranges for these dolphins are reported at 10 to 26°C but most often between 18° and 22°C.

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

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

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

- **Atlantic spotted dolphin *(Stenella frontalis)***

The Atlantic spotted dolphin is classified as a data deficient species by the IUCN. The global abundance of the Atlantic spotted dolphin is unknown. In the western North Atlantic, the population estimated for most of the U.S. Atlantic waters (between Florida and Maryland) is 47,400, and the most current stock estimate for the northern Gulf of Mexico is an estimated 37,611 Atlantic spotted dolphins (Waring et al., 2009).

The Atlantic spotted dolphin is found only in the tropical and warm-temperate waters of the Atlantic Ocean. They are commonly found around the southeastern U.S. and the Gulf coasts, in the Caribbean, and off West Africa. They inhabit waters around the continental shelf and the continental shelf-break. Atlantic spotted dolphins are usually near the 200 m (656 ft) contour, but they occasionally swim closer to shore in order to feed.

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

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

- **Spinner dolphin (*Stenella longirostris*)**

Spinner dolphins are classified as a data deficient species by the IUCN. Spinner dolphins are one of the most abundant dolphin species in the world. In the ETP there is an estimated 1,250,000 (Jefferson et al., 2008). In the northern Gulf of Mexico, there are an estimated 1,989 individuals in the stock while in the Pacific there are an estimated 2,805 spinner dolphins in the Hawaiian stock (Carretta et al., 2009; Waring et al., 2009).

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

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

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

- **Clymene dolphin (*Stenella clymene*)**

Clymene dolphins are one of the more poorly known dolphin species and are classified as data deficient by the IUCN. Global population estimates are unknown, but there are an estimated 6,086 in the western North Atlantic and an estimated 6,575 in the northern Gulf of Mexico (Waring et al., 2009).

Clymene dolphins are only found in the tropical to warm-temperate waters of the Atlantic Ocean from New Jersey in the northwestern Atlantic Ocean to Brazil and West Africa (Angola) in the South Atlantic Ocean (Jefferson et al., 2008). Most sightings of Clymene dolphins have been in deep, oceanic waters, but they have also been observed close to shore in areas where deep water approaches the coast. Very little is known about their ecology (Jefferson, 2009).

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

- **Peale's dolphin (*Lagenorhynchus australis*)**

Peale's dolphins are classified at data deficient under the IUCN. Although the only abundance estimate for this species is 200 individuals in southern Chilean waters, the species is considered to be fairly abundant throughout its range (Jefferson et al., 2008). Peale's dolphins inhabit the open coastal waters of Patagonia, Tierra del Fuego, and Chile as well as the deep, protected bays and channels of southern Chile (Goodall, 2009). Peale's dolphins are routinely observed in the waters of the Falkland Islands (Jefferson et al. 2008). The dive sequences Peale's dolphins are usually three short dives followed by one longer dive with dive durations from 3 to 157 seconds, averaging 28 seconds (Goodall, 2009).

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

- **Dusky dolphin (*Lagenorhynchus obscurus*)**

The dusky dolphin is listed as data deficient species under the IUCN. No global population estimates are available for this species. Dusky dolphins occur off New Zealand, central and southern South America, southwestern and southern Africa, southern Australia, and several islands in the South Atlantic and southern Indian Oceans (Jefferson et al., 2008; Van Waerebeek and Würsig, 2009). Dusky dolphins occur primarily in neritic waters but have been observed in deep waters when it approaches close to continental or island coasts (Van Waerebeek and Würsig, 2009). Although no well-defined seasonal migration patterns are apparent, this species are known to move over a range of 780 km (421 nmi) (Van Waerebeek and Würsig, 2009). Dusky dolphins off Argentina and New Zealand move inshore-offshore on both a diurnal and a seasonal scale. Calving takes place from November to February (Croll et al., 1999).

Off Argentina, the mean dive time for dusky dolphins was 21 sec, with shorter dives during the day and longer dives at night (Würsig, 1982). Dusky dolphins in New Zealand swim at mean routine speeds between 4.5 and 12.2 km/hr (2.4 and 6.6 kts) (Würsig and Würsig, 1980; Cipriano, 1992).

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

- **Atlantic white-sided dolphin *(Lagenorhynchus acutus)***

The Atlantic white-sided dolphin is listed as a least concern (lower risk) species under the IUCN. The estimated population in the North Atlantic is 150,000 to 300,000 Atlantic white-sided dolphins (Cipriano, 2009). In the western North Atlantic, there are an estimated 63,368 Atlantic white-sided dolphins (Waring et al., 2009), and in the eastern North Atlantic off the western coast of Scotland, there are an estimated 96,000 Atlantic white-sided dolphins (Jefferson et al., 2008).

Atlantic white-sided dolphins are found only in the cold-temperate waters of the North Atlantic from about 38°N (south of U.S. Cape Cod) and the Brittany coast of France north to southern Greenland, Iceland, and southern Svalbard (Jefferson et al., 2008). They are generally found in continental shelf and slope waters but are also observed in shallow and oceanic waters. Cape Cod is the southern limit to the Atlantic white-sided dolphin, with an eastern limit of Georges Bank and Brittany. It has been noted that there are seasonal shifts in abundance for the Atlantic white-sided dolphin (Jefferson et al., 2008). Calving occurs during the summer months with peaks in June and July (Croll et al., 1999; Jefferson et al., 2008). Atlantic white-sided dolphins are probably not deep divers. A tagged dolphin dove for an average of 38.8 seconds with 76 % of dives lasting less than 1 minute (Mate et al., 1994). This dolphin also swam at an average speed of 5.7 km/hr (3.1 kts) (Mate et al., 1994). The maximum dive time recorded from a tagged animal was 4 min (Cipriano, 2009).

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

- **White beaked dolphin (*Lagenorhynchus albirostris)***

The white beaked dolphin is classified as a least concern (lower risk) species under the IUCN. There is no global population estimate for this species. A total of 7,856 white-beaked dolphins are estimated in the North Sea and adjacent waters (Hammond et al., 2002) while 2,003 white-beaked dolphins are estimated in the western North Atlantic (Waring et al., 2009).

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

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

- **Hourglass dolphin (*Lagenorhynchus cruciger*)**

Hourglass dolphins are listed as least concern/low risk species under the IUCN. There is no global population abundance available, but Kasamatsu and Joyce (1995) estimated the abundance of hourglass dolphins south of the Antarctic Convergence as 144,300 dolphins.

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

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

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

Pacific white-sided dolphins are listed as least concern/low risk species under the IUCN. In the North Pacific Ocean, an abundance of 931,000 to 990,000 Pacific white-sided dolphins has been estimated (Jefferson et al., 2008; Black, 2009). There are an estimated 20,719 Pacific white-sided dolphins in the waters of the U.S. west coast (CA, OR, and WA) and an estimated 26,880 in the Gulf of Alaska (Angliss and Allen, 2009; Carretta et al., 2009). Some animals found in the Gulf of Alaska could also be part of the U.S. west coast stock. In Japanese waters, 30,000 to 50,000 Pacific white-sided dolphins have been estimated to occur (Nishiwaki, 1972).

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

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

- **Rough-toothed dolphin (*Steno bredanensis*)**

The rough-toothed dolphin is classified as data deficient species by the IUCN. Globally, few population estimates are available for the rough-toothed dolphin except in the ETP, where the stock was estimated at 145,900 individuals (Wade and Gerrodette, 1993), and in the U.S. Gulf of Mexico, where the stock estimate is 2,653 dolphins (Waring et al., 2009), and in Hawaiian waters, where the stock was estimated at 19,904 individuals (Carretta et al., 2009). Occurrence data are insufficient elsewhere to estimate abundances.

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

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

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

- **Northern right whale dolphin *(Lissodelphis borealis)***

The northern right whale dolphin is classified as a least concern (lower risk) species by the IUCN. The global population in the North Pacific Ocean of the northern right whale dolphin is estimated as 68,000 animals (Jefferson et al., 2008). In the U.S. waters of California, Oregon, and Washington, 12,876 northern right whale dolphins have been estimated (Carretta et al., 2009).

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

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

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

➢ **Southern right whale dolphin *(Lissodelphis peronii)***

The southern right whale dolphin is classified as a data deficient species by the IUCN. The global population estimate for this species is unknown and virtually nothing known regarding the population status of this species.

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

Subfamily Cephalorhynchinae

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

Commerson's, Chilean, and Heaviside's dolphins are classified as data deficient species while the Hector's dolphin is classified as endangered under the IUCN. The worldwide population size for all species of *Cephalorhynchus* spp. is unknown. The South American population of Commerson's dolphins is estimated as 31,000 individuals (Dawson, 2009), while the Chilean dolphin population is not as well enumerated, with estimates ranging from 59 to several thousand animals (Jefferson et al., 2008; Dawson, 2009). In New Zealand waters, Hector's dolphins are estimated as 111 animals surrounding the North Island with 7,270 animals found around the South Island (Slooten et al., 2002; Dawson, 2009). Only one population estimate of 6,345 animals exists for Heaviside's dolphins in the Cape Town, South Africa region (Dawson, 2009).

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

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

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

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

<u>Phocoenidae</u>

- **Dall's porpoise (*Phocoenoides dalli*)**

Dall's porpoise is considered lower risk (conservation dependent) under the IUCN. The total population of Dall's porpoise is unknown but is considered to be one of the most common cetacean species in the central North Pacific (Jefferson et al., 2008; Jefferson, 2009b). There are an estimated 104,000 harbor porpoises along the Pacific coast of Japan and 554,000 in the Okhotsk Sea (Jefferson et al., 2008). In U.S. waters, there are an estimated 83,400 Dall's porpoises in the Alaskan stock while 48,376 are estimated for the California, Oregon, and Washington stock (Angliss and Allen, 2009; Carretta et al., 2009).

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

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

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

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

- **Harbor porpoise (*Phocoena phocoena*)**

The harbor porpoise is classified as vulnerable under IUCN. The global population for the harbor porpoise is unknown. In the Gulf of Maine, there are an estimated 89,054 harbor porpoises (Waring et al., 2009), 27,000 in the Gulf of Saint Lawrence, 28,000 in Iceland waters, 11,000 in Norwegian waters, 36,000 in Kattegat, 268,000 in the North Sea, and 36,000 in the waters around Ireland (Jefferson et al., 2008). There are an estimated 90,407 in Alaskan waters and an estimated 77,980 harbor porpoises occur in the U.S. west coast waters (Angliss and Allen, 2009; Carretta et al., 2009).

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

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

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

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

- **Spectacled porpoise (*Phocoena dioptrica*)**

The spectacled porpoise is one of the world's most poorly known cetaceans. This species is classified as data deficient by the IUCN. There is no information about the abundance of this species (Goodall, 2009b). There are also no data on diving, swim speeds, hearing, or vocalizations.

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

3.2.5 MARINE MAMMALS—PINNIPEDS

Pinnipeds (sea lions, seals, and walruses) include more than 30 species that are globally distributed amphibious mammals with varying degrees of aquatic specialization (Gentry, 1998; Berta, 2009). Walruses are distributed only in Arctic waters, where SURTASS LFA sonar operations will not occur; thus no further discussion of the walrus is included.

Otariids have retained more extensive morphological ties with land. Eared seals are distinguished by swimming with their foreflippers and moving on all fours on land. In contrast, true seals swim with undulating motions of the rear flippers and have a type of crawling motion on land. Otariids have ear flaps (pinnae) that are similar to carnivore ears. Phocid ears have no external features and are more water-adapted. Otariids have also retained their fur coats (Berta, 2009), whereas phocids and walruses have lost much of their fur and instead have thick layers of blubber. Otariids mate on land whereas phocids mate in the water. Otariids leave calving rookeries to forage during lactation, and due to their need to hunt, otariids can only rear pups in limited sites close to productive marine areas (Gentry, 1998). Phocids, on the other hand, fast during lactation and therefore have fewer limitations on breeding site location. On average, pinnipeds range in size from 45 to 3,200 kg (99 to 7,055 lb) and from approximately 1 m (3.3 ft) to 5 m (16.5 ft) in length (Bonner, 1990).

Many pinniped populations today have been reduced by commercial exploitation, incidental mortality, disease, predation, and habitat destruction (Bowen et al., 2009). Pinnipeds were hunted for their furs, blubber, hides, and organs. Some stocks have begun to recover. However, populations of species such as the northern fur seal and the Steller sea lion continue to decline (Gentry, 2009). The reduction in population raises concern about the potential risk of extinction. The ESA, along with CITES and IUCN, designates a protected status generally based on natural or manmade factors affecting the continued existence of species.

Pinnipeds usually feed under water, diving several times with short surface intervals. This series of diving and surfacing is known as a dive bout. Seasonal changes in temperature and nutrient availability affect prey distribution and abundance, and therefore affect foraging efforts and dive bout characteristics. Foraging areas are often associated with ocean fronts and upwelling zones. Feeding habits are most dependent on the ecology of the prey and the age of the animal. Diet composition can change with the distribution and abundance of prey. Additionally, the hunting habits of pinnipeds may change with age. For example, harbor seal pups eat pelagic herring and squid whereas adult harbor seals eat benthic animals. The amount of benthic prey in the diet of the bearded seal also increases with age (Berta, 2009; Bowen et al., 2009). Phocids are generally benthic feeders, whereas in the otariid family, fur seals feed on small fish at the surface and sea lions feed on larger fish over continental shelves (Gentry, 1998).

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

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

Social systems are based on aggregations of pinnipeds forming large colonies for polygynous breeding and raising young. The size of the colonies may correlate with resource availability and predation pressure. Pinnipeds are generally long-lived with longevity estimates of 40 years or more (Berta, 2009). Age of sexual maturity ranges from 2 to 6 years (Boyd, 2009). All pinnipeds produce single young on land or ice and most gather to bear young and breed once a year.

Pinnipeds are known for their diving ability. On average, smaller species dive for roughly 10 min and larger pinnipeds can dive for over an hour. Maximum depths vary from less than 100 m (328 ft) to over 1,500 m (4,921 ft) (Berta, 2009).

Hearing capabilities and sound production are highly developed in all pinniped species studied to date. It is assumed that pinnipeds rely heavily on sound and hearing for breeding activities and social interactions (Schusterman, 1978; Berta, 2009; Frankel, 2009). They are able to hear and produce sounds in both air and water. Pinnipeds have different functional hearing ranges in air and water. Their air-borne vocalizations include grunts, snorts, and barks, which are often used as aggression or warning signals, or to communicate in the context of breeding and rearing young. Under water, pinnipeds can vocalize using whistles, trills, clicks, bleats, chirps, and buzzes as well as lyrical calls (Schusterman, 1978; Berta, 2009; Frankel, 2009). Sensitivity to sounds at frequencies above 1 kHz has been well documented. However, there have been few studies on their sensitivity to low frequency sounds. Various studies have examined the hearing capabilities of some pinniped species, particularly ringed seals, harp seals, harbor seals, California sea lions, and northern fur seals (Mohl, 1968a; Terhune and Ronald, 1972; Terhune and Ronald, 1975a and 1975b; Kastak and Schusterman, 1996; Kastak and Schusterman, 1998). Kastak and Schusterman (1998) suggest that the pinniped ear may respond to acoustic pressure rather than particle motion when in the water. Sound intensity level and the measurement of the rate of energy flow in the sound field was used to describe amphibious thresholds in an experiment studying low-frequency hearing in two California sea lions, a harbor seal, and an elephant seal. Results suggest that California sea lions are relatively insensitive to most anthropogenic sound in the water, as sea lions have a higher hearing threshold (116.3 to 119.4 dB RL) at frequencies of 100 Hz than typical anthropogenic noise sources at moderate distances from the source. Harbor seals are approximately 20 dB more sensitive to signals at 100 Hz, compared to California sea lions, and are more likely to hear low-frequency anthropogenic noise. Elephant seals are the most sensitive to low-frequency sound under water with a threshold of 89.9 dB RL at 100 Hz. Kastak and Schusterman (1996 and 1998) also suggest that elephant seals may not habituate well to certain types of sound (in contrast to sea lions and harbor seals), but in fact may become more sensitive to disturbing noises and environmental features associated with the noises.

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

The California sea lion is one of the few otariid species whose underwater sounds have been well studied. Other otariid species with documented vocalizations are South American sea lions and northern fur seals (Fernandez-Juricic et al., 1999; Insley, 2000). Otariid hearing abilities are thought to be intermediate between Hawaiian monk seals and other phocids, with a cutoff in hearing sensitivity at the high frequency end between 36 and 40 kHz. Underwater low frequency sensitivity is between approximately 100 Hz and 1 kHz. The underwater hearing of fur seals is most sensitive with detection thresholds of approximately 60 dB RL at frequencies between 4 and 28 kHz (Moore and Schusterman, 1987; Babushina et al., 1991).

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

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

3.2.5.1 Otariidae Species

The Otariidae family of pinnipeds includes 16 otariid species, of which 15 are included in this document for further consideration (Table 3-4). One otariid species, the Antarctic fur seal, is not considered due to its restricted occurrence in a polar region where SURTASS LFA sonar will not operate.

- **South American fur seal (*Arctocephalus australis*)**

The South American fur seal is listed as a least concern (lower risk) species under the IUCN. The abundance of the Southern fur seal and its subspecies, which only occurs in the Falkland Islands, is not well known. The South American fur seal’s coastal and offshore populations are currently estimated at 235,000 to 285,000 animals (Arnould, 2009).

South American fur seals range from central Peru to the Straits of Magellan in the southern Pacific Ocean and from southern Brazil to Uruguay in the southern Atlantic Ocean (Jefferson et al., 2008). Most colonies of South American fur seals are located on offshore islands except in Peru, where the colonies are located on the mainland (Arnould, 2009). Males are sometimes seen seasonally up to 600 km (324 nmi) offshore (Jefferson et al., 2008). These fur seals are believed to occur predominantly in continental shelf and continental slope waters.

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

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

➢ **New Zealand fur seal (*Arctocephalus forsteri*)**

The New Zealand fur seal is listed as a least concern (lower risk) species under the IUCN. The global population estimate is 135,000 seals, with 35,000 found in Australia (Jefferson et al., 2008). The New Zealand fur seal is a temperate species having two genetically distinct populations. One population is around both the North and South islands of New Zealand, with the larger population around South Island. The second population is found on the coast of southern and western Australia (Jefferson et al., 2008). Their principal breeding colonies occur at South Island and Stewart Island along the coast of western and southern Australia and off Tasmania at Maatsuyker Island. Breeding colonies also exist at the subantarctic Chatham, Campbell, Antipodes, Bounty, Aukland, and Macquarie islands, and at Kangaroo Island off southern Australia (Reeves et al., 2002). The New Zealand fur seal prefers rocky and windy habitats that are protected from the sun for breeding (Jefferson et al., 2008).

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

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

➢ **Galapagos fur seal (*Arctocephalus galapagoensis*)**

The Galapagos fur seal is listed as endangered under the IUCN. The population is estimated currently as 12,000 individuals although estimates from the late 1989s were about 40,000 animals (Jefferson et al., 2008; Arnould, 2009).

Galapagos fur seals are non-migratory. Their distributional range is limited to the equatorial region throughout the Galapagos Islands (Arnould, 2009). These seals haul out on rock shorelines with most colonies located in the western and northern parts of the Galapagos Archipelago and occasionally come ashore on the mainland Ecuadorian coast (Jefferson et al., 2008).

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

➢ **Juan Fernandez fur seal (*Arctocephalus philippii)***

The Juan Fernandez fur seal is classified as near threatened under the IUCN. The species was believed to have been hunted to extinction until 1965 when a small remnant population was located. The population is currently estimated at 18,000 seals (Arnould, 2009).

Juan Fernandez fur seals are restricted to the Juan Fernandez island group off the coast of north central Chile (Jefferson et al., 2008). Currently this seal occupies four major breeding colonies and hauls out on rocky shorelines (Arnould, 2009).

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

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

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

South African or Cape fur seals are listed as a species of least concern (lower risk) by the IUCN. The most recent population census in 2004 indicates that the population of South African fur seals is stable at an estimated 2 million animals (Arnould, 2009).

South African fur seals occur along the southern African coast from South Africa to Angola (Jefferson et al., 2008). Breeding occurs at 25 colonies along the coasts of South Africa and Namibia, including four mainland colonies (Arnould, 2009).

South African fur seals feed within approximately 5 km (2.7 nmi) of land and are believed to be non-migratory. Females fur seals dove to an average depth and duration of 45 m (ft) for 2.1 min with the maximum depth and duration of 204 m (669 ft) and 7.5 min (Kooyman and Gentry, 1986). No swim speed data are available for this species. There is also no information available on the hearing abilities or sound production of the South African fur seal.

- **Australian fur seal (*Arctocephalus pusillus doriferus*)**

Australian fur seals are listed as a species of least concern (lower risk) by the IUCN. Most of their breeding and haulout sites are protected by Australian federal, state, and territorial laws. Currently, the population of Australian fur seals is estimated at 92,000 animals (Arnould, 2009).

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

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

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

- **Guadalupe fur seal (*Arctocephalus townsendi)***

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

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

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

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

- **Subantarctic fur seal (*Arctocephalus tropicalis*)**

Subantarctic fur seals are considered a least concern (lower risk) species under the IUCN. The current population of this widely dispersed fur seal is more than 310,000 animals (Arnould, 2009). More than 200,000 seals occur at Gough Island in the South Atlantic with good sized colonies occurring in the southern Indian Ocean at Prince Edward Island with 75,000 animals and Amsterdam Island with 50,000 (Arnould, 2009).

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

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

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

- **Northern fur seal (*Callorhinus ursinus*)**

Northern fur seals are currently classified as a vulnerable species under IUCN and depleted under the MMPA. There is no current global population estimate available for this species. The eastern Pacific stock is estimated to be 665,550 seals (Angliss and Allen, 2009). The San Miguel Island stock is estimated to be 9,424 seals (Carretta et al., 2009).

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

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

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

- **Steller sea lion (*Eumetopias jubatus*)**

The Steller sea lion is also known as the northern sea lion. The species is classified as an endangered species under IUCN. The Western population is listed as endangered under the ESA, and the Eastern population is listed as threatened under the ESA. The Steller sea lion is considered depleted throughout its range under the MMPA. The worldwide population size for this species is estimated to be 100,000 (Loughlin, 2009). The eastern U.S. stock (east of Cape Suckling, Alaska) in the Pacific is estimated to be between 45,095 and 55,832. The western U.S. stock (west of Cape Suckling, Alaska) in the Pacific is estimated to be 44,780 (Angliss and Allen, 2009).

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

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

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

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

- **California sea lion (*Zalophus californianus*)**

California sea lions are listed as a least concern (lower risk) species under the IUCN. The population size for this species is estimated to be 238,000 seals (Carretta et al., 2009). California sea lions are common along the Pacific coast of the United States and Mexico, ranging from the Tres Marias Islands, Mexico, to the Gulf of Alaska, although California sea lions are rare farther north than Vancouver, British Columbia (Jefferson et al., 2008, Heath and Perrin, 2009). The principal breeding areas for the California sea lion are the Channel Islands off southern California, the islands off the coast of Baja California, Mexico, and in the Gulf of California (Heath and Perrin, 2009).

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

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

- **Galapagos sea lion (*Zalophus wollebaeki*)**

Galapagos sea lions are classified as endangered under IUCN. The current population is estimated to be between 20,000 and 50,000 seals (Jefferson et al., 2008). Galapagos sea lions are an equatorial species closely related to California sea lions. Their range is restricted to the Galapagos Islands with a small colony on La Plata Island off the coast of Ecuador. Occasionally, vagrants can be seen along the Ecuador and Columbia coasts, particularly around Isla del Coco, Costa Rica, and Isla del Gorgona (Heath and Perrin, 2009).

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

- **Australian sea lion (*Neophoca cinerea*)**

The Australian sea lion is listed as endangered under the IUCN due to its small, genetically fragmented population, which appears to be declining at some colonies. Additionally, most major colonies are at risk of extinction from fishery bycatch. The Seal Bay area has been designated as a conservation park for these sea lions (Ling, 2009). The total population of Australian sea lions has most recently been estimated as 9,794 animals (Ling, 2009).

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

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

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

- **New Zealand sea lion (*Phocarctos hookeri*)**

The New Zealand sea lion, also known as Hooker's sea lion, is listed under the IUCN as vulnerable. This sea lion has an estimated abundance of 12,500 individuals and is considered to be a stable population (Gales, 2009).

This rarely occurring sea lion is endemic to New Zealand waters and has one of the most restricted ranges of all pinnipeds (Gales, 2009). This sea lion occur in two geographically isolated and genetically distinct populations around New Zealand and southern and western coast of Australia (Jefferson et al., 2008). Although once found in all the New Zealand waters, the current breeding range of the New Zealand sea lion is limited to two groups of subantarctic islands, the Auckland and Campbell Islands, with pups occasionally born along the shore of the South Island; approximately 86% of New Zealand sea lion pups are born in the Auckland Islands (Gales, 2009).

New Zealand sea lions are among the deepest and longest divers of the otariids, diving to a mean water depth of 123 m (404 ft) with an average dive duration of 3.9 min (Gales, 2009). The maximum foraging dive depth recorded for a lactating female was 550 m (1,804 ft) and the longest dive time was 11.5 min (Costa and Gales, 2000). Swim speeds are about 1.3 m/sec (2.5 kts) (Williams, 2009).

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

- **South American sea lion (*Otaria flavescens*)**

South American sea lions are listed as a least concern (lower risk) species under the IUCN. The current total population is estimated to be between 200,000 and 300,000 seals (Jefferson et al., 2008), with 110,000 sea lions occurring along the southwestern Atlantic coastal areas (Cappozzo and Perrin, 2009).

South American sea lions are nearly continuously distributed along most of South America from southern Brazil to northern Peru, including the Falkland Islands and Tierra del Fuego (Jefferson et al., 2008). This sea lion is principally concentrated in central and southern Patagonia, where more than 53 breeding colonies are found (Cappozzo and Perrin, 2009). The South American sea lion is primarily found in continental shelf and continental slope waters (Jefferson et al., 2008).

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

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

3.2.5.2 Phocidae Species

The family Phocidae includes 18 species of true or earless seals, of which eight species have been eliminated from further consideration in this document since they occur in areas (polar or inshore) where SURTASS LFA sonar will not operate, leaving 10 phocid seal species to be considered (Table 3-5).

- **Mediterranean monk seal (*Monachus monachus)***

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

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

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

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

- **Hawaiian monk seal (*Monachus schauinslandi*)**

Hawaiian monk seals are listed as endangered under the ESA, classified as endangered under IUCN, and protected under CITES. The best available population estimate for this species is 1,208 individuals (Carretta et al., 2009).

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

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

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

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

The total population estimate for the northern elephant seal is over 150,000 (Jefferson et al., 2008). The population estimate for the California breeding stock of this species is 124,000 as of 2005 (Carretta et al., 2009). The population of southern elephant seals has been estimated at 650,000 seals (Jefferson et al., 2008). Two major populations of southern elephant seals are experiencing a decline while northern elephant seals are increasing in number.

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

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

Elephant seals may have poor in-air hearing sensitivity due to their aquatic and deep-diving lifestyle. Their ears may be better adapted for in-water hearing in terms of energy efficiency, which is reflected in the lower intensity thresholds under water, as well as receiving and transducing the mechanical stimulus which is reflected in the lower pressure thresholds under water (Kastak and Schusterman, 1999). Kastak and Schusterman (1999) found that hearing sensitivity in air is generally poor, but the best hearing frequencies were found to be between 3.2 and 15 kHz with the greatest sensitivity at 6.3 kHz and an upper frequency limit of 20 kHz (all at 43 dB re: 20 µPa). Underwater, the best hearing range was found to be between 3.2 and 45 kHz, with greatest sensitivity at 6.4 kHz and an upper frequency limit of 55 kHz (all at 58 dB RL) (Kastak and Schusterman, 1999). Kastak and Schusterman (1998) found that northern elephant seals can hear underwater sounds in the range of 75 Hz to 6.3 kHz. Kastak and Schusterman (1996) found hearing sensitivity increased for frequencies below 64 kHz, and the animals were still able to hear sounds below 100 Hz. One juvenile was measured as having a hearing threshold of 90 dB RL at 100

Hz (Fletcher et al., 1996). Since their hearing is better underwater, it is assumed that elephant seals are more sensitive to anthropogenic low frequency sound (Kastak and Schusterman, 1996). There are no direct hearing data available for southern elephant seals.

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

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

- **Ribbon seal (*Phoca fasciata*)**

Ribbon seals are classified as a data deficient species by the IUCN. Although no current abundance estimates are available for regional or global populations, Burns (1981) estimated the worldwide population of ribbon seals at 240,000 in the mid-1970s, with an estimate for the Bering Sea at 90,000-100,000, while Fedoseev (2000) reported an average population of 370,000 ribbon seals in the Sea of Okhotsk between 1968 and 1990. Mizuno et al. (2002) reported an average abundance of 2,697 seals for the southern Sea of Okhotstk off Hokaido, Japan for March through April 2000.

The distribution of ribbon seals is limited to the northern North Pacific Ocean and an area of the Arctic Ocean north of the Chukchi Sea, with predominant occurrence in the Bering Sea and Sea of Okhotsk (Jefferson et al., 2008; Fedoseev, 2009). Ribbon seals are associated with the southern edge of the pack ice from winter through early summer, where they pup and molt on the ice that is commonly found along the continental shelf where there is high water circulation (Fedoseev, 2009). During the summer months, ribbon seals have a pelagic phase that may encompass a broader distributional range than when the seals are dependent upon sea ice (Jefferson et al., 2008). Swim speeds and dive data are unknown for this species.

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

- **Spotted seal (*Phoca largha*)**

Spotted or largha seals are classified as a data deficient species by the IUCN. The Southern Distinct Population Segment of spotted seals, which consists of breeding concentrations in the Yellow Sea and Peter the Great Bay in China and Russia, is listed as threatened under the ESA. The global population for this species is unknown. Jefferson et al. (2008) reported abundances of between 100,000 and 135,000 seals in the Bering Sea, 100,000 to 130,000 seals in the Sea of Okhotsk, and an estimated 4,500 seals in the Bohai Sea off China. The last reliable population estimate for the Bering Sea stock of spotted seals was estimated in 1992, with a maximum of 59,214 seals (Angliss and Allen, 2009). Trukhin (2005 as reported in Burns, 2009) reported an overall population estimate of 290,000 seals in the 1990s. Mizuno et al. (2002) reported an average abundance of 10,099 seals in the southern Sea of Okhotsk off Hokaido, Japan for March and April 2000. Additionally, Trukhin and Mizuno (2002) reported 1,000 spotted seals in Peter the Great Bay (southwestern Sea of Okhotsk area) and that this population had maintained this stable number of seals for at least 10 years.

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

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

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

- **Harbor seal (*Phoca vitulina*)**

Harbor seals are also known as common seals. This species is classified as least concern (lower risk) by the IUCN. The global population of harbor seals is estimated to be between 300,000 and 500,000 seals (Jefferson et al., 2008). Five subspecies of the harbor seal have been classified throughout the Northern Hemisphere. In the western North Atlantic there are an estimated 99,340 seals (Waring et al., 2009). In Alaska including the Gulf of Alaska and the Bering Sea, the statewide population of harbor seals is estimated to be 180,017 individuals (Angliss and Allen, 2009). The California stock estimate of harbor seals is estimated to be 34,233 seals, while in Oregon and Washington, 24,732 seals are estimated (Carretta et al., 2009). In inland Washington, there are an estimated 14,612 harbor seals (Carretta et al., 2009).

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

Harbor seals are generally considered to be sedentary, but their known seasonal and annual movements are varied. They haul out mainly on land, but they do use icebergs in Alaska and Greenland. When they haul out on land, they prefer natural substrates of mud flats, gravel bars and beaches, and rocks. Breeding grounds are generally associated with isolated places such as pack ice, offshore rocks, and vacant beaches (Riedman, 1990).

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

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

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

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

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

- **Gray seal (*Halichoerus grypus*)**

Gray seals are classified as a least concern (lower risk) species by the IUCN. Gray seals have a global population estimate of 380,000 seals (Jefferson et al., 2008). In the western North Atlantic there is an estimated population of 125,541 to 169,064 seals (Waring et al., 2009) In the Baltic Sea there is an estimated 17,600 gray seals (Jefferson et al., 2008).

Gray seals occur in temperate and sub-polar regions mostly in the north Atlantic Ocean Baltic Sea and the eastern and North Atlantic (Jefferson et al., 2008). Gray seals breed on remote islands that are typically uninhabited or on fast ice. The biggest island breeding colony is on Sable Island (Hall and Thompson, 2009). Gray seals breed on drifting ice and offshore islands throughout their range. This species is not known to undergo seasonal movements.

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

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

- **Hooded seal (*Cystophora cristata*)**

Hooded seals are classified as a vulnerable species by the IUCN. The global population of hooded seals is estimated at 660,000 seals (Kovacs, 2009). Three stocks are recognized to set harvest quotas: Canadian, Davis Strait, and the West Ice (west of Jan Mayen Island) stocks (Kovacs, 2009). The abundance of the West Ice stock has been stable at around 70,000 hooded seals for the last 20 years (Kovacs, 2009).

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

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

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

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

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

- **Harp seal (*Pagophilus groenlandicus*)**

The harp seal is considered least concern by the IUCN. Population sizes for the three stocks of harp seals in the North Atlantic Ocean were recently estimated as 5.5 million seals for the northwest Atlantic stock, 741,670 animals in the West Ice stock (Greenland Sea near Jan Mayen Island), and 2,425,480 seals in the White Sea (Lavigne, 2009; Waring et al., 2009).

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

Previously, harp seals were thought to be shallow divers, but dives to maximum water depths of 568 m (Folkow et al., 2004) and dive durations up to 16 min (Schreer and Kovacs, 1997) now demonstrate that harp seals are moderately deep divers. Folkow et al. (2004) found that more than 12% of all dives recorded during their study were to depths more than 300 m. Harp seal’s mean dive durations range from 3.8 to 8.1 min (Lydersen and Kovacs, 1993; Folkow et al., 2004).

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

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

3.2.6 PROTECTED HABITATS

Many habitats in the marine environment are protected for a variety of reasons, but typically habitats are designated to conserve and manage natural and cultural resources. Protected marine and aquatic habitats have defined boundaries and are typically enabled under some Federal, State, or international legal authority. Habitats are protected for a variety of reasons including intrinsic ecological value; biological importance to specific marine species or taxa, which are often also protected by federal or international agreements; management of fisheries; and cultural or historic significance. Three types of marine and aquatic habitats protected under U.S. legislation or Presidential EO, critical habitat, essential fish habitat, and marine protected areas, are described in this section.

3.2.6.1 Critical Habitat

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

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

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

Seventy-three marine and anadromous species have been listed as threatened or endangered under the ESA. Critical habitat has only been designated for six of the ESA-listed marine mammal, three sea turtle, nine marine or anadromous fish, and three marine invertebrate or plant species (Table 3-6; NMFS, 2011). The NMFS has jurisdiction over the marine and anadromous species listed under ESA and their designated critical habitat.

3.2.6.2 Essential Fish Habitat—U.S. EEZ Waters

In recognition of the critical importance that habitat plays to all lifestages of fish and invertebrate species, the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), as amended, protects habitat essential to the production of federally managed marine and anadromous species within the U.S. EEZ. The MSFCMA, reauthorized and amended by the Sustainable Fisheries Act, called for the identification and protection essential fish habitat (EFH). Under the MSFCMA, the NMFS has exclusive federal management authority over U.S. domestic fisheries resources and oversees the nine regional fishery management councils (FMCs) and approves all Fishery Management Plans (FMPs). The 1996 EFH mandate and 2002 Final EFH Rule require that regional FMCs, through federal FMPs, describe and

Table 3-6. Marine and anadromous species listed under the ESA for which critical habitat has been designated.

Species	Status Under ESA	Listed Distinct Population Segment (DPS)/Population/Evolutionarily Significant Unit (ESU)	Critical Habitat—Type of Habitat Designated
Marine Mammals			
Beluga whale	Endangered	Cook Inlet	Inshore
Killer whale	Endangered	Southern Resident	Inshore
North Atlantic right whale	Endangered		Marine, nearshore and >12 nmi
North Pacific right whale	Endangered		Marine, nearshore and >12 nmi
Hawaiian monk seal	Endangered		Marine, nearshore <12 nmi
Steller sea lion	Threatened	Eastern	Marine, nearshore and >12 nmi
	Endangered	Western	Marine, nearshore <12 nmi
Sea Turtles			
Green turtle	Endangered	Florida and Pacific Mexico breeding colonies	
	Threatened	All other areas	Marine, nearshore <12 nmi
Hawksbill turtle	Endangered		Marine, nearshore <12 nmi
Leatherback turtle	Endangered		Marine, nearshore <12 nmi
Marine/Anadromous Fishes			
Atlantic salmon	Endangered	Gulf of Maine	Inland, river
Chinook salmon	Threatened	California coastal	Inshore, estuarine
	Threatened	Central valley spring-run	Inland, river
	Threatened	Lower Columbia River	Inland, river
	Endangered	Upper Columbia River spring-run	Inland, river
	Threatened	Puget Sound	Inshore
	Endangered	Sacramento River winter-run	Inland, river
	Threatened	Snake River fall-run	Inland, river
	Threatened	Snake River spring/summer-run	Inland, river
	Threatened	Upper Willamette River	Inland, river
Chum salmon	Threatened	Columbia River	Inland, river
	Threatened	Hood Canal summer-run	Inshore
Coho salmon	Endangered	Central California coast	Inshore, estuarine
	Threatened	Oregon coast	Inshore, estuarine
	Threatened	Southern Oregon and northern California coasts	Inshore, estuarine
Sockeye salmon	Threatened	Ozette Lake	Inland, lake

Table 3-6. Marine and anadromous species listed under the ESA for which critical habitat has been designated.

Species	Status Under ESA	Listed Distinct Population Segment (DPS)/Population/Evolutionarily Significant Unit (ESU)	Critical Habitat—Type of Habitat Designated
	Endangered	Snake River	Inland, river
Steelhead trout	Threatened	Central California coast	Inshore, estuarine
	Threatened	Snake River Basin	Inland, river
	Threatened	Upper Columbia River	Inland, river
	Endangered	Southern California	Inland, river
	Threatened	Middle Columbia River	Inland, river
	Threatened	Lower Columbia River	Inland, river
	Threatened	Upper Willamette River	Inland, river
	Threatened	Northern California	Inland, river
	Threatened	South-Central California coast	Inshore, estuarine
	Threatened	California Central Valley	Inland, river
Green sturgeon	Threatened	Southern	Marine, nearshore >12 nmi
Gulf sturgeon	Threatened		Inshore and Marine <12 nmi
Smalltooth sawfish	Endangered	U.S. portion of range	Inshore and Marine <12 nmi
Marine Invertebrates			
Elkhorn coral	Threatened		Marine, nearshore <12 nmi
Staghorn coral	Threatened		Marine, nearshore <12 nmi
Marine Plants			
Johnson seagrass	Threatened		Inshore

identify EFH for each federally managed species, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitats. The NMFS' Highly Migratory Species (HMS) Division functions as a FMC (Secretarial FMC) to oversee EFH designation and FMP preparation for Atlantic highly migratory species, such as sharks and tuna, since the habitat essential to these species may cross FMC and federal jurisdictional boundaries (NMFS, 2009a).

Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" and the term "fish" as "finfish, mollusks, crustaceans, and all other forms of marine animals and plant life other than marine mammals and birds" (16 U.S.C. §1802[10]). The regulations for implementing EFH clarify that "waters" include all aquatic areas and their biological, chemical, and physical properties, while "substrate" includes the associated biological communities that make these areas suitable fish habitats (50 CFR §50). Habitats used at any time during a species' life cycle (i.e., during at least one of its lifestages) must be accounted for when describing and identifying EFH, including inshore bays and estuaries (NMFS, 2002). Habitat areas of particular concern (HAPC) are subsets of EFH areas that are designated to indicate an areas' rarity, susceptibility to anthropogenic-induced degradation, special ecological importance, or location in an environmentally stressed region. HAPC do not confer additional protection or restriction but are intended to prioritize conservation efforts.

The MSFCMA requires federal agencies that fund, permit, or carry out activities that may adversely affect EFH to consult with the NMFS regarding the potential impacts of the federal actions on EFH and respond in writing to the NMFS or FMC recommendations. NMFS' conservation recommendations are non-binding (NMFS, 2002). Adverse effects are defined as "any impact that reduces quality and/or quantity of EFH"; adverse effects include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH (50 CFR §600). Adverse effects to EFH may result from actions occurring within or outside of the areal extent of the designated EFH and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of federal actions. NMFS (2002) describes the process by which federal agencies can integrate MSFCMA EFH consultations with ESA Section 7 consultations.

Nine FMCs, including the HMS Division of NMFS, are responsible for designating EFH and HAPC in all U.S. territorial waters for hundreds of marine and anadromous fish and invertebrate species (Table 3-7). The types of general habitat that have been designated as EFH in U.S. territorial waters include:

- **Benthic Habitat:** These seafloor habitats may be designated for specific substrate types (e.g., rocks, gravel, sand, clay, mud, silt, shell fragments, and hard bottom). These habitats are utilized by a variety species for spawning/nesting, development, dispersal, and feeding (SAFMC, 1998).
- **Structured Habitats:** Areas that provide shelter for a variety of species and include:
  - Artificial Reefs - Human-made structures made of various types of materials and used primarily by adult fishes, especially spawning adults (SAFMC, 1998).
  - Biogenic Habitat - Created by living organisms such as sponges, mussels, hydroids, amphipod tubes, hydroids, red algae, bryozoans, vermeteid and coral reefs, all of which are home to many reef fishes and invertebrates.
- **Pelagic *Sargassum*:** Mats of the pelagic species of the brown algae, *Sargassum,* that are found on the surface of open ocean areas of the North Atlantic Ocean and play a unique role by providing shelter, food source, and a prey aggregating site for numerous fishes, especially the larval lifestage.
- **Marine Waters:** All seawater from the surface of the ocean to the seafloor (i.e., water column) but not including the ocean bottom. Depending upon the species, the designated habitat may refer only to a specific part of the water column, such as surface or bottom waters, to specific water depths in the water column, such as waters from 100 to 1,000 m, or to the entire water column. This habitat may

also specify the part of the continental margin over which the marine waters are located, such as continental shelf waters, or to the marine ecological zone of the ocean, such as pelagic waters. This habitat is important for a wide variety of species and lifestages.

  - Surge Zone: This high energy shoreline area is the region of the littoral zone where waves break onto the shore or beach.

- **Surface Water Currents:** Currents such as the Gulf Stream, which is the dominant surface circulation feature in the U.S. Atlantic EEZ waters, is a key dispersal mechanism for larvae of many species of fishes and crustaceans.
- **Topographic Features:** These seafloor habitat areas have high vertical (bathymetric) relief and include seamounts, hard rock banks, escarpments, submarine canyons, deep slope terraces, and the continental or insular shelf break.
- **Estuarine Areas:** Inshore aquatic areas where saltwater and freshwater mix typify estuarine (e.g., bay, river, lagoon) habitats. Specific estuarine habitats, such as salt marshes or beds of submerged aquatic vegetation, may be designated. These types of EFH are very important early developmental habitats for many commercially valuable species that may spend their later juvenile and adult lifestages in marine waters.
- **Vegetated Beds:** Inshore and nearshore beds or communities of algae (e.g., kelp beds), mangroves, or aquatic vegetation (seagrasses). These densely vegetated habitats are sources of shelter and food for many fish and invertebrate species.
- **Marine Protected Areas (MPAs):** Specific waters within the U.S. EEZ under jurisdiction of the WPRFMC where fishing is prohibited or only allowed by special permit. Waters landward of the 91-m (299-ft) isobath surrounding Howland, Baker, and Jarvis Islands, Rose Atoll, and Kingman Reef and in a box designated by four corner geographic coordinates around French Frigate Shoals have been designated as no-take (no fishing) MPAs while waters from shore to the 91-m (299-ft) isobath surrounding Palmyra and Johnson Atolls and Wake Island are low-use MPAs, where fishing is only allowed by special permit (WPRFMC, 2006).

Since SURTASS LFA sonar routinely operates at a minimum distance of at least 12 nmi from shore, the inshore and nearshore types of EFH, such as estuarine areas, vegetated beds, surge zones, structured habitat, and marine protected areas, would not occur in potential SURTASS LFA operational areas within the waters of the U.S. EEZ (Table 3-7). Thus, the amount of EFH designated in potential operating areas is somewhat reduced (Table 3-7). Although EFH is designated for adult lifestages in potential U.S. operating areas, EFH for early developmental stages (i.e., eggs and larvae or equivalent lifestages) dominates much of the oceanic areas in which SURTASS LFA will potentially operate, particularly in U.S. tropical waters.

3.2.6.3 Marine Protected Areas

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

Table 3-7. Geographic area of jurisdiction in U.S. EEZ waters and number of species/species groups for which EFH has been designated by each of the nine Fishery Management Councils as well as the number of designated EFH species/species groups in potential SURTASS LFA OPAREAs (CFMC, 2009; GMFMC, 2009; MAFMC, 2009; NEFMC, 2009, NMFS, 2009a; NMFS, 2009b; NPFMC, 2009; PFMC, 2009; SAFMC, 2009; WPFMC, 2009).

Fishery Management Council	Geographic Area of Jurisdiction	Number Species/Species Groups for Which EFH has been Designated	Number Species/Species Groups for Which EFH is Designated in Potential SURTASS LFA OPAREAs
New England FMC	U.S. EEZ waters of Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine	27	15
Mid-Atlantic FMC	U.S. EEZ waters of New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, and North Carolina	12	9
South Atlantic FMC	U.S. EEZ waters of North Carolina, South Carolina, Georgia, and eastern Florida (to Key West)	90 plus 2 co-managed with GMFMC	~80
Gulf of Mexico FMC	U.S. EEZ waters of western Florida (from Key West), Alabama, Mississippi, Louisiana, and Texas	62 plus 2 co-managed with SAFMC	62
Caribbean FMC	U.S. EEZ waters of Puerto Rico and U.S. Virgin Islands	304	304
Pacific FMC	U.S. EEZ waters of California, Oregon, and Washington	115	~99
North Pacific FMC	U.S. EEZ waters of Alaska	34	25
Western Pacific Regional FMC	U.S. EEZ waters of Hawaiian Archipelago (including Main and Northwest Hawaiian Islands and Midway), Johnson Atoll, Palmyra Atoll/Kingman Reef, Jarvis Island, American Samoa, Howland Island, Baker Island, Wake Island, Guam, and Northern Mariana Islands	>223	~207
Secretarial FMC (NMFS Highly Migratory Species Division)—Atlantic HMS	U.S. Atlantic and Gulf of Mexico EEZ waters	50	36

MPAs have been proven to be effective conservation tools to manage fisheries, preserve habitat and biodiversity, and enhance the aesthetic and recreational value of marine areas (NRC, 2000b). Although the objectives for establishing protection of marine areas vary widely, MPAs are typically used to achieve two broad objectives: 1) habitat protection, and 2) fisheries management and protection (Agardy, 2001). Many MPAs are multi-use areas while others only allow restricted uses within the designated MPA boundaries.

U.S. Marine Protected Areas

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

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

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

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

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

In April 2009, the NMPAC, in collaboration with federal, state, and territory agencies, organizations/associations, industry, and the public, announced the establishment of the National MPA System with its initial listing of over 200 MPAs (Tables 3-8 through 3-14). The list of National System

Table 3-8. MPAs in or adjacent to U.S. Gulf of Mexico waters that are currently part of the national MPA system (NMPAC, 2009b and 2009c).

National Wildlife Refuges (NWR)	National Wildlife Refuges (NWR) (Continued)	National Park (NP) System
Ten Thousand Island	Grand Bay	Everglades NP
J.N. Ding Darling	Breton	Dry Tortugas NP
Matlacha Pass	Delta	
Pine Island	Shell Keys	**National Marine Sanctuary**
Island Bay	Sabine	Florida Keys
Pinellas	Anahuac	Flower Garden Banks
Chassahowitzka	Brazoria	
Crystal River	San Bernard	**National Estuarine Research Reserve**
Cedar Keys	Big Boggy	Rookery Bay
Lower Suwannee	Aransas	
Big Branch Marsh	National Key Deer Refuge	
St. Vincent	Great White Heron	
St. Marks	Key West	
Bon Secour		

Table 3-9. MPAs in or adjacent to Caribbean Sea waters of U.S. territories that are currently part of the national MPA system (NMPAC, 2009c and 2009c).

National Park System	
Virgin Islands Coral Reef NM	Virgin Islands NP

Table 3-10. MPAs in or adjacent to U.S. Alaska waters that are currently part of the national MPA system (NMPAC, 2009b and 2009c).

National Wildlife Refuges	National Park System
Yukon Delta	Glacier Bay NP and Preserve
Alaska Maritime	
Arctic	

Table 3-11. MPAs in or adjacent to U.S. Atlantic waters that are currently part of the national MPA system (NMPAC, 2009b and 2009c).

National Wildlife Refuge (NWR)	National Wildlife Refuge (NWR) (Continued)	National Estuarine Research Reserve
Cross Island	Martin	Guana Tolomato Matanzas
Pond Island	Supawna Meadows	Waquoit Bay
Rachel Carson	Susquehanna	Jacques Cousteau
Great Bay	Blackwater	
Parker River	Bombay Hook	**National Park System**
Mashpee	Eastern Neck	Biscayne NP
Edwin B. Forsythe	Occoquan Bay	Assateague Island NS
Monomoy	Featherstone	
Nomans Land Island	Plum Tree Island	**National Marine Sanctuary**
Sachuest Point	Fisherman Island	NOAA's Monitor
John H. Chafee	Pea Island	Gray's Reef
Ninigret	Eastern Shore of Virginia	Gerry E. Studds/Stellwagen Bank
Stuart B. McKinney	Alligator River	
Target Rock	Swanquarter	**Natural Area Preserves**
Oyster Bay	Cedar Island	Dameron Marsh
Block Island	Waccamaw	Hughlett Point
Conscience Point	Cape Romain	Bethel Beach
Wertheim	ACE Basin	Savage Neck Dunes
Seatuck	Pelican Island	
Cape May	Crocodile Lake	**State Park/Preserve/ Sanctuary**
Prime Hook	Back Bay	Blue Crab Sanctuary
Chincoteague	Mackay Island	False Cape State Park
Wallops Island	Currituck	U-1105 Black Panther Historic Shipwreck Preserve

Table 3-12. MPAs in or adjacent to U.S. Pacific waters off California, Oregon, and Washington that are currently part of the national MPA system (NMPAC, 2009b and 2009c).

National Wildlife Refuges	**National Park System**	**Areas of Special Biological Significance**	**Areas of Special Biological Significance**	**State Marine Conservation Area**
Dungeness	Channel Islands NP	King Range	Irvine Coast	Año Nuevo
Protection Island	Point Reyes NS	Jughandle Cove	Southeast Santa Catalina Island	Greyhound Rock
Grays Harbor	**Underwater Park**	Saunders Reef	San Clemente Island	Soquel Canyon
Nisqually	Blake Island	Del Mar Landing	Northwest Santa Catalina Island	Portugese Ledge
Willapa	Deception Pass	Gerstle Cove	Farnsworth Bank	Elkhorn Slough
Lewis and Clark	**Special Management**	Farallon Island	Santa Barbara Island	Piedras Blancas
Nestucca Bay	San Juan Channel and Upright	James V. Fitzgerald	San Nicolas Island	Point Lobos
Siletz Bay	Haro Strait	Año Nuevo	Point Lobos	Edward F. Ricketts
Bandon Marsh	**State Marine Recreational**	Redwood National Park	Anacapa Island	Cambria
San Pablo Bay	Morro Bay	Bodega	Begg Rock	Carmel Bay A
Marin Islands	**State Marine Reserve**	Bird Rock	**State Marine Reserve**	Point Sur
Don Edwards San Francisco Bay	Natural Bridges	Point Reyes Headlands	Lovers Point	Big Creek
Sweetwater Marsh	Elkhorn Slough	Double Point	Carmel Pinnacles	White Rock (Cambria)
National Marine Sanctuary	Moro Cojo Slough	Duxbury Reef	Point Sur	Point Buchon
Olympic Coast	Piedras Blancas	Pacific Grove	Big Creek	**Aquatic Reserve**
Cordell Bank	Point Lobos	Julia Pfeiffer Burns	Morro Bay	Maury Island
Gulf of the Farallones	Asilomar	Salmon Creek Coast	Point Buchon	Fidalgo Bay
Monterey Bay	Vandenberg	Carmel Bay	Lovers Point	Cypress Island
Channel Islands	Natural Bridges	Laguna Point to Latigo Point		Cherry Point
Marine Preserve	**Wildlife Area**	Robert E. Badham	**Conservation Area**	**Seabird Sanctuary**
Shaw Island San Juan Islands	South Puget Sound	Santa Rosa Island	Orchard Rocks	Zella M. Schultz/Protection
Friday Harbor San Juan Islands		Santa Cruz Island	Sund Rock	
Argyle Lagoon San Juan Islands		Heisler Park	Brackett's Landing Shoreline Sanctuary	
False Bay San Juan Islands		Sand Diego-Scripps		
Yellow and Low Islands San Juan		La Jolla		
Admiralty Head		San Miguel Island		

Table 3-13. MPAs in or adjacent to U.S. Pacific waters of Hawaii that are currently part of the national MPA system (NMPAC, 2009b and 2009c).

National Park System	**National Wildlife Refuges**	**State Marine Life Conservation Districts**
Papahanaumokuakea Marine NM	Midway Atoll	Hanauma Bay
Fishery Management Areas	**State Reserves**	Molokini Shoal
West Hawaii Regional	Ahihi-Kinau Natural Area	Pupukea
National Marine Sanctuary	Kahoolawe Island	Kealakekua Bay
Hawaiian Islands Humpback Whale		

Table 3-14. MPAs in or adjacent to Pacific Ocean waters of U.S. territories that are currently part of the national MPA system (NMPAC, 2009b and 2009c).

National Wildlife Refuges	**National Wildlife Refuges (continued)**	**National Marine Sanctuary**
Guam	Johnston Island	Fagatelle (American Samoa)
Baker Island	Kingman Reef	
Howland Island	Palmyra Atoll	
Jarvis Island		
Rose Atoll		

MPAs contains all the mutually accepted MPAs that were nominated during the initial listing. Eligible MPAs can become part of the national system by applying to the NMPAC through their managing agency. Federal agencies that function in the marine or aquatic environment have a responsibility under EO 13158. Section 5 of EO 13158 stipulates, "…each Federal agency whose actions affect the natural or cultural resources that are protected by MPAs shall identify such actions. To the extent permitted by law and to the maximum extent practicable, each federal agency, in taking such actions, shall avoid harm to the natural and cultural resources that are protected by an MPA."

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

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

International Marine Protected Areas

Although there are several efforts to document international MPAs, no network or system of international MPAs currently exists. International MPAs encompass a very wide variety habitat types and types of

MPAs as well as a good degree of variability in the levels of protection and legal mandates associated with each MPA. It is, thus, even more difficult to compile an international list of MPAs than it is in the U.S. MPAs have been designated by nearly every coastal country of the world, and by current estimates, more than 5,000 MPAs exist globally (Figure 3-6) (Agardy et al., 2003; WDPA, 2009). International waters (i.e., the high seas) are contained within the boundaries of some MPAs such as the Pelagos Sanctuary for the Conservation of Marine Mammals in the Mediterranean (WDPA, 2009). A number of international MPAs have been established for the sole purpose of protecting cetaceans.

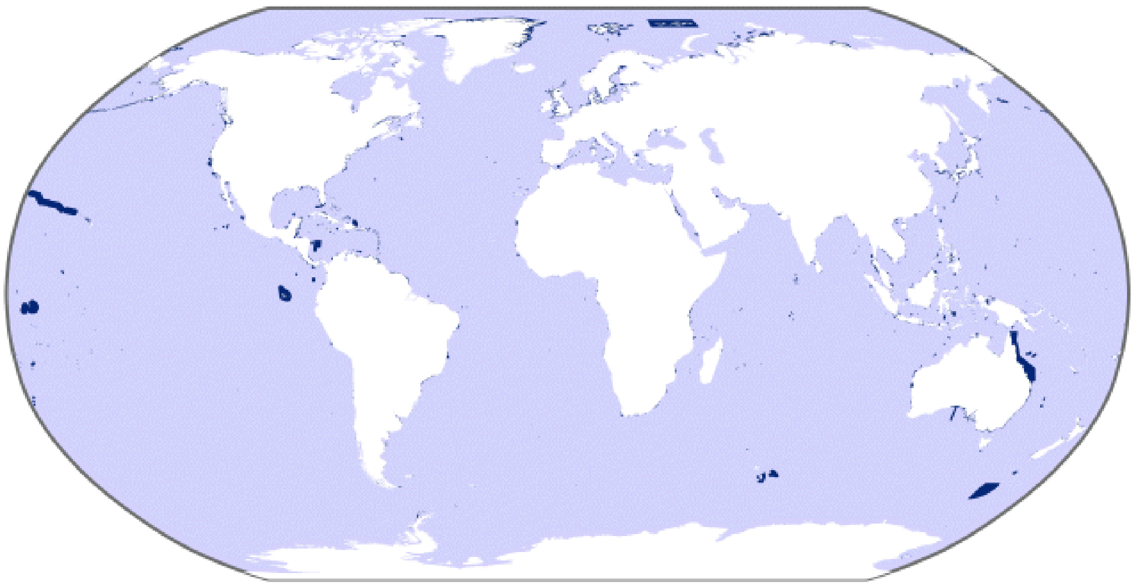

Figure 3-6. Locations (in dark blue) of international MPAs in all world oceans (Wood, 2007).

Although most international MPAs lie along the coast of the designating country, some international MPAs encompass large extents of ocean area and encompass international as well as territorial waters (Table 3-15). Many of the large oceanic MPAs are also listed as World Heritage Sites (UNESCO, 2009).

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

3.3 SOCIOECONOMICS

As SURTASS LFA sonar operates in open ocean areas it has the potential to interact with other activities taking place in these areas, including: commercial fishing, aboriginal subsistence whaling, oceanographic research, and recreational activities. The following section will outline activities that may take place concurrently with SURTASS LFA sonar operations. Many aquatic activities take place in near-shore or inland water areas where SURTASS LFA sonar is not currently authorized to operate. Additionally, SURTASS LFA sonar activities do not currently take place in other protected areas such as OBIAs.

Table 3-15. Examples of larger-scale international MPAs that are located within potential SURTASS LFA sonar operating areas (Project Planet Ocean, 2009; UNESCO, 2009; WDPA,2009).

NAME	DESIGNATING COUNTRY	LOCATION	OCEAN AREA
Pelagos Sanctuary for the Conservation of Marine Mammals in the Mediterranean	Italy, Monaco, Spain, and international waters	Mediterranean Sea roughly centered at 8.7796°N, 42.7124°E (Ligurian Sea)	87,492 km^2/ 8,749,200 hectares
Phoenix Island Protected Area	Republic of Kiribati	Pacific Ocean, roughly between Fiji and Hawaiian Islands, (just southeast of Howland Island)	41,500,000 hectares/415,000 km^2
Cocos Island National Park	Costa Rica	280 nmi off Pacific coast of Costa Rica	1,998 km^2/199,790 hectares
Malpelo Island Fauna and Flora Sanctuary	Columbia	~265 nmi off Pacific coast of Columbia; roughly centered at 3°51'07" S and 81°35'4"E	8,575 km^2
Galapagos Marine Reserve	Ecuador	The reserve extends 40 nautical miles out to sea from the islands' baseline; centered at ~0.137°S, 90.629°W	13,000 km^2
Great Barrier Reef Marine Part	Australia	Pacific Ocean; World Heritage Site	344,000 km^2
Heard and Macdonald Islands MPA	Australia	Indian Ocean; 51.663°S, 74.935°E	65,000 km^2
Southeast Commonwealth Marine Reserve Network	Australia	Indian Ocean; >12 nmi from shore but in Australia EEZ	226,458 km^2
Seaflower Marine Protected Area	Columbia	Atlantic Ocean; 13°30'0"N, 81°0'0"W; World Heritage Site	65,000 km^2
Marine Mammal Sanctuary of the Dominican Republic	Dominican Republic	Atlantic Ocean (Caribbean Sea); 19°56'9"N, 69°19'31"W	25,000 km^2

3.3.1 COMMERCIAL FISHERIES

The geographic sphere of SURTASS LFA sonar's acoustic influence overlaps the distribution of many fish species. Some pelagic and demersal fish species have the potential to be affected by SURTASS LFA sonar because some have demonstrated response to LF sound (Subchapter 3.2.2). If SURTASS LFA sonar has the potential to affect fish species, then it follows that this could potentially affect commercial fisheries that coincide with geographic areas in which SURTASS LFA sonar may operate. This section provides an overview of global marine fisheries production, employment, and trade for many of the major fishing countries that may be affected by SURTASS LFA sonar. As SURTASS LFA sonar is currently only authorized to operate further than 22 km (12 nmi) from coastal areas, only those fisheries that occur more than the standoff distance will be discussed.

3.3.1.1 Marine Fisheries Production

Marine fishing for commercial, recreational, industrial, or subsistence purposes occurs in almost all global waters with the most productive regions in coastal waters overlying the continental shelves. This is due to their higher primary productivity and the fact that the shallow ocean floor allows for the use of nets and traps. In contrast, in the deep areas of the open ocean where fish populations are less densely distributed, different methods are employed, such as longline and drift nets. Commercial fishermen work offshore waters for species such as sharks, swordfish, tuna, and whales, while recreational fishers seek ocean pelagic species such as billfish, dolphinfish, tunas, and wahoo.

Information on global marine fisheries production by geographic location is compiled annually by the Food and Agriculture Organization (FAO) of the United Nations (UN). Nominal catches, as expressed in metric tons (mt), represent the live-weight-equivalent of fish or other marine species obtained by capture or aquaculture as recorded at the time of landing. Catches are recorded at the location of the landing, providing the FAO with information on the species caught by the landing's country, continent, and FAO fishing zone. The FAO has collected fisheries data by country, detailing nominal catch, consumption rates, trade of fisheries goods, and the economic and ecological impacts of fishing. FAO's nominal catch data cover fish, crustaceans, mollusks, and miscellaneous aquatic animals caught for commercial, recreational, industrial, and subsistence purposes, as well as marine mammals and plants. In their global fisheries production totals, however, FAO does not include marine mammals and plants. Information on marine mammal catches is presented later in this subchapter.

<u>Global Fisheries</u>

The general composition of the majority of global marine fisheries catches in 2006 was marine fishes, crustaceans, and mollusks at a total 82.0 million mt of nominal landings (Table 3-16). Of the top 15 marine fishes landed globally, landings of the Peruvian anchovy are by far the largest, with over 7 million mt caught in 2006 (Table 3-17) (FAO, 2008). Other significant catch volumes include species of pollock, tuna, herring, whiting, mackerel, hairtail, sardine, squid, cod, and shrimp (FAO, 2008). In 2006, China, Peru, and the U.S. remained the top worldwide fisheries producing countries, with China remaining the larger producer (FAO, 2009).

<u>Regional Trends</u>

By ocean basin, the Pacific generates the highest landings of marine fishes in the world (Table 3-18; FAO, 2009). Overall, landings in the Pacific and Indian Oceans continued to increase while landing production in the Atlantic Ocean decreased (FAO, 2009). Global production from capture fisheries (as opposed to those farmed, i.e., aquaculture) has remained basically stable since 2000 when the total capture production was 86 million mt; FAO statistics for capture fisheries for 2006 were 81 million mt (Table 3-16) (FAO, 2008 and 2009). The Northwest Pacific marine fishing region was by far the greatest single contributor to global marine fisheries production, recording over 21 million mt of the global totals for 2006 (FAO, 2008). The Northwest Pacific includes the marine waters of China, Japan, and the Russian Federation and for decades has been the world's most productive fishing region (FAO, 2008). China is the leading fisheries producing nation in the world (Table 3-19).

The Southeast Pacific region marine fishery, including all Pacific waters of South America, also was a major contributor to global marine fisheries catches in 2006, providing landings of over 12 million mt (FAO, 2008). This area of the world's oceans has historically been the most dynamic fishing region, due to El Niño/Southern Oscillation events, and is dominated by small pelagic species. In 2006, the combined zones of the Pacific Ocean yielded the majority of all marine catches, with over 50 million mt, or 61% of the world's catches in marine waters (FAO, 2008).

Table 3-16. Landings (metric tons) for 2006 of global marine fisheries (FAO, 2008).

ISSCAAP[28] Division	Landings (MT)	Percent of World Landings
Freshwater fish	23,242	<0.1
Diadromous[29] fish	1,296,270	1.58
Marine fish	67,407,975	82.27
Crustaceans	5,682,169	6.94
Mollusks	7,162,595	8.74
Whales, seals, other aquatic mammals[30]	NA[31]	
Miscellaneous aquatic animals	358,387	0.44
Miscellaneous aquatic products	NA	
Aquatic plants[2]	NA	
Total	81,930,638	100

Table 3-17. Top 15 principal marine species landed globally in 2006 (FAO, 2008).

Species Name	Scientific Name	Landings (MT)
Anchovetta (Peruvian anchovy)	*Engraulis ringens*	7,007,157
Alaska pollock	*Theragra chalcogramma*	2,860,487
Skipjack tuna	*Katsuwonus pelamis*	2,480,812
Atlantic herring	*Clupea harengus*	2,244,595
Blue whiting (Poutassou)	*Micromesistius poutassou*	2,032,207
Chub mackerel	*Scomber japonicus*	2,030,795
Chilean jack mackerel	*Trachurus murphyi*	1,828,999
Japanese anchovy	*Engraulis japonicus*	1,656,906
Largehead hairtail	*Trichiurus lepturus*	1,587,786
Yellowfin tuna	*Thunnus albacares*	1,129,415
European pilchard (Sardine)	*Sardina pilchardus*	944,012
Jumbo flying squid	*Dosidicus gigas*	848,858
Atlantic cod	*Gadus morhua*	823,482
Akiami paste shrimp	*Acetes japonicus*	729,020
Argentine shortfin squid	*Illex argentines*	704,263

28 ISSCAAP = International Standard Statistical Classification of Aquatic Animals and Plants.
29 Diadromous fishes are those species that regularly migrate between freshwater and saltwater.
30 Data on aquatic mammals and plants are excluded from all national, regional, and global totals.
31 NA= not available or unobtainable

Table 3-18. Nominal worldwide landings for 2000 and 2006 by mass (metric tons) for marine fishing regions (FAO, 2008).

MARINE FISHING AREA	FAO AREA	2000 LANDINGS (MT)	2006 LANDINGS (MT)
Atlantic, Northwest	21	2,068,154	2,198,703
Atlantic, Northeast	27	11,018,183	9,077,072
Atlantic, Western Central	31	1,815,758	1,511,194
Atlantic, Eastern Central	34	3,662,464	3,270,319
Mediterranean and Black Sea	37	1,515,339	1,622,672
Atlantic, Southwest	41	2,295,118	2,368,172
Atlantic, Southeast	47	1,634,473	1,366,737
Atlantic, Antarctic	48	123,562	112,728
Indian Ocean, Western	51	3,968,396	4,470,336
Indian Ocean, Eastern	57	5,089,359	5,773,031
Indian Ocean, Antarctic	58	12,587	11,466
Pacific, Northwest	61	23,202,716	21,581,589
Pacific, Northeast	67	2,477,803	3,069,870
Pacific, Western Central	71	9,715,493	11,249,737
Pacific, Eastern Central	77	1,725,814	1,585,774
Pacific, Southwest	81	714,039	631,232
Pacific, Southeast	87	15,784,720	12,026,124
Pacific, Antarctic	88	870	3,882

Table 3-19. Top 10 worldwide fishing nations by mass landed (FAO, 2008).

COUNTRY	TOTAL 2000 LANDINGS (MT)	TOTAL 2006 LANDINGS (MT)
China	16,987,325	17,092,146
Peru	10,657,260	7,017,491
U.S.	4,717,638	4,859,872
Indonesia	4,082,810	4,759,080
Japan	4,985,894	4,186,980
Chile	4,300,474	4,168,461
India	3,666,427	3,855,467
Russian Federation	3,973,535	3,284,126
Thailand	2,997,124	2,776,295
Philippines	1,896,132	2,318,984

Trends of Top Fish Producing Countries

Brief descriptions (nominal catch, consumption rates, trade of fisheries goods, and the economic and ecological impacts of fishing) of the top worldwide fish producing nations are discussed below. It should be noted that the landing numbers presented in these sections include all capture fisheries, including those from inland and nearshore fisheries, waters in which SURTASS LFA sonar is not currently authorized to operate.

- **China**

China has led the world in landings of marine species since 1997 (Table 3-19) (FAO, 2007a and 2008). With a population of over 1.3 billion and a lengthy continental coastline of approximately 14,500 km, fish and other aquatic products are, and will remain, of nutritional and economic importance to the People's Republic of China (CIA, 2011). Chinese fishing operations take place in the northwestern Pacific Ocean, East China Sea, South China Sea, and Yellow Sea, as well as at distant-water fishing locations in the Pacific Ocean, Atlantic Ocean, and Indian Ocean. China also has a long history of near-shore, inland, and freshwater aquaculture.

Of the more than 3,000 species of marine life that are found along the China's coast, over 100 species are targeted for harvest. These include; finfish, crustaceans, cephalopods, shellfish, seaweed, and miscellaneous (including jellyfish). In 2006, the total aquatic output of China reached 51.5 million mt, with 17.1 million mt of this total coming from capture fisheries and 34.4 million mt from aquaculture (FAO, 2007a). Of the total output, more than 75% was intended for direct human consumption, with the remaining 13 million tons intended for animal feed and other purposes (FAO, 2007a).

In 2004, fish and other aquatics products represented 10.5% of the Chinese agricultural gross domestic product (GDP), which in turn represents 13.1% of the overall Chinese GDP. By 2011, agriculture represented only 9.6% of China's GDP (CIA, 2011). Total value of fishery and aquaculture products amounted to $45.9 billion in 2005. China is the leading world fish exporter, with $U.S.9 billion and $U.S. 9.3 billion in exports in 2006 and 2007, respectively (FAO, 2007 and 2008). Fishery-related employment in China peaked at 13.7 million people in 2001 (FAO, 2007a).

- **Peru**

Peru's fishery industry is important economically, not only in terms of the foreign currency and jobs that it generates, but also in terms of the volume produced, especially fishmeal and fish oil, and frozen, canned, and cured products for direct human consumption. Peru's fisheries traditionally are based on marine pelagic resources, mainly harvesting anchovy and other fish species such as jack and chub mackerels, but in recent years, landings of giant squid and dolphinfish (dorado) have increased. In 2006, Peru landed over 7 million mt of marine fish products (FAO, 2008). Anchovy catches amounted to 6.4 million mt in 2001, but in 2003 and subsequent years, anchovy landings decreased following an El Nino/Southern Oscillation event that occurred in 2002 through 2003 (FAO, 2007; IFFO, 2009). Aquaculture is also important, with 39,009 mt of fishery products have been cultured in 2008, with aquaculture exports in the same year being valued at $U.S. 94 million (FAO, 2010).

Peruvian fisheries are the second largest generator of foreign currency after mining, contributing $U.S. 619 million to the nation's 2005 GDP, although fisheries production and processing have only contributed ~1.4% to the GDP over the last 10 years (FAO, 2010). Peru's anchovy fishery generates 30 to 35% of the world's fish oil and fishmeal (IFFO, 2009). By recent estimates, fisheries in Peru directly or indirectly employ some 100,000 to 160,000 people (IFFO, 2009; FAO, 2010). In 2008, 8% of Peru's exports were from fisheries, with 75% of that export revenue coming from the export of anchovy-derived fishmeal and fish oil; total 2008 fishmeal and fish oil exports were 1.81 million mt, valued at $U.S. 2.01 billion (IFFO, 2009). In monetary value, the 2008 Peruvian fisheries exports were valued at $U.S. 2.4 billion while fishery imports were valued at $U.S. 73.7 million (FAO, 2010).

* **United States**

Fisheries are an essential aspect of life along the U.S.'s 19,924 km coastline (FAO, 2005). U.S. fisheries are pursued in coastal and U.S. EEZ waters as well as in inland waters (rivers and lakes) and non-U.S. waters. In 2006, the U.S. ranked third in total global marine fishery landings (Table 3-19), harvesting 4.86 million mt at a monetary value roughly equivalent to $4.1 billion in U.S. waters (NMFS, 2007d; FAO, 2008). In 2005, U.S. fishery catch (including aquaculture and capture) accounted for 3.7% of the world's total (NMFS, 2007d). The top U.S. fisheries in terms of revenue for 2006 were shrimp ($456 million), walleye pollock ($429 million), American lobster ($395 million), sea scallops ($385 million), and Pacific salmon ($312 million); these five species/species groups generated $2.0 billion in 2006, accounting for almost 50% of total landings revenue (NMFS, 2007d). Additionally, landings by U.S. fishermen in ports outside the 50 U.S. states/ports and from foreign processing permitted in U.S. waters provided 70 mt, valued at $61 million; most of these landings consisted of tuna and swordfish landed in American Samoa and other foreign ports (NMFS, 2007e). Aquaculture in the U.S. generated an additional 357,741 mt of fishery products for an estimated value of $1,092,386 in 2005 (NMFS, 2007e). In 2005, the U.S. fishing fleet supported 36,150 powered vessels (>5 tons) (FAO, 2005).

In 2006, the U.S. exported edible fishery products worth $4.2 billion for a total export value of $17.8 billion for all fishery products, while importing $13.4 billion of edible fishery products for a total of $27.7 billion of total fish products (NMFS, 2007e; FAO, 2008). Overall, the U.S. fishing industry generated over $103 billion in sales and $44.3 billion in income as well as supported over 1.5 million jobs in 2006 (NMFS, 2007d). U.S. commercial fisheries, including fisheries production and the marketing of fisheries products, contributed $35.1 billion to the U.S. gross national product (GNP) (NMFS, 2007d).

* **Indonesia**

In 2006, Indonesia landed about 4.8 million mt of edible fishery products, which was a slight increase from the 4.5 million mt landed in 2004 (FAO, 2006 and 2008). In 2004, 18.1% of marine fisheries landings came from North Java, with 6.4% in West Sumatra, 2.9% in South Java, 8.7% in Mallacca Strait, 12.2% in East Sumatra, 5.6% in Bali-Nusatenggara, 5.8% in South-West Kalimantan, 3.4% in East Kalimantan, 11.6% in South Sulawesi, 7.3% in North Sulawesi, and 18.0% in Maluku-Papua (FAO, 2006). Overall in 2004, tunas represented 16.6% of the landings while 5.5% of landings were shrimp, 70.3% were other fishes, and 7.6% were other aquatic organisms (FAO, 2006). Although marine fisheries showed an overall increase in production, the landings of tuna and shrimp remained stable.

The contribution of Indonesian fisheries to the 2004 GDP was 2.4%. The port that landed the most fishery production in 2005 was Tual (FAO, 2006). More than 549,100 powered fishing vessels were recorded in 2004 throughout Indonesia (FAO, 2006). Export fishery products from Indonesia reached $1.7 billion in 2004, with the main destination being China, Thailand, Japan, U.S., Singapore, and Republic of Korea. An important indicator of the value of Indonesian fisheries is employment. Fisheries and aquaculture provided nearly 6 million Indonesians with direct employment in 2005, with 3.3 million fishermen and 2.5 million fish farmers being employed (FAO, 2006). As of 2004, there were nearly 730,000 fishing vessels in Indonesia (FAO, 2006).

* **Japan**

Japan consists of numerous islands, with an extensive and complex coastline that is 29,751 km long (FAO, 2009a). Marine fisheries are the most important sector of Japan's fishing industry, which ranks fifth in the world with 2006 landings of 4.19 million mt (FAO, 2008). For statistical convenience, Japanese marine fisheries are divided into three categories: distant-water fisheries (operated mainly on the high seas, as well as under bilateral agreements in the EEZs of foreign countries); offshore fisheries (operated mainly in the domestic EEZ, as well as under bilateral agreements in the EEZs of neighboring countries); and coastal fisheries (operated mainly in waters adjacent to fishing villages). In 2006, the distant-water and offshore fisheries yielded 2.7 million mt in landings with a value of $U.S.5.8 billion while the coastal fisheries landed 1.3 million mt that was valued at $U.S.5.5 billion (FAO, 2009a). Aquaculture plays an important role in the seafood supply of Japan, producing 1.1 million mt in 2007, with a monetary value of $U.S.3.8 billion; seaweeds are the principal (42%) aquaculture product, followed by scallops and oysters (FAO, 2009a). Nearly 239,810 people were employed in the 2006 fisheries businesses in Japan, while that number fell to 204,330 individuals in 2007 (FAO, 2009a). Japan supports an extensive fishing fleet of 232,534 powered vessels (FAO, 2009a).

In 2006, 86% of Japan's domestic fish catch was destined for human consumption, and of that percentage, 16% was exported for a total of $U.S.1.7 billion (FAO, 2009a). Japan, however, remains one of the world's largest fishery product importers, second only to China both in volume and value, accounting for $U.S. 13.2 billion in 2007 (FAO, 2009a). China has been the largest fishery product exporter to Japan since 1998, although imports from China decreased, by value, in 2007 by 13% (FAO, 2009a).

- **Chile**

By 2006, Chile landed 4.2 million mt of fishery products, making it the sixth largest producer of fishery products in the world (FAO, 2008). In 2004, capture fisheries and aquaculture contributed 3.18% or $U.S.2.24 billion to Chile's GNP (FAO, 2004). The dominant marine species landed in Chilean fisheries are anchovy, mackerel, horse mackerel, and sardines.

Chile exported $U.S.2.5 million in fish products during 2004 (FAO, 2007a). Of that total, aquaculture exports accounted for $ U.S.1.6 million of the export value, corresponding to 390,740 mt of products, mainly salmon (92.3%), mussels (2.5%), algae (2.3%) and scallops (1.7%) (FAO, 2004). Almost all of the aquaculture production is exported, mainly to the United States, Japan, and the European Union. The aquaculture industry plays a large role in Chilean fisheries, with 688,000 mt being harvested in 2004. In 2004, the aquaculture industry generated 17,853 direct jobs plus another 20,000 indirect jobs (FAO, 2004).

- **India**

Fisheries play an important role in the national economy, providing direct or indirect employment to an estimated 14.7 million people and contributing 1.07% of the total 2004 GDP or $U.S.7.4 billion (FAO, 2004a). In 2003, the total Indian fisheries production for direct human consumption was 5.6 million mt with another 348,319 mt produced for non-food use; additionally, 5,029 mt of aquatic products were imported, while 461,989 mt were exported (FAO, 2004a). Fishery exports accounted for $ U.S.1.4 million in foreign exchange during 2004 (FAO, 2004a). India's fishing fleet consists of 55,000 traditional motorized craft, 1,250 mechanized boats, and about 100 deep-sea fishing vessels.

Marine fishery landings consist of as many as 65 important species or species groups, with pelagic and mid-water species contributing more than 50% to the total landings volume. About 81% of the fish catch is marketed as fresh or chilled and forms staple food along the coastal and inland landing centers. Aquaculture is becoming an important fishery producer in India, with 2.1 million mt of fishery products produced in 2004 (FAO, 2004a). Fish and shrimp are predominantly cultured in India.

- **Russian Federation**

With the second longest coastline in the world and access to three oceans and numerous seas along its borders, commercial fisheries are an important industry in Russia. In 2006, fisheries contributed $U.S.3.02 billion to the Russian Federation GDP (FAO, 2007b). The fishery sector has remained generally stable in absolute terms in recent years, so its share of the GDP has decreased as the economy in general has expanded. Despite this large contribution nationally, Russian fisheries are currently unable to meet domestic demand for fish and seafood products due to the decreasing catch and the growing export to the East Asia markets (which remain much more attractive for the fishing enterprises than delivery to the domestic market). The fishery industry provides employment to 145,000 to 150,000 people (FAO, 2007b).The majority of Russia's fishery landings come from within its marine waters with landings from foreign waters or the high seas contributing less than 25% to the total landings, which were 3.8 million mt in 2006 (FAO, 2008). Aquaculture provides little to overall fishery production, contributing just 3.6% in 2005 to total fishery landings (FAO, 2007b).

In 2004 to 2005, landing from the northeast Atlantic (including the Barents Sea) region of the Russian Federation supplied 40% of the total national catch, while the northwest Pacific (mainly the seas of the Russian Far East including the Sea of Okhotsk, Sea of Japan, and Bering Sea) contributed 56% of the overall catch (FAO, 2007b). Most of the catch consisted of Alaska pollock (44%), herring (13%), cod (10%), and Pacific salmon (9%). The Russian fishing fleet consisted of 2,500 fishing vessels, 46 floating factories, and 366 transport vessels in 2002 with 5,500 motorized boats in the inland fishery (FAO, 2007b).

- **Thailand**

Marine fisheries have a significant socio-economic role in Thailand, with fisheries contributing $U.S.3.1 billion or 1.2% to the GDP (FAO, 2009b). Landings in 2006 were about 3 million mt, increasing to 3.5 million mt in 2007, with more than 58% of the landings resulting from marine fisheries with the remainder from aquaculture and inland fisheries (FAO, 2009b). Only about 60% of the marine landings came from Thai waters with the remaining 40% harvested from waters outside Thailand's EEZ. As much as 68% of the marine fish landings come from the east coast of Thailand while 32% are harvested from the west coast of peninsular Thailand.

In 2000, the marine fishery in Thailand consisted of 58,119 motorized vessels with many more traditional vessels also used for smaller scale enterprises. Overall, as many as 2 million people are employed in Thai fisheries-related industries, including aquaculture (FAO, 2009b). In 2008, $U.S.6 billion of fishery products were exported by Thailand, while $U.S.2.4 billion were imported.

Aquaculture has been historically important in Thailand, with both coastal and freshwater aquaculture industries now thriving. Total aquaculture production in 2007 was nearly 1.3 million mt, valued at $U.S.2.4 billion; coastal aquaculture accounted for 64% of the total production volume and 71% of the value (FAO, 2009b). Shrimp are the principal species cultured by coastal aquaculture with fishes such as tilapia and catfish cultured by freshwater aquaculture facilities.

- **Philippines**

In 2003, the reported marine fisheries production of the Philippines was 2.2 million mt and had risen to 2.3 million mt by 2006 (FAO, 2003 and 2008). The 2003 production was valued at $U.S.1.8 billion, accounting for 2.2% of the GDP. More than 2 million people were employed by fishery-related businesses in 2002, with more than 800,000 motorized boats and rafts employed in the municipal[32] fishing sector alone (FAO, 2003). The catch from municipal fisheries in 2003 constituted 54.5% small pelagics, 22.9% tunas, 7.4% demersal fishes, and 15.2% invertebrates, while the commercial fisheries catch in 2003 was comprised of small pelagics (59.6 %), tunas (36.2%), and demersal fishes (4.2%). Municipal fishermen in the Philippines commonly use fish aggregating devices called payao, or bamboo rafts, which are located some distance from shore and from which the fishermen moor their boats and fish with handlines (FAO, 2003).

Aquaculture production includes both marine and freshwater cultivation. In 2003, aquaculture produced 17.7% of the total fish production of the Philippines, with the principal cultured products including seaweed (988,889 mt), milkfish (202,973 mt), tilapia (109,373 mt), and jumbo tiger shrimp (34,997 mt)

[32] Coastal fisheries that operate within 15 km (8 nmi) of the coast and use small motorized and non-motorized, traditional boats called bancas. Commercial fisheries operate beyond 15 km from shore and use large, motorized vessels to fish.

(FAO, 2003). The Philippines is the world's largest producer of carageenophyte (*Kappaphycus* spp. and *Eucheuma* spp.) seaweed.

The Philippines is an exporter as well as importer of fish and fishery products. Total exports of fish and fishery products amounted to 202,016 mt with a value over $U.S.525.4 million in 2003. The exported products consisted mainly of fresh and processed fish, crustaceans, mollusks, shrimp, and seaweed. For the past several years, the Philippines have been importing large quantities of pelagic fishes, such as tuna, and fishmeal; the 2003 value of the fishery-related products amounted to $U.S.80.4 million (FAO, 2003).

3.3.1.2 Fisheries Trade

Fisheries and aquaculture play, either directly or indirectly, an essential role in the livelihoods of millions of people around the world. In 2006, 43.5 million people were directly engaged, part time or full time, in primary production of fish, either by fishing or in aquaculture (FAO, 2007a). In the last three decades, employment in the primary fisheries sector has grown faster than the world's population and employment in traditional agriculture. Eighty-six percent of the fishers and fish farmers worldwide are located in Asia, with China having the most (8.1 million fishers and 4.5 million fish farmers) (FAO, 2007a). Fishery employment in China experienced strong increases in the 1980s and 1990s, to peak at 13.7 million people in 2001 but declining by 8% in the period 2001 to 2006 (FAO, 2007a). In 2006, other countries with a significant number of fishers and fish farmers were India, Indonesia, the Philippines, and Viet Nam. Most fishers are small-scale, artisanal, operating on coastal and inland fishery resources (FAO, 2007a).

While the number of people employed in fisheries and aquaculture has been growing steadily in most low-income and middle-income countries of the world, employment in the sector has fallen or remained stationary in most industrialized economies. In Japan and Norway, the numbers of fishermen have more than halved since 1970, down 61% and 42%, respectively (FAO, 2007a). In many industrialized countries, the decline has occurred mainly in capture fisheries, while the number of working in aquaculture has increased. In 2006, the estimated number of fishers in industrialized countries was about 860,000, representing a decline of 24% compared with 1990 (FAO, 2007a).

In addition to its contribution to economic activity, employment, and in generating foreign exchange, trade in fish and fishery products plays an important role in improving food security and contributes to meeting nutrition needs. Fish and fishery products are highly traded, with more than 37% (live weight equivalent) of total production being traded internationally. In 2006, 194 countries reported exports of fish and fishery products with world exports of fish and fishery products reached $85.9 billion; this represented an increase of 62.7% from 1996 (FAO, 2007a and 2008).

Since 2002, China has been the world's largest exporter of fish and fishery products and has further consolidated its leading position over the last few years (Table 3-20). In 2006, China's exports reached $U.S.9.0 billion and grew further to $9.3 billion in 2007 (FAO, 2008). China's fishery exports have increased remarkably since the early 1990s. This increase is linked to its growing fishery production, as well as the expansion of its fish-processing industry, reflecting competitive labor and production costs. Despite this growth, fishery exports represented only 1% of China's total merchandise exports in 2006 and 2007 (FAO, 2007a). In addition to exports from domestic fisheries production, China also exports reprocessed imported raw material, adding considerable value in the process.

China has also experienced a significant increase in its fishery imports over the past decade. In 2006, it was the sixth-largest importer, spending $U.S.4.1 billion, with imports reaching $4.5 billion in 2007 (FAO, 2007a). This growth has been particularly noticeable since the country's accession to the World Trade Organization (WTO) in late 2001, as a consequence of which it lowered import duties, including those on fish and fishery products. The growth in imports is partly a result of the above-mentioned imports by China's processors of raw material for reprocessing and export. However, it also reflects China's growing domestic consumption of species, mainly of high value, that are not available from local sources.

Table 3-20. Top 10 exporters and importers of fish and fishery products (FAO 2007a and 2008).

EXPORTERS	1996	2006	APR[33] (%)
	(U.S. $ MILLIONS)		
China	2,857	8,968	12.1
Norway	3,416	5,503	4.9
Thailand	4,118	5,236	2.4
U.S.	3,148	4,143	2.8
Denmark	2,699	3,987	4.0
Canada	2,291	3,660	4.8
Chile	1,698	3,557	7.7
Viet Nam	504	3,358	20.9
Spain	1,447	2,849	7.0
Netherlands	1,470	2,812	6.7
Top 10 Subtotal	23,648	44,073	6.4
Total for Remainder of World	29,139	41,818	3.7
World Total	52,787	85,891	5.0
IMPORTERS			
Japan	17,024	13,971	2.0
U.S.	7,080	13,271	6.5
Spain	3,135	6,359	7.3
France	3,194	5,069	4.7
Italy	2,591	4,717	6.2
China	1,184	4,126	13.3
Germany	2,543	3,739	3.9
United Kingdom	2,065	3,714	6.0
Denmark	1,619	2,838	5.8
Republic of Korea	1,054	2,729	10.0
Top 10 Subtotal	41,489	60,533	3.8
Total for Remainder of World	11,297	25,357	8.4
World Total	52,786	85,890	5.0

In addition to China, other developing countries play a major role in the fishery industry. In 2006, 79% of world fishery production took place in developing countries, with exports of fishery products representing 49% ($42.5 billion) and 59% (31.6 million mt) of world exports (FAO, 2007a). An important share of their exports consisted of fishmeal (35% by quantity but only 5% by value). In 2006, developing countries contributed 70% of the world's non-food fishery exports, by quantity, and significantly increased their share of the quantity of fish exports destined for human consumption, from 43% in 1996 to 53% in 2006 (FAO, 2007a).

[33] APR refers to the average annual percentage growth rate for 1996 to 2006.

3.3.1.3 Marine Mammals

As previously noted, information on nominal catches of marine mammals is not included in total fisheries catch data; however, FAO does compile data on marine mammal catches as reported by each country. Unlike the fisheries data, catch volume reflects the number of the individual species caught, not the total weight in metric tons.

Whale captures are guided by measures set forth by the International Whaling Commission (IWC) who also designate whale sanctuaries, set limits on the numbers and sizes of whales that may be captured, and provide open and closed seasons and areas for whaling. The IWC was established under the International Convention for the Regulation of Whaling signed in 1946 and membership in the IWC is open to any country that adheres to the 1946 Convention.

In 1982 the IWC implemented a "pause" or moratorium in commercial whaling, which took effect during the 1985 to 1986 whaling season and is still in effect today. Aboriginal subsistence whaling and collections for scientific research conducted by member nations are still permitted.

Subsistence Whaling

Since its inception, the IWC has recognized that aboriginal subsistence whaling is of a different nature to commercial whaling. This is reflected in the different objectives for the two types of whaling. For aboriginal subsistence whaling the IWC objectives are to:

- Ensure risks of extinction are not seriously increased (highest priority);
- Enable harvests in perpetuity appropriate to cultural and nutritional requirements; and
- Maintain stocks at highest net recruitment level, and if below, ensure they move towards it.

Under current IWC regulations, aboriginal subsistence whaling is permitted for Denmark (for Greenland with takes of fin and minke whales), the Russian Federation (for Siberia with takes of gray and bowhead whales), St Vincent and The Grenadines (for Bequia with takes of humpback whales), and the U.S. (for Alaska with takes of bowhead whales and for Oregon with takes of gray whales) (Table 3-21). It is the responsibility of national governments to provide the Commission with evidence of the cultural and subsistence needs of their people. The Scientific Committee provides scientific advice on safe catch limits for such stocks.

With the completion of the Revised Management Procedure for commercial whaling, the Commission asked the Scientific Committee to begin the process of developing a new procedure for the management of aboriginal subsistence whaling—the Aboriginal Whaling Management Procedure. This is an iterative and ongoing effort. The Commission will ultimately establish an Aboriginal Whaling Scheme that comprises the scientific and logistical (e.g., inspection/observation) aspects of the management of all aboriginal fisheries. Within this framework the scientific component might comprise some general aspects common to all fisheries and an overall AWMP within which there will be common components and case-specific components (IWC, 2009a).

As of January 2009, the AWMP was still in development. Until the AWMP is completed, the Committee provides advice on a more ad hoc basis, carrying out major reviews according to the needs of the Commission in terms of establishing catch limits and the availability of data. It also carries out brief annual reviews of each stock (IWC, 2009b).

3.3.2 OTHER RECREATIONAL ACTIVITIES

In addition to fishing, other recreational activities in marine waters include boating, surfing, water skiing, swimming, diving, and whale watching. Many of these activities would not be affected by SURTASS LFA sonar transmissions because they are conducted above the water's surface and/or do not involve the use or creation of underwater sound. Also, many of these activities occur mostly in coastal waters, away from where SURTASS LFA sonar would operate. An exception may be whale watching where there may be a

Table 3-21. Aboriginal subsistence hunting as reported by the IWC (IWC, 2009b and 2009c).

Subsistence Nation	Ocean Area[34]	Harvested Marine Mammal Species						
		Fin	Humpback	Sei	Gray	Minke	Bowhead	Total
2003								
Denmark: W. Greenland	NA	9	1	0	0	185	0	195
Denmark: E. Greenland	NA	0	0	0	0	14	0	14
St. Vincent and The Grenadines	NA	0	1	0	0	0	0	1
Russia	NP	0	0	0	128	0	3	131
U.S.	NP	0	0	0	0	0	48	48
Total		9	2	0	128	199	51	389
2004								
Denmark: W. Greenland	NA	13	1	0	0	179	0	193
Denmark: E. Greenland	NA	0	0	0	0	11	0	11
St. Vincent and The Grenadines	NA	0	0	0	0	0	0	0
Russia	NP	0	0	0	111	0	1	112
U.S.	NP	0	0	0	0	0	43	43
Total		13	1	0	111	190	44	359
2005								
Denmark: W. Greenland	NA	13	0	0	0	176	0	189
Denmark: E. Greenland	NA	0	0	0	0	4	0	4
St. Vincent and The Grenadines	NA	0	1	0	0	0	0	1
Russia	NP	0	0	0	124	0	2	126
U.S.	NP	0	0	0	0	0	68	68
Total		13	1	0	124	180	70	388
2006								
Denmark: W. Greenland	NA	10	1	1	0	181	0	193
Denmark: E. Greenland	NA	1	0	0	0	3	0	4
St. Vincent and The Grenadines	NA	0	1	0	0	0	0	1
Russia	NP	0	0	0	134	0	3	137
U.S.	NP	0	0	0	0	0	39	39
Total		11	2	1	134	184	42	374
2007								
Denmark: W. Greenland	NA	12	0	0	0	167	0	179
Denmark: E. Greenland	NA	0	0	0	0	2	0	2
St. Vincent and The Grenadines	NA	0	1	0	0	0	0	1
Russia	NP	0	0	0	131	0	0	131
U.S.: Alaska	NP	0	0	0	0	0	63	63
U.S.: Washington (Makah Tribe)	NP	0	0	0	1	0	0	1
Total		12	1	0	132	169	63	377

34 NA= North Atlantic Ocean, NP=North Pacific Ocean

possibility that whale behavior would be affected but only if sonar operations were being conducted nearby. Only those activities that could be affected, albeit remotely, by SURTASS LFA sonar are further addressed in this subchapter.

3.3.2.1 Swimming and Snorkeling

Recreational swimming and snorkeling occur in marine waters worldwide. Most swimming sites are located immediately adjacent to the coastline and well within 5.6 km (3 nmi) of the coast. Most swimming activity occurs at the air/water interface, (i.e., immediately adjacent to the ocean's surface). For snorkeling activity, the swimming area nominally extends from the surface to depths not greater than 2 m (6.5 ft); deeper depths than this are unlikely for the average recreational swimmer. Other than for very short periods of time, people usually do not go below 2 m (6.5 ft).

3.3.2.2 Recreational Diving

Recreational diving sites are generally located between the shoreline and the 40 m (130 ft) depth contour, but can occur outside this boundary. Global diving statistics indicate a substantial growth in activity as measured by the number of divers that were certified during that time. The Professional Association of Diving Instructors (PADI), the world's largest dive training organization, issued 932,486 diving certifications in 2008 (PADI, 2008a). In fact, between 1967 and 2008, PADI issued a cumulative total of 17,532,116 diving certifications (PADI, 2008a).

It is estimated that over 1.2 million dive trips are taken to warm-water destinations each year (Simmonds, 1997), including the Caribbean, Gulf of Mexico, Pacific Ocean, Mediterranean Sea, and Indian Ocean, as well as other locations (Table 3-22). Surveys of the demographics of diving students and instructors conducted by PADI show that between 2002 and 2008 most divers were males approximately 30 years old (PADI, 2008b).

3.3.2.3 Whale Watching

Whale watching[35] worldwide has expanded rapidly over the last decade and is now considered a major component of global ecotourism, with an overall annual growth rate of 3.7%. However, regions such as Asia, Central America/Caribbean, and South America have experienced even higher growth rates in whale watching, with annual growth of 17%, 13%, and 10%, respectively (O'Connor et al, 2009). An estimated 13 million people participate in whale-watching excursions in 119 countries and territories, generating total revenue of $U.S.2.1 billion (O'Connor et al., 2009). Whale watching has become an industry of more than 3,300 whale watching trip operators that employ 13,200 people (O'Connor et al., 2009). North America (Canada and the U.S.) is the world's largest whale watching destination, with over 6 million whale watchers in 2008; despite record numbers of whale watchers, the North American whale watch industry is mature with one of the lowest annual growth rates. Australia is the only other country that takes more than 1 million people whale watching each year (O'Connor et al., 2009).

Due to the seasonal occurrence of cetaceans in many worldwide regions due to migrational movements, by association, whale watching is often a seasonal enterprise. Although whale watching is nearly always done from boats, some operators offer whale watching excursions in airplanes and helicopters. Most whale-watching activities focus on humpback, gray, northern and southern right, fin, blue, minke, sperm, short-finned pilot, and killer whales, as well as bottlenose dolphins (Hoyt, 2001).

The IWC and other organizations concerned with the preservation of cetaceans worldwide support whale watching as a sustainable use of cetacean resources (Spalding, 1998; IWC, 2004). In 1996, the IWC first adopted the following general principles for managing the then emerging whale watching industry to help minimize adverse effects on whale populations:

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[35] Whale watching refers to the viewing of all wild cetaceans, including whales, dolphins, and porpoises

Table 3-22. Worldwide major recreational diving locations (Scuba Travel LTD, 2009).

Diving Location—Greater Atlantic Ocean	Diving Location—Greater Pacific Ocean
Bay of Pigs, Cuba	Aliwal Shoal, South Africa
Cenotes, Playa Del Carmen, Mexico	Protea Banks, South Africa
Palancanar Bricks, Cozumel, Mexico	Sodwana Bay, South Africa
Cozumel, Mexico	Malpelo Island, Colombia
Santa Rosa Wall, Cozumel, Mexico	Manta Ray Night Dive, Kailua Kona, Hawaii, U.S.
Dos Ojos (Los Cenotes), Playa del Carmen, Mexico	Holmes Reef, Coral Sea, Australia
Dirty rock, Cocos Island, Costa Rica	Yongala, Australia
Pedras Secas, Noronha, Brazil	Perpendicular wall, Christmas Island, Australia
Great Blue Hole, Belize	Pixie pinnacle and pixie wall, GBR, Australia
Half Moon Wall, Belize	Navy Pier, Western Australia
Los Testigos Islands, Venezuela	Osprey Reef, Coral Sea, Australia
Sugar Wreck, Grand Bahama Island, Bahamas	Cod Hole, Northern Great Barrier Reef, Australia
Wreck of the Bahama Mama, New Providence, Bahamas	Fish Rock, Off South West Rocks in NSW, Australia
Bloody Bay wall, Little Cayman, Cayman Islands	Canibal Rock, Komodo, Indonesia
Stingray City, Grand Cayman, Cayman Islands	Castle Rock - Komodo National Park, Indonesia
Shark Alley, Grand Cayman, Cayman Islands	Gili Air, Indonesia
Diamond Rocks, Kilkee, Ireland	Lombok Strait, Indonesia
The Canyons, Utila, Honduras	Liberty, Bali, Indonesia
Blockship Tabarka, Scapa Flow, Orkney, United Kingdom	Lekuan 1, Bunaken National Park, N. Sulewesi, Indonesia
Booroo, Isle of Man, United Kingdom	Blue Corner Wall, Palau, Micronesia
Eddystone Reef, United Kingdom	Ulong Channel, Palau, Micronesia
Toucari Caves, Dominica	Peleliu Express, Palau, Micronesia
Diving Location—Indian Ocean	Tiputa pass, Rangiroa, New Zealand
Office, Mozambique	Rainbow Warrier, New Zealand
Great Basses reef, Sri Lanka	Poor Knights, New Zealand
Mafia Island, Tanzania	President Coolidge, Vanuatu
Mnemba Island, Tanzania	Puerto Galera, Philippines
Manta reef, Mozambique	Tubbataha, Palawan, Philippines
Marbini Padre, Malaysia	Wakaya Passage,Fiji
Barra Reef, Mozambique	Shark Fin Point, Fiji
East Timor	Fish Factory, Vuna Reef, Taveuni, Fiji
Diving Location—Greater Mediterranean Sea	Fujikawa Maru, Truk Lagoon (Chuuk Lagoon)
Big Brother, Egyptian Red Sea	Rangali Madivaru, Maldives
Blue Hole, Dahab, Egyptian Red Sea	The Express, Kuredu, Maldives
Daedelus, Egyptian Red Sea	The Point, Layang - Layang
Elphinstone Reef, Egyptian Red Sea	Garuae Pass, Fakarava Island, French Polynesia
Cirkewwa, Malta	Tiputa Pass, Rangiroa, Polynesia
Blue Hole,Gozo, Malta	Barracuda Point, Sipadan Island, Malaysia
Ras Mohammed, Egyptian Red Sea	Turtle Tavern, Sipadan, Malaysia

Table 3-22. Worldwide major recreational diving locations (Scuba Travel LTD, 2009).

DIVING LOCATION—GREATER MEDITERRANEAN SEA	DIVING LOCATION—GREATER PACIFIC OCEAN
Ghiannis D, Egypt	Hanging Garden, Sipadan, Malaysia
Jackson Reef, Egypt	South Point, Sipadan, Malaysia
Little Brother, Egyptian Red Sea	Sipadan Drop Off, Malaysia
Shark and Yolanda Reef, Egyptian Red Sea	Similans, Thailand
Chios island, Greece	Hin Muang, Thailand
St Johns, Egypt	Japanese Gardens, Koh Tao, Thailand
Straits of Tiran, Egyptian Red Sea	Richelieu Rock, Thailand
The Zenobia, Cyprus	Grand Central Station, Gizo, Solomon Islands
Thistlegorm, Egyptian Red Sea	Darwin Island and Arch, Galapagos
Umbria, Sudan	Gordon's Rock, Galapagos
Sha'ab Rumi South, Sudan	Wolf Island, Galapogos
	Joel’s, Papua New Guinea
	Cortes Bank, California, U.S.
	Tanner Bank, California, U.S.

- Manage the development of whale watching to minimize the risk of adverse impacts;
- Design, maintain, and operate platforms to minimize the risk of adverse effects on cetaceans including disturbance from noise; and
- Allow the cetaceans to control the nature and duration of “interactions” (IWC, 2004).

There are; however, costs to whale watching. In addition to the possible pollution from to the use of boats and trash thrown into the water by whale watchers, there are also the unknown potential effects on cetacean behavior and health as well as and the risk of harassment and harm to the very cetaceans that are being viewed. Ship strikes, for instance, are a risk associated with whale watching. Of the 134 ship strike accounts where the type of vessel is known 19 ship strike reports were by whale-watching vessels (Jensen and Silber, 2004).

3.3.3 RESEARCH AND EXPLORATION ACTIVITIES

This section summarizes the various research and exploration activities occurring or expected to occur in the ocean, with a focus on those activities that generate or make use of acoustic signals in conducting their operations. These acoustics signals could be hampered by SURTASS LFA sonar transmissions, or they could interfere with SURTASS LFA sonar operations. These could occur because of the signals/transmissions interfering with each other through masking, production of anomalous data, or raising overall ambient noise levels. Included are activities undertaken by private companies for commercial purposes as well as those by government agencies and their contractors. The discussion is restricted to activities that are conducted undersea. Surface activities such as maritime transportation, surface research, and fishing are excluded from consideration.

3.3.3.1 Oceanographic Research

Acoustic and seismic research has contributed more to understanding Earth’s physical history, natural hazard potential, and climate systems than perhaps all other scientific technology combined. Sound travels freely through the oceans and can be used to measure topography and to map geology, ocean temperatures, and currents. Marine acoustic surveys are fundamental tools guiding explorations of this planet. Numerous scientific research vessels from around the world are engaged in studying all of the

Earth's oceans and the underlying seafloor. The data that are being collected are critical to informed decision making regarding our future (LDEO, 2004). Researchers use ship-mounted equipment and unmanned and manned submersible vehicles. For example, several U.S. institutions, including the Woods Hole Oceanographic Institution; Scripps Institution of Oceanography at the University of California, San Diego; Lamont-Doherty Earth Observatory at Columbia University; and several science centers operated by NMFS, conduct research each year over the world's oceans.

Remotely Operated Vehicles (ROVs)

Remotely operated vehicles are unmanned underwater robots that are controlled by a pilot, via a tether that is spooled out from a support vessel (i.e., either a ship or another underwater vehicle). NOAA owns or leases ROVs such as the Kraken, Phantom, Hela, Jason/Medea, and Spectrum II, which are fitted with camera, lighting, and sampling systems that allow scientists to be virtually transported, through real-time video transmission, to depths beyond 21,385 feet. ROVs are commonly used in situations when scuba diving is not feasible due to depth and time limitations or when expensive manned submersibles are not cost effective. The advantages of ROVs include greatly extended bottom times, reduced human risk, reduced operating costs, and the ability to deploy in harsher environments. ROVs have been used to conduct research in a wide range of environments—from the tropics to the poles.

The NOAA Office of Ocean Exploration and Research has ordered a deep-ocean ROV for use on the Okeanos Explorer. Built by Phoenix International and a sister-vehicle to a new U.S. Navy ROV, this vehicle will dive up to a 19,685 foot depth and use high definition video cameras to provide exceptional new data from the ocean floor. The ROV will be part of a "two-body" system with a camera sled operating just above the ROV. This will provide additional sensors and lighting and a valuable overhead view for scientists. The system will also include an "X-bot," a very small ROV able to access confined or hazardous areas such as submarine caves (NOAA, 2009a)

ROVs are also controlled using transponders, and a typical research effort involves placement of multiple transponder units on the ocean floor. Transponders send and receive HF FM signals to and from the research vehicle and the controlling ship on the surface. Signals establish location and control movement of the vessel and support its data-gathering activities.

With over 900 work class vehicles built to date and over 500 in commercial operation ROVs have become an important tool, without which development of offshore oil and gas would have been severely restricted (PRLog, 2006). The World AUV and ROV Report (PRLog, 2006) values the 2004 world market for ROV operations at $600 million and forecasts that after some years of difficulties, the long-term growth trend will resume and is predicted to reach $750 million in 2008. The five-year forecast shows Western Europe, North America, and Africa to be the most significant regions (PRLog, 2006). Support of offshore oil and gas drilling operations and construction support are shown as the largest sectors, together with submarine cable maintenance—but this activity is mostly not open to competitive tendering.

Autonomous Undersea Vehicles (AUVs)

Autonomous undersea vehicles (AUVs) are the most recent class of undersea research technology and can be described as a rapidly evolving class of un-tethered and unmanned submersibles. As the name suggests, AUVs can be preprogrammed to conduct various measurements, video surveillance, etc. Since they are independent of the surface, they are typically battery powered and controlled by computers using various levels of artificial intelligence. As platforms for scientific sensors, these vehicles operate at depths, over distances and with endurances that cannot be achieved with the same economies using human-guided devices. To date, most scientific AUVs have executed wide-area seafloor surveys and habitat characterization missions.

NOAA operates a number of AUVs for these purposes and, through its Undersea Research Program, offers the use of two state-of-the-art vehicles to undersea researchers: a high-endurance Slocum-class underwater glider capable of diving to depths of 656 feet from Webb Research, and a new large-frame, deepwater Explorer-class vehicle capable of diving to 7217 feet from International Submarine Engineering. The latter vehicle began operations in 2006 (NOAA, 2009b).

The Autonomous Undersea Systems Institute (AUSI) is an independent research institute that coordinates research for AUVs and related systems. Research programs include intelligent AUV control, architectural issues, long-range AUV development, and problem solving. AUSI hosts the International Symposium on Unmanned Untethered Submersible Technology at the University of New Hampshire.

The Autonomous Undersea Vehicle Applications Center (AUVAC) brings together academic, private sector, and government organizations in support of AUVs, in order to advance AUV system technology, promote AUV interoperability, and increase AUV availability in support of national ocean community needs. AUVAC recently published a website to encourage collaboration within the AUV community, from the point of view of both users and research and technology developers. This website documents current and emerging AUV technologies and makes this information available to prospective users (AUVAC, 2009).

Manned Submersible Vehicles

Manned submersible vehicles are also used in ocean research. These vehicles communicate with their deployment ship using radios. Through the use of human occupied submersibles, scientists can be physically transported to great depths of the oceans, far beyond the physiological restrictions of wet diving on the human body.

Submersibles owned by NOAA include the Pisces IV and V, two of only nine submersibles in the world that can dive to depths of more than 6,562 feet. Both carry a pilot and two scientists. The submersibles are custom equipped to accommodate a variety of mission requirements. Standard gear includes external video and still cameras, two hydraulic manipulator arms, a conductivity/temperature/depth profiler and sonar. Their use has provided unprecedented knowledge of the Pacific’s undersea volcanic processes and deep sea coral habitats. Through partnerships, NOAA can also lease other submarines, including the Johnson Sea Link, Delta, and Alvin (NOAA, 2009c)

Seismic Surveys

Seismic surveys are conducted using air gun arrays, multi-beam bathymetric sonars, and sub-bottom profilers. The air guns are towed behind the source vessel and emit a seismic pulse which is then picked up by a hydrophone and map out the earth’s crust. The multi-beam sonar images the seafloor using short pulses at high frequency. The sub-bottom profiler maps the bottom topography while supplying information on sedimentary features (LGL, 2003).

Ocean Acoustic Tomography

Ocean acoustic tomography is a research effort initiated by Scripps, the Massachusetts Institute of Technology (MIT), and others to determine the effectiveness of LF sound transmissions to map features of ocean circulation. LF sound slows down or speeds up as it travels across boundaries of different temperatures, pressures, or salinities. Although travel times must be measured to a nominal accuracy of 1 millisecond, tomographic transmissions consist of long coded signals lasting 30 seconds or more. These transmissions are audible near the source, but over most of the ocean they are below ambient noise levels, requiring sophisticated spread-spectrum signal processing techniques to recover them (WHOI, 2008). The ATOC project, an international research effort utilizing LF sound to observe temperature change in the oceans, has been completed in California and Hawaii. Under a program that concluded in 2007, Scripps reused the sound source in Hawaii for its North Pacific Acoustic Laboratory (NPAL). NPAL's objectives combined:

- A second phase of research on the feasibility and value of large-scale acoustic thermometry;
- Long-range underwater sound transmission studies; and
- Marine mammal monitoring and studies.

The Kauai acoustic source began transmitting in late 1997, continuing through fall 1999. After a hiatus of 2 years while marine mammal permitting issues were sorted out, the Kauai acoustic source resumed transmissions in January 2002, continuing to transmit for another 5 years at regular 4-day intervals (NPAL, 2009).

University-National Oceanographic Laboratory System (UNOLS)

The University-National Oceanographic Laboratory System (UNOLS) is a consortium of 61 academic institutions involved in federally-funded oceanographic research. Seventeen of these institutions operate the 22 ships of the UNOLS Fleet (UNOLS, 2009). Ship schedules, geographic locations of proposed cruises, and other information about UNOLS are available at http://www.gso.uri.edu/unols/unols.html.

3.3.3.2 Oil and Gas Production

Major offshore oil and gas production regions include the continental shelf of the U.S. (Prudhoe Bay, Gulf of Mexico, and Southern California), the coasts of Venezuela and Mexico, the Persian Gulf, the North Sea, and the waters off Indonesia. Deepwater (greater than 305 m [1,000 ft]) 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. In 2006 Chevron, Devon Energy, and Norway-based Statoil ASA announced the successful discovery of oil at a staggering depth beneath the surface of the Gulf of Mexico. Their well delves through 2,134 meters (7,000 feet) of seawater and more than 6,100 meters (20,000 feet) of seafloor to strike oil in the lower tertiary formation (National Geographic News, 2006).

The U.S. Outer Continental Shelf (OCS) refers to 1.7 billion acres of submerged lands for which the Federal government has jurisdiction seaward of state boundaries, generally beginning 3 nmi off the coastline (for all states except Texas and Gulf coast Florida, which have a 9 nmi state limit) and extending 200 nmi to the edge of the EEZ. In 2009, the OCS accounted for 11.5% (2,506 billion ft^2) of the nation’s natural gas production and 31% (593,754 barrels) of its oil production (MMS, 2010). This was a decrease from the 2007 OCS production, that accounted for 14% (2,860 billion ft^2) of the U.S. natural gas production and 27% (429,329,179 barrels) of oil production from 3,795 production facilities on 8,124 Federal leases that covered more than 43 million acres (MMS, 2009).

Currently, two types of offshore geophysical surveys are performed to obtain information on subsurface geologic formations in order to identify potential oil and gas reserves. Both methods employ high-energy seismic surveys (HESS). High-resolution seismic surveys are used in the initial site evaluation for drill rig emplacement and platform design. Deep seismic surveys are used to more accurately assess potential hydrocarbon reservoirs.

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. These data acquisition systems are commonly used along with air guns and map the ocean floor in great detail.

When commercially viable reserves are identified, wells are drilled to confirm the presence of exploitable resources. Initial wells in a field are drilled from a ship and once commercial levels of production are proven, permanent platforms and pipelines are installed. Alternatively, a new type of floating facility, representing an alternative to platform construction, may be used. Four or five development wells go into production, while the remaining wells are capped and abandoned. Capping is accomplished by ROVs or manned submarine vehicles.

Subsea systems to install wellhead and related equipment on the ocean floor are used in the construction of 5 to 7% of wells while the remaining systems use surface wellhead equipment. Both types of systems use divers to connect production lines to pipeline systems. Installation of pipelines also requires survey of the seafloor to select a pipeline route. These surveys generally rely on the use of sonars that generate HF sound waves such as chirps and pinger signals.

Once wells and wellheads are established, they are operated around the clock for their project life, except for periods of maintenance and repair. Divers are occasionally needed to repair pipeline connections or subsea production systems. Divers also participate in removal of the platform and capping of wells when the field is abandoned.

AUV technology has developed as the offshore oil industry has ventured into much deeper waters. Conventional survey techniques with towed sensors were not practical due to the length of cable required to enable the tow fish to be as close to the seabed as possible to achieve the data resolution required. With the longer cable lengths, positioning accuracy also deteriorated and the length of time to conduct the surveys increased dramatically caused by the vessel line turns required for grids to be surveyed. A typical AUV will carry acoustic side-scan, profilers, and swathe systems as well as Inertial Navigation Systems and acoustic telemetry for communication with the mother vessel, all leading edge technology. AUV propulsion is supplied by on-board batteries or fuel cells which have to be able to operate for up to 60 hours without changes. The electrical power is provided from the reaction of chemicals stored in the vehicle. AUV equipment has to be strong physically to withstand the pressures at depths of 3,500 m. The technologies being used are right at the cutting edge and are complex, sophisticated and expensive, but the survey results being achieved from the sonars, profilers and swathe systems are startling (Offshore Technology, 2008).

3.3.4 COASTAL ZONE MANAGEMENT

The Coastal Zone Management Act (CZMA) was enacted on October 27, 1972, to encourage coastal states, Great Lake states, and U.S. territories and commonwealths (collectively referred to as coastal states) to develop comprehensive programs to manage and balance competing uses of and impacts to coastal resources. The CZMA created a federal-state partnership in the management and use of coastal resources. An important part of this partnership involves the requirement that Federal agency activities affecting the coastal zone be consistent to the maximum extent practicable with the state’s approved enforceable policies.

NOAA’s Office of Ocean and Coastal Resource Management (OCRM) works with the Nation’s coastal states and territories to manage and conserve ocean and coastal uses and resources. Thirty-four out of 35 coastal states and territories have active NOAA-approved coastal zone management programs. The 35th state, Illinois, is currently developing its coastal program.

The specific coastal zone management policies identified under state programs vary depending upon the specific issues faced by their region. Many policies address the use, management, and/or development of land within the designated coastal region, often to reduce coastal hazards, promote water-dependent or appropriate land uses, and provide public access. Some policies seek to improve air or water quality in the coastal areas. Others address the protection of sensitive marine resources and habitats, support for coastal recreational activities, and the promotion of marine and estuarine research and education. While coastal zone management programs provide detailed recommendations on a variety of projects that may occur in coastal waters, they do not regulate the movement of commercial, recreational, or military shipping or boating. In addition, none of the programs contain specific provisions regarding sonar activities or related acoustic impacts.

Each state’s coastal zone management program is required to contain the following elements:

- Identification of the boundaries of the coastal zone subject to the management program;
- Definition of permissible land uses and water users within the coastal zone;
- Inventory and designation of areas of particular concern within the coastal zone;
- Identification of the means by which the State proposes to exert control over the land and water uses;
- Broad guidelines on priorities of uses in particular areas;
- Description of the organizational structure proposed to implement the program;
- Definition of the term “beach” and a planning process for the protection of, and access to, public beaches and other public coastal areas of environmental, recreational, historical, aesthetic, ecological, or cultural value;
- Planning process addressing the location of energy facilities; and
- Planning process addressing shoreline erosion.

The landward boundaries of the coastal zone vary by state, reflecting both the natural and man-made environment. The seaward boundaries generally extend to the outer limits of the jurisdiction of the state, but not more than 3 nmi into the Atlantic or Pacific Oceans or Great Lakes (or 9 nmi for Texas and Gulf Florida). The extent of each state’s coastal zone boundary, however, is defined by each state in their coastal zone management plan.

If any federal activity affects state coastal resources, they are subject to Section 307(c)(1) of the Federal Coastal Zone Management Act Reauthorization Amendments of 1979, which requires federal agencies conducting or supporting activities within or outside the coastal zone that affect any land, water use, or natural resources of the coastal zone to be consistent, to the maximum extent practicable, with the enforceable policies of the affected state’s coastal zone management program. A determination of consistency must be submitted by the responsible federal agency to the affected state’s coastal program or commission for review. The determination generally includes a detailed description of the proposed activity, its expected effects upon the land or water uses or natural resources of the state’s coastal zone, and an evaluation of the proposed activity in light of the applicable enforceable policies in the state’s program.

Most of the state programs also identify geographic “areas of particular concern.” Areas of particular concern are typically areas of high natural productivity or essential habitat for living resources, including fish and wildlife, and areas where development and facilities are dependent upon the utilization of, or access to, coastal waters.

The Final SURTASS LFA Sonar OEIS/EIS (see Final OEIS/EIS Table 3.3-5) provided information on the areas of particular concern and the relevant coastal zone management policies for each coastal state/territory near which SURTASS LFA sonar is likely to be operated.

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4.0 IMPACTS OF PROPOSED ACTION AND ALTERNATIVES

This chapter supplements the analyses and results on the potential impacts or effects on various components of the environment that could result from the implementation of the proposed action, and of alternatives to the proposed action. The basis for this analysis is consistent with the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001) and FSEIS (DoN, 2007a) and has been updated based on the best available literature, the Long Term Monitoring Program of current SURTASS LFA sonar operations, and continuing research. Further, no new data contradict any of the assumptions or conclusions presented in Chapter 4 of both the FOEIS/EIS and FSEIS; hence, their contents are incorporated herein by reference.

For SURTASS LFA sonar alternatives, potential impacts should be reviewed in the context of the basic operational characteristics of the system:

- A maximum of four systems, with the potential to be deployed in the Pacific-Indian Ocean area and in the Atlantic Ocean-Mediterranean Sea area.
- The USNS IMPECCABLE (T-AGOS 23) is equipped with a SURTASS LFA sonar system. Three additional VICTORIOUS Class (T-AGOS 19) platforms have been equipped with or, are scheduled to be outfitted with, compact LFA (CLFA) systems (see Subchapter 2.1). These vessels are, or will be, U.S. Coast Guard-certified for operations. In addition, they will operate in accordance with all applicable federal and U.S. Navy rules and regulations related to environmental compliance. SURTASS LFA sonar vessel movements are not unusual or extraordinary and are part of routine operations of seagoing vessels. Therefore, there should be no unregulated environmental impacts from the operation of the SURTASS LFA sonar vessels.
- At-sea missions would be temporary in nature (see Subchapter 2.2 [Operating Profile]). Of an estimated maximum 294 underway days per year per vessel, the SURTASS LFA sonar would be operated in the active mode a maximum of 240 days. During these 240 days, active transmissions would occur for a maximum of 432 hours per year per vessel. (See FOEIS/EIS Subchapter 2.2).
- Average duty cycle (ratio of sound "on" time to total time) of the SURTASS LFA sonar active transmission mode is less than 20%. The typical duty cycle, based on historical LFA operational parameters since 2003 is nominally 7.5 to 10%. That is, 7.5 to 20% of the time the LFA transmitters could be on; and 80 to 92.5% of the time the LFA transmitters would be off, thus adding no sound into the water. On an annual basis, each SURTASS LFA vessel is limited to transmitting no more than 4.9% of the time (432 hrs/8,760 hrs).

References to Underwater Sound Levels

- **References to underwater sound pressure level (SPL) in this SEIS/SOEIS are values given in decibels (dBs), and are assumed to be standardized at 1 microPascal at 1 m (dB re 1 μPa @ 1 m [rms]) for source level (SL) and dB re 1 μPa (rms) for received level (RL), unless otherwise stated (Urick, 1983; ANSI, 2006).**
- **In this SEIS/SOEIS, underwater sound exposure level (SEL) is a measure of energy, specifically the squared instantaneous pressure integrated over time and expressed as an equivalent one-second in duration signal, unless otherwise stated; the appropriate units for SEL are dB re 1 μPa²-sec (Urick, 1983; ANSI, 2006; Southall et al., 2007).**
- **The term "Single Ping Equivalent" (SPE) (as defined in Chapter 4 and Appendix C of this SEIS/SOEIS) is an intermediate calculation for input to the risk continuum used in this document. SPE accounts for the energy of all the LFA acoustic transmissions that a modeled animal receives during an entire LFA mission (modeled for operations from 7 to 20 days). Calculating the potential risk from SURTASS LFA is a complex process and the reader is referred to Appendix C for details. As discussed in Appendix C, SPE is a function of SPL, not SEL. SPE levels will be expressed as "dB SPE" in this document, as they have been in the SURTASS LFA sonar FOEIS/FEIS and FSEIS documents (DoN, 2001 and 2007a).**

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

- **Non-auditory injury**: This includes the potential for resonance of the lungs/organs, tissue damage, and mortality. For the purposes of the SURTASS LFA sonar analyses presented in this SEIS/SOEIS, all marine animals exposed to underwater sound with >180 dB re 1 μPa (rms) RL are evaluated as if they are injured (Level A "harassment" under the MMPA). Even though actual injury would not occur unless animals were exposed to sound at a level greater than this value (Southall et al., 2007), the analysis in the document will continue to define LFA's injury level as >180 dB re 1 μPa (rms) RL. This should be viewed as a conservative value, used to maintain consistency in the analytical methodologies previously utilized in LFA environmental impact statements (DoN, 2001 and 2007a), in incidental take application under the MMPA, and in consultations under the Endangered Species Act (ESA).
- **Permanent threshold shift (PTS)**: A severe situation occurs when sound intensity is very high or of such long duration that the result is a permanent hearing loss on the part of the listener, which is referred to as permanent threshold shift (PTS). This constitutes Level A "harassment" under the MMPA, as does any other injury to a marine mammal. The intensity and duration of an underwater sound that will cause PTS varies across species and even among individual animals. PTS is a consequence of the death of the sensory hair cells of the auditory epithelia of the ear and a resultant loss of hearing ability in the general vicinity of the frequencies of stimulation (Salvi et al., 1986; Myrberg, 1990; Richardson et al., 1995). PTS results in a permanent elevation in hearing threshold—an unrecoverable reduction in hearing sensitivity (Southall et al., 2007).
- **Temporary threshold shift (TTS)**: Underwater sounds of sufficient loudness can cause a temporary condition known as temporary threshold shift (TTS) in which an animal's hearing is impaired for a period of time. After termination of the sound, normal hearing ability returns over a period that may range anywhere from minutes to days, depending on many factors, including the intensity and duration of exposure to the sound. Hair cells may be temporarily affected by exposure to the sound, but they are not permanently damaged or killed. Thus, TTS is not considered an injury (Richardson et

al., 1995; Southall et al., 2007), although during a period of TTS, animals may be at some disadvantage in terms of detecting predators or prey.

- **Behavioral change**: Various vertebrate species are affected by the presence of intense sounds in their environment (Salvi et al., 1986; Richardson et al., 1995). Behavioral responses to these sounds vary from subtle changes in surfacing and breathing patterns, to cessation of vocalization, to active avoidance or escape from regions of high sound levels (Wartzok, et al., 2004). For military readiness activities, such as the use of SURTASS LFA sonar, Level B "harassment" under the MMPA is defined as any act that disturbs or is likely to disturb a marine mammal by causing disruption of natural behavioral patterns to a point where the patterns are abandoned or significantly altered. Behaviors include migration, surfacing, nursing, breeding, feeding, and sheltering. The National Research Council (NRC, 2005) discusses biologically significant behaviors and possible effects. It states that an action or activity becomes biologically significant to an individual animal when it affects the ability of the animal to grow, survive, and reproduce. These are the effects on individuals that can have population-level consequences and affect the viability of the species (NRC, 2005). While sea turtles and fish do not fall under MMPA harassment definitions, like marine mammals, it is possible that loud sounds could disturb the behavior of fish and sea turtles, resulting in similar consequences as for marine mammals.
- **Masking**: The presence of intense sounds in the environment can potentially interfere with an animal's ability to hear sounds of relevance to it. This effect, known as "auditory masking," could interfere with the animal's ability to detect biologically-relevant sounds, such as those produced by predators or prey, thus increasing the likelihood of the animal not finding food or being preyed upon.

The acoustic environment in the ocean is dynamic, consisting of both anthropogenic and natural noises. The understanding of the transmission of sound, or acoustic propagation, in the ocean environment is important to the readers' comprehension of this complex subject. A tutorial on the fundamentals of underwater sound was provided as Appendix B of the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001) to assist the reader in understanding the technical aspects of the document. The information in this appendix remains valid, and its contents are incorporated herein by reference. Additional references pertinent to this discussion include:

- Urick, R.J. 1983. Principles of Underwater Sound, 3rd Edition. Los Altos, California: McGraw-Hill, Inc.
- Richardson, W.J., C.R.J. Green, C.I. Malme, and D.H. Thomson. 1995. Marine Mammals and Noise. San Diego, California: Academic Press.
- Bradley, D.L. and R. Stern. 2008. Underwater Sound and The Marine Mammal Environment: A Guide to Fundamental Principles. Marine Mammal Commission. Rockville, Maryland.
- OMP and MAI (Office of Marine Programs and Marine Acoustics, Inc.). 2010. Discovery of sound in the sea (DOSITS). Office of Marine Programs, University of Rhode Island. <http:www.dosits.org>. (Scowcroft et al., 2006).

4.1 POTENTIAL IMPACTS ON FISH STOCKS

Since the original SURTASS LFA sonar FOEIS/EIS (DoN, 2001) and FSEIS (DoN, 2007a), there have been a number of useful studies on the potential effects of underwater sound on fish, including sharks, and several other pertinent studies that have come forth. This sub-chapter will provide summaries of the recent research and update the analysis of the potential effects of the alternatives based on the following SURTASS LFA sonar operational parameters:

- Small number of SURTASS LFA sonar systems to be deployed;
- Geographic restrictions imposed on system employment;
- Narrow bandwidth of SURTASS LFA sonar active signal (approximately 30 Hz);
- Slowly moving ship, coupled with low system duty cycle, would mean that fish would spend less time in the LFA mitigation zone (180-dB SPL sound field); therefore, with a ship speed of less than 9.3

km/hr (5 kt), the potential for animals being in the sonar transmit beam during the estimated 7.5 to 20% of the time the sonar is actually transmitting is very low; and

- Small size of the LFA mitigation zone (180-dB SPL sound field) relative to fisheries provinces and open ocean areas.

Due to the lack of more definitive data on fish/shark stock distributions in the open ocean, it is not feasible to estimate the percentage of a stock that could be located in a SURTASS LFA sonar operations area at a potentially vulnerable depth during an LFA sound transmission.

4.1.1 POTENTIAL IMPACTS ON FISH (CLASS OSTEICHTHYES) STOCKS

There have been several studies on the effects of both Navy sonar and seismic airguns[36] that are relevant to potential effects of SURTASS LFA sonar on Osteichthyes (bony fish). In the most pertinent of these, the Navy funded independent scientists to analyze the effects of SURTASS LFA sonar on fish. Results from this study were originally presented in the FSEIS (DoN, 2007a). The findings from this study have been presented at conferences, peer-reviewed and published in scientific journals (Popper et al., 2005a, 2007; Halvorsen et al., 2006; Kane et al., 2010). These results have now been updated with a related study that examined in detail the effects of SURTASS LFA sonar on fish physiology (Kane et al., 2010). Several other studies have assessed the effects of seismic airguns on fish. Thus, while most research before 2001 studied the effects of sounds using pure tones of much longer duration than the SURTASS LFA sonar signals (see FOEIS/EIS, Subchapter 4.1.1.1), many of the more recent studies provide insight into the impact of each of these sounds on fish. With the caveat that only a few species have been examined in these studies, the investigations found little or no effect of high intensity sounds on a number of taxonomically and morphologically diverse species of fish; and there was no mortality as a result of sound exposure, even when fish were maintained for days post-exposure.

4.1.1.1 Non-Auditory Injury

A number of investigators have suggested that fish exposed to high intensity sounds could show a range of non-auditory injuries, extending from the cellular level to gross damage of the swim bladder and circulatory system (reviewed in Popper and Hastings, 2009a). However, the bulk of the data suggesting such injuries come from studies that tested the effects of explosives on fish (Yelverton et al., 1975; and reviews in Hastings, 2008 and Popper and Hastings, 2009a and 2009b). There is less evidence for such damage (albeit, from very few studies) when fish are exposed to sounds similar to those produced by sonars, pile driving, shipping noise, and other anthropogenic sources.

Studies estimating the effects of sound on terrestrial mammals suggest that lungs and other organs are potentially damaged by sound (Fletcher et al., 1976; Yang et al., 1996; Dodd et al., 1997; see also Henderson, 2008 for review of noise standards for humans). There is also some evidence, in “gray” literature reports (i.e., non-peer-reviewed), that high sound pressure levels may cause tearing or rupturing of the swim bladder of some (but not all) fish species (Gaspin, 1975; Yelverton et al., 1975). Most recently, similar results have been observed in fish exposed to the impulsive sounds from pile driving when fish are at an undetermined range but very close to the pile driving source (Abbott and Bing-Sawyer, 2002; Caltrans, 2004). However, such studies have yet to be repeated under controlled experimental conditions and none have received scientific peer review (Popper and Hastings, 2009b).

The only studies that examined the effects of sound on non-auditory tissues have been the recent work using SURTASS LFA sonar (undertaken by the U.S. Navy) and seismic airguns, both of which are

[36] Seismic airguns differ from SURTASS LFA sonar in that they generally transmit in the 5 to 20 Hz frequency band and their typical airgun array firing rate is once every 9 to 14 seconds, but for very deep water surveys, the rate could once every 42 sec. Airgun acoustic signals are typically measured in peak-to-peak pressures, which are generally higher than continuous sound levels from other ship and industrial noise. Broadband SLs of 248 to 255 dB SPL (peak-to-peak) are typical for a full-scale array but can be as high as 259 dB SPL. Airgun onset is generally much more rapid (sharper) than that of sonar.

reviewed below (Popper et al., 2005b, 2007; Song et al., 2008; Kane et al., 2010). The significant point from these studies is that neither source, despite being very intense, had any effect on non-auditory tissues. In all fish, the swim bladder was intact after exposure, and in the one study that involved an expert fish pathologist (to ensure that the non-auditory tissues of the fish sacrificed were examined properly), there was no damage to tissues either at the gross or cellular levels (Popper et al., 2007; Kane et al., 2010). These studies provide the first direct evidence that sounds, including seismic airguns and SURTASS LFA sonar, may be of concern, but that does not necessarily mean that they kill or damage fish. However, it must be cautioned, as done by Hastings et al. (1996), McCauley et al. (2003), Popper et al. (2007), and Kastelein et al. (2008) (among others) that all studies to date have been done with a very limited number of species, and that extrapolation among species, and to other sound sources (or even to other levels or durations of the same sound sources), must be done with extreme caution, at least until there are more data upon which to base any extrapolations.

Few studies have directly examined the effects of sound on fish mortality (see reviews in Popper and Hastings, 2009a, b), although recent studies using high intensity seismic airguns and LFA and mid-frequency active (MFA) sonars have found no mortality (McCauley et al., 2000 and 2003; Popper et al., 2005b, 2007; Hastings et al., 2008). In contrast, one report by Turnpenny et al. (1994) suggested that sound exposure could produce substantial damage in caged fish. However, reviews by subject matter experts found problems with this report and concluded that it did not appear to reflect the best available science on this issue for several reasons. Further discussion on this issue is provided in Subchapter 4.1.1.2 of the FSEIS (DoN, 2007a), which is incorporated by reference herein.

4.1.1.2 Permanent Loss of Hearing

A number of studies have examined the effects of high intensity sound on the sensory hair cells of the ear. These cells transduce (convert) the mechanical energy in the sound field into a signal that is compatible with the nervous system. Loss of these cells in terrestrial animals results in permanent hearing loss (Fletcher and Busnel, 1978; Saunders et al., 1991). Thus, it is likely that comparable damage to sensory hair cells in fish could also result in hearing loss. However, while there are studies indicating some damage to sensory hair cells in fish resulting from exposure to very intense underwater sound, only one study (Smith et al., 2006) has measured fish hearing before and after such damage occurred. Although it looks at a non-marine species hearing specialist, exposed to sounds lower in intensity than SURTASS LFA sonar, pile driving, and seismic studies, this study shows rapid repair of hair cells and recovery of hearing (Smith et al., 2006). While these data suggest that at least one species with damaged sensory hair cells also had hearing loss, it is clear that there was recovery from both cell damage and hearing loss, with hearing coming back even before all sensory hair cells were repaired.

There have been four earlier studies that examined the effects of high intensity sounds on fish ears. Hastings et al. (1996) investigated the effects of intense sound stimulation on the ear and lateral line of a non-specialist freshwater fish (*Astronotus ocellatus,* the oscar). The investigators exposed fish for one hour to a continuous sound signal at 300 Hz and a RL of 180 dB re 1 µPa (rms), and upon examination four days afterward found some damage to the sensory hair cells of two of the otolith organs[37], the lagena[38] and utricle[39]. There was no apparent damage with other frequencies, sounds with shorter duty cycles, or shorter stimulation time, or when the ear was studied immediately after the cessation of stimulation. The interpretation of these results by the investigators was that exposure to a high intensity underwater sound has the potential to damage the sensory cells of the ears of fish. However, the sound

[37] The otolith organs sense gravity and linear acceleration such as from due to initiation of movement in a straight line. Persons or animals without otolith organs or defective otoliths have poorer abilities to sense motion as well as orientation to gravity.

[38] The laguna is part of the vestibular system in fish and amphibians, and it contains the asterisci otolith. In fish, the laguna is implied in hearing and the registration of vertical linear acceleration.

[39] The utricle sends input to the brain via the superior division of the nerve.

has to be continuous and last at least one hour; and the damage was only evident some time after exposure.

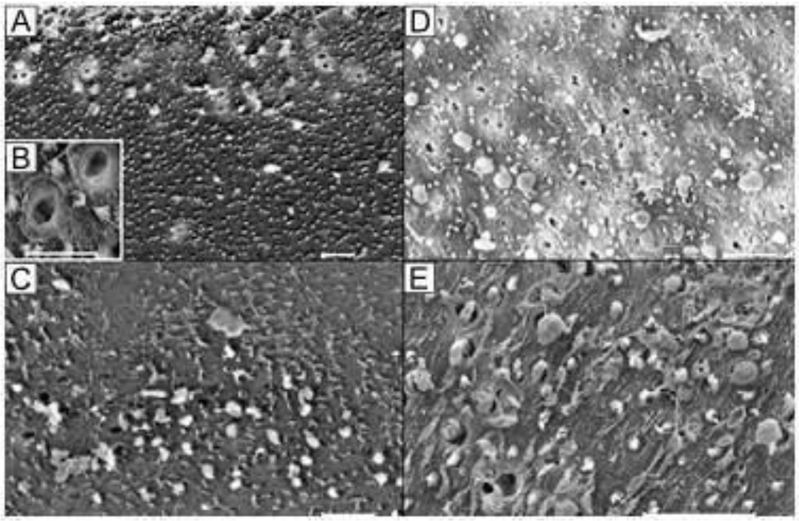
Additional studies suggest that intense sound may result in damage to the sensory hair cells in the ears of other species. Cox et al. (1986a, 1986b; 1987) exposed goldfish (*Carassius auratus*), a freshwater hearing specialist, to pure tones at 250 and 500 Hz at 204 and 197 dB re 1 µPa (rms) RL, respectively, for two hours. They found some indications of sensory hair cell damage, but these were not extensive. Enger (1981) determined that some ciliary bundles (the sensory part of the hair cell) on sensory cells of the inner ear of the Atlantic cod (*Gadus morhua*) were damaged when exposed to underwater sounds at several frequencies from 50 to 400 Hz at 180 dB re 1 µPa (rms) RL for 1 to 5 hours.

McCauley et al. (2003) examined the effects on the sensory tissues of the ears of the Australian fish, the pink snapper (*Pagrus auratus*), after exposure to a seismic airgun. Fish were placed in a cage and exposed to emissions of a single seismic airgun that was moved toward and away from the test cage. The airgun had a SL of 222.6 dB re 1 µPa at 1 m (peak to peak), or 203.6 dB re 1 µPa at 1 m (rms). It was deployed at 5 m (16.4 ft) depth and towed from a distance of 400 to 800 m (1,312 to 2,625 ft) from the cage to a position as close as 5 to 15 m (16.4 to 49.2 ft) to the cage and then back to the starting point. The goal was to present a signal that was similar to that which fish might encounter if they are near an active airgun survey that is moving back and forth over a survey site.

The animals were maintained for varying time periods post-exposure. The fish were then sacrificed, and the ears examined using scanning electron microscopy (SEM) (Figure 4-1). The investigators reported that there was some damage to the ciliary bundles of the sensory hair cells of the saccular sensory epithelium (the other end organs were not examined). Additionally, the extent of damage increased the longer the period between animal exposure and examination. The animals that were maintained the longest, to 58 days post-exposure, had the greatest damage to ciliary bundles, according to the investigators. Significantly, all of the experimental animals survived for the full 58 days post-exposure and were fed and appeared to behave normally. While indirect evidence, these observations suggest that there was no other permanent injury to the fish such as damage to the swim bladder.

Although both the Hastings et al. (1996) and McCauley et al. (2003) studies, as well as a study by Enger (1981), suggested that high-intensity sounds could potentially result in damage to sensory hair cells, it is important to note several caveats in considering these results. These caveats (as pointed out by the authors of the two more recent papers) include: 1) the use of only a few species in the studies and that these species may not be representative of other species; 2) the inability of the caged fish in any of the studies to depart the immediate sound field and thus lessen sound exposure and the likelihood of damage; and 3) the relatively long duration of the experimental sounds as compared to the shorter exposures that might be expected with SURTASS LFA sonar or other types of human-generated underwater sounds at high signal levels.

As will be discussed below, a recent study on the effects of SURTASS LFA sonar sounds on three species of fish (rainbow trout, channel catfish, and hybrid sunfish), also examined long-term effects 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 (Popper et al., 2005a, 2007; Halvorsen et al., 2006).



Scanning electron micrographs of the saccular sensory epithelium of the pink snapper following exposure to a seismic airgun (see text for parameters). (a, b, c) Epithelia from fish sacrificed 18 hours after exposure to the airgun. The photographs show numerous holes and "blebbing" (i.e., blistering). (d and e) Photographs from saccular epithelia of fish sacrificed 58 days after exposure. This tissue shows extensive damage. Scale bars: a, 20 μm; b, 2 μm; c, d, e, 20 μm. (From McCauley et al., 2003).

Figure 4-1. Scanning electron micrographs of the saccular sensory epithelium of the pink snapper following exposure to a seismic airgun.

Another potential issue with regard to damage to the ear is that it may be possible for fish to regenerate or repair damaged sensory cells resulting from exposure to intense sounds (Smith et al., 2006). While this does not occur in mammals (where hair cell loss leads to permanent deafness), regeneration and restoration of hearing appears to occur in birds (reviewed in Dooling and Dent, 2001). Moreover, Lombarte et al. (1993) found that sensory hair cells in the ear of the oscar that have been damaged by the ototoxic drug[40] gentamicin sulphate would regenerate within 10 to 15 days of the termination of the drug regime. More recently, Smith et al. (2006) showed recovery of hair cells from noise damage in the goldfish (*Carassius auratus*), a species of hearing specialist. Unlike mammals, fish continue to produce sensory hair cells throughout much of their lives (Lombarte and Popper, 1994; Higgs et al., 2001). Since hair cells recover from drug damage, and at least one species is now known to be able to recover from damage due to long-term exposure to increased background sounds (Smith et al., 2006), it may be speculated that there might be recovery from at least some levels of noise injury in all fish. However, while the Smith et al. (2006) study shows recovery from general increases in background noise, it must be kept in mind that these sounds were far lower in intensity than other underwater anthropogenic sounds (e.g., sonar, seismic exploration, pile driving). In addition, it is not yet known if hair cell replacement would occur after very high magnitudes of damage, or if the recovery would be fast enough to prevent mortality if the fish could not adequately hear prey or predators. Moreover, the results from the McCauley et al. (2003) study showed no signs of recovery 58 days after damage from very intense seismic airgun exposure and, in fact, there was more damage at 58 days than immediately after exposure.

4.1.1.3 Temporary Loss of Hearing—Experimental Results

In addition to the possibility of causing permanent injury to fish ear sensory hair cells, underwater sound may cause TTS, a temporary and reversible loss of hearing that may last for minutes to days. TTS is quite common in humans and often occurs after being exposed to loud music. The precise physiological

[40] Ototoxic drugs are drugs that can cause temporary or permanent hearing loss. They can also make an existing hearing loss worse.

mechanism for TTS is not well understood. It may result from fatigue of the sensory hair cells because of their being over-stimulated or from some small damage to cells that are repaired over time. The duration of TTS depends on a variety of factors including intensity and duration of the stimulus.

The first TTS study on fish showed that a 149 dB re 1 µPa (rms) RL exposure to a pure tone for eight continuous hours might cause TTS of more than 10 dB SPL in goldfish (Popper and Clarke, 1976). More recently, a series of studies have further demonstrated TTS in a number of different species using both continuous tones and various noises.

Smith et al. (2004a, 2004b, 2006) examined the effects of increased background noise on hearing capabilities of goldfish (*Carassius auratus*) and tilapia (*Oreochromis niloticus*). The purpose of these studies was to determine the detailed parameters of hearing loss that might be expected from exposure to sounds that differ in duration, and in which animals were tested over different recovery times post-exposure. Smith et al. found that goldfish showed a 5-dB SPL TTS after only 10 minutes of exposure to band-limited noise (0.1 to 10 kHz, approximately 170 dB re 1 µPa (rms) RL overall spectral sound pressure level). Following three weeks of exposure to the same stimulus, goldfish had a 28-dB SPL TTS and the fish took more than two weeks to return to normal hearing. These results should be noted in context with those for tilapia cited below.

Generally, similar results were obtained for goldfish exposed to white noise at 158 dB re 1 µPa (rms) RL for 24 hours by Wysocki and Ladich (2005). In this study, the investigators found that recovery of full hearing sensitivity took up to two weeks. They also investigated temporal resolving power[41] of goldfish before and after noise exposure and found a decrease in temporal resolution capabilities that continued for up to three days. This kind of hearing loss could be critical since many species of fish appear to use temporal patterns of sounds to discriminate between sounds (e.g., sounds of different species) (Myrberg and Spires, 1980). Thus, the effects of noise exposure in fish may not only result in effects on the lowest sound detectable (threshold), but also the way that fish resolve signals from one another.

In contrast to hearing losses in goldfish as reported by Smith et al. (2004b) as well as Wyoscki and Ladich (2005), Smith et al. (2004a) showed no TTS after up to 21 days of noise exposure at 170 dB re 1 µPa (rms) RL for the hearing-generalist tilapia. It is not particularly surprising that the results differ between goldfish and tilapia since the former is a hearing specialist with high sound sensitivity while tilapia is a hearing generalist and does not hear as well as goldfish.

These findings were also partly supported by Scholik and Yan (2001), who studied another hearing specialist, the fathead minnow (*Pimephales promelas*), and found that there was substantial hearing loss that continued for more than 14 days after termination of a 24-hour exposure to white noise from 0.3 to 2.0 kHz, with an overall spectral sound pressure level of 142 dB re 1 µPa (rms) RL. In contrast, Scholik and Yan (2002) studied effects of sound exposure in a hearing generalist, the bluegill sunfish (*Lepomis macrochirus*) and found no TTS.

While these earlier studies demonstrated TTS in some species and not in others, all of them used relatively low-intensity sounds that are well below the levels that fish might encounter when exposed to signals such as those produced by SURTASS LFA sonar, pile driving, or seismic exploration using airguns (or nearby movement of high-tonnage shipping). Several recent studies, however, tested the effects of such high-intensity sound not only on hearing, but also on other non-auditory structures. In each case, the study was designed to provide what might be considered "worst-case" sound exposure and to have all appropriate controls to ensure that the results were from the noise and not from human handling

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[41] Temporal resolving power is the ability to discriminate between time intervals of different lengths. If a time interval is too short, then a sound will be heard as continuous rather than being made up of pulses. Fish sounds are often pulses that are repeated rather quickly, and different sounds, or sounds of different species, may have different pulse intervals. If a fish cannot discriminate among different intervals, it has poor ability to discriminate among different sounds.

or other factors. Several studies that deal with seismic airguns are of interest from a scientific sense regarding SURTASS LFA sonar. They showed there were differences in the effects of airguns on the hearing thresholds of different species. Additional studies deal directly with SURTASS LFA sonar.

Effects of Seismic Airguns on Fish Hearing

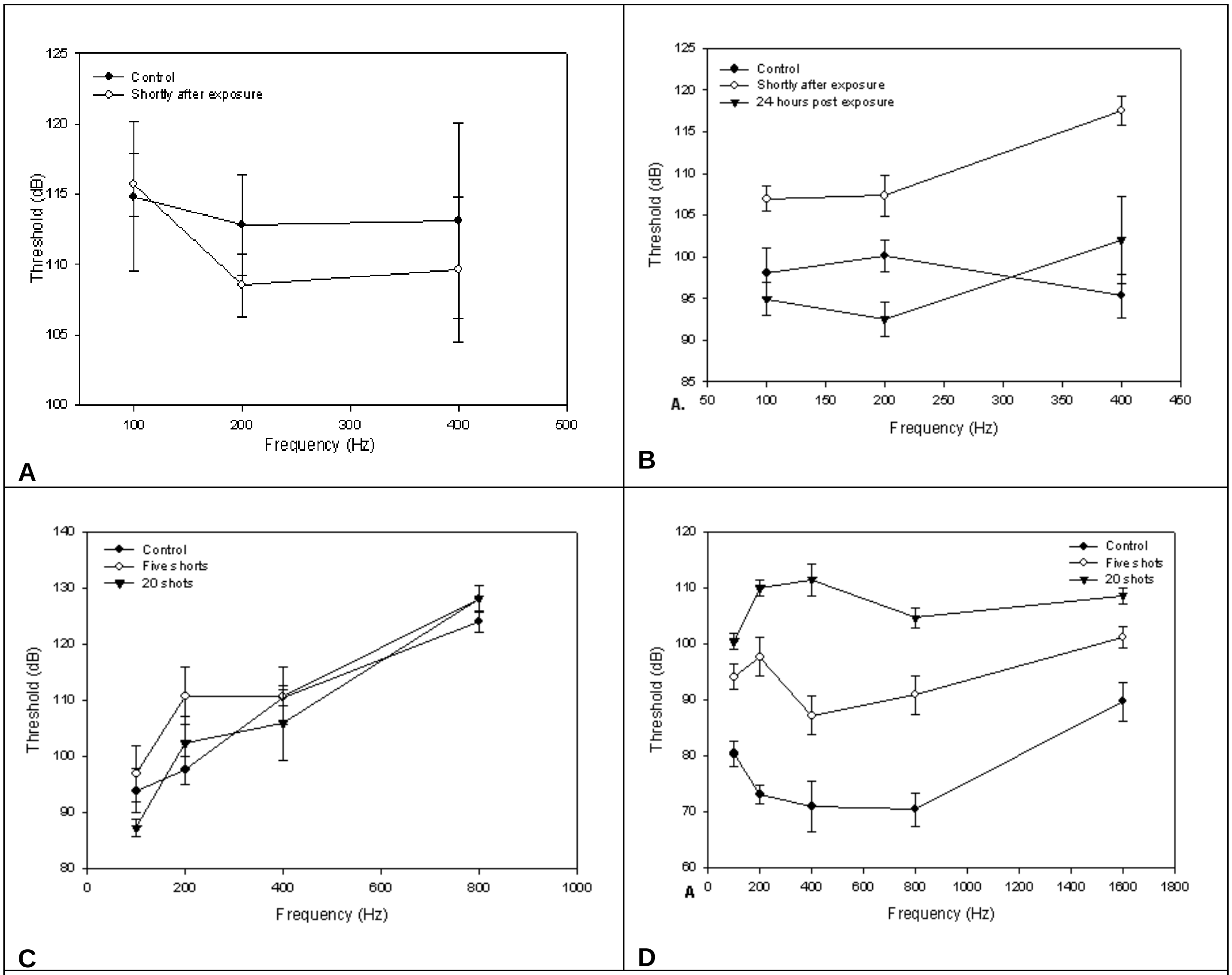
Popper et al. (2005b) examined the effects of exposure to a seismic airgun array on three species of fish found in the Mackenzie River Delta near Inuvik, Northwest Territories, Canada. The species included one hearing specialist, the lake chub (*Couesius plumbeus*), and two species that are not known to have specializations that would enhance hearing, the northern pike (*Esox lucius*), and the broad whitefish (*Coregonus nasus*). In brief, caged fish were exposed to 5 or 20 shots from a 12,000 cubic centimeters (cc) (730 in^3) airgun array. The signals were fully calibrated and, unlike in earlier studies, exposure was determined not only for SPL (rms), but also for peak sound levels and for sound exposure levels (SELs). In this study in the 2 Hz to 10 kHz band, average mean peak SPL was 207 dB re 1 µPa RL, the average mean 90% SPL (rms) sound level was 197 dB re 1 µPa RL, while the average mean SEL was 178 dB re 1 μPa^2-sec RL.

The study was designed so the level of sound exposure would be as substantial as any that these species are likely to encounter in a riverine seismic survey where there is a single pass of the fish by the seismic device.[42] Fish were placed in a test cage, exposed to the airgun array, and then tested for hearing immediately after sound exposure, and then 24 hours post-exposure. Testing was done by the auditory evoked potentials (AEP) method used by Smith et al. (2004a) and Scholik and Yan (2001, 2002). In addition, the experiment used baseline animals that were never placed in the test cage and control animals that were handled in precisely the same way as test animals, other than for exposure to the airgun sound.

The results (Figure 4-2) showed a temporary hearing loss for both lake chub and northern pike to both 5 and 20 airgun shots. There was no hearing loss to the same signals in the broad whitefish, a relative of salmon. Hearing loss was on the order of 20 to 25 dB at some frequencies for both the northern pike and lake chub, and recovery took place within 24 hours, with fish hearing returning to normal. While a full pathological study was not conducted, fish of all three species survived the sound exposure and were alive more than 24 hours after exposure. Those fish of all three species sacrificed after AEP testing had intact swim bladders. There was no apparent external or internal damage to other body tissues (e.g., no bleeding or grossly damaged tissues), although it is important to note that the observer in this case (unlike in the following LFA study) was not a trained pathologist.

Most importantly, this study showed that there were differences in the effects of airguns on the hearing thresholds of the different species studied. In effect, these results substantiate the argument made by Hastings et al. (1996) and McCauley et al. (2003) that it is difficult to extrapolate among species with regard to the effects of intense underwater sounds.

[42] In oceanic seismic surveys, the survey boat pulls the seismic device back and forth across the survey area in repeated paths, with each path parallel to, but some distance from, the previous path. Thus, an animal remaining in the vicinity of the middle of the survey area(e.g., foraging) would be exposed to repeated signals for a far longer time than in a river survey where the survey boat moves continuously in one direction. The McCauley et al. (2003) study was designed to more closely resemble an ocean survey, though it only pulled the airgun to and from the caged fish twice.



Results from exposure of fish to a seismic survey (Popper et al., 2005b). (A) Thresholds of broad whitefish for control and experimental animals showing no statistically significant hearing loss. (B) Thresholds from northern pike just after exposure and 24 hours post-exposure. Fish showed a significant hearing loss just after exposure, but thresholds were not significantly different from controls at 24 hours. (C) Thresholds for small, young of the year, northern pike. Interestingly, these fish showed no hearing loss compared to controls after exposure to 5 or 20 airgun shots. (D) Lake chub, a hearing specialist, showed substantial hearing loss after 5 shots of the airguns and even more loss after 20 shots. Both groups of animals, however, showed full recovery of hearing loss within 24 hours. (All figures from Popper et al., 2005b).

Figure 4-2. Hearing thresholds for different fish in a study investigating the effects of exposure to a seismic airgun array on fish hearing.

More recently, Hastings et al. (2008) examined the effects of seismic airguns on hearing in several tropical reef fish species in Western Australia following exposure to sound from a 2,055 cubic-inch seismic airgun array being used in a three-dimensional marine seismic survey. The experiments included several fish species, including a hearing specialist, the pinecone soldierfish (*Myripristis murdjan*), and three species that are not known to have any structures that would increase hearing sensitivity: the blue green damselfish (*Chromis viridis*), the sabre squirrelfish (*Sargocentron spiniferum*), and the bluestripe seaperch (*Lutjanus kasmira*). The fish were exposed in the field to an actual airgun survey and then brought to a boat in which they were tested for hearing changes. The cumulative SEL was 189-190 dB re

1 μPa^2-sec at the closest point of the seismic airgun passing of the fish, and some fish were exposed to two passes of the array, while others to one pass. Appropriate controls were used to allow for effects of handling of animals.

Results showed no effect on hearing in any species other than the blue green damselfish. In this species, there was no hearing loss reported one day after testing, but at either 4 or 7 to 8 days after testing there was a significant hearing loss (up to 15 dB SPL) at 225 and 455 Hz but not at other tested frequencies. While the explanation for this hearing loss is not clear, Hastings et al. (2008) point out that these were the smallest fish in the study, and it is possible that lack of food over the post-exposure period resulted in physiological problems that were manifested in hearing loss.

The lack of any hearing effect on the reef fish is interesting, particularly as compared to the results from Popper et al. (2005b), who found some hearing loss in some species after exposure to cumulative SEL of about 183 dB re 1 μPa^2-sec. The differences between the studies are important, but many factors could account for this, including use of very different species, different types of airguns, or the actual sound spectrum to which fish were exposed. Those in the Popper et al. (2005b) study were in shallow water with limited low frequency propagation, whereas those in Hastings et al. (2008) were in deeper water, with more low frequency energy in the signal. How this would change the effects of sound on fish hearing is not known, but points to the difficulty in extrapolating data between experiments at this stage of our knowledge.

Effects of SURTASS LFA Sonar on Fish Hearing

Dr. Popper and his colleagues (Popper, et al., 2005a, 2007; Halvorsen et al., 2006; Kane et al., 2010) examined whether exposure to high-intensity, low frequency sonar, such as the Navy's SURTASS LFA sonar, would affect fish. An LFA sonar array has the potential to ensonify fish with sound levels over 180 dB re 1 μPa (rms) RL within approximately 1 km (0.54 nmi) from the array. Moreover, LFA sonar uses frequencies from 100 to 500 Hz, the range in which most fish are able to detect sound and the range of best hearing for many species (Fay, 1988a; Popper et al., 2003; Ladich and Popper, 2004). Thus, the sonar not only has the hypothetical potential to damage organ systems in fish due to the signal intensity, but it has the direct potential of affecting hearing because the auditory system of many fish is most sensitive in the frequency range in which the sonar operates.

- **Fish species studied**

This study, which took place at the Naval Undersea Warfare Center (NUWC) sonar test facility on Seneca Lake, NY, examined the effect of LFA on hearing, the structure of the ear, and select non-auditory systems in the rainbow trout (*Onchorynchus mykiss*) and channel catfish (*Ictalurus punctatus*) (Popper et al., 2005a, 2007; Halvorsen et al., 2006; Kane et al., 2010). Additional studies were done with a hybrid sunfish species, *Lepomis* sp.

The rainbow trout is a hearing generalist (or "non-specialist"), while the channel catfish is a specialist[43]. These two species were chosen since there is evidence that there may be a significantly different impact of underwater noise exposure on fish that hear well and those that do not hear well, as discussed above with regard to TTS as a result of exposure to lower intensity sounds (Hastings et al., 1996; Smith et al., 2004a, b; Popper et al., 2005a). Most importantly, rainbow trout were chosen for study since they are excellent reference species[44] for listed salmonids from the U.S. west coast, all of which are of the same

[43] In a recent review, Popper and Fay (2009b) have argued that the terms hearing "generalist" and "specialist" should be dropped since there is so much overlap in hearing capabilities and mechanisms among different species. Instead, Popper and Fay suggest that different hearing capabilities should be treated on a "continuum" of capabilities (Popper and Fay, 2009b). For more details, see discussion in Chapter 3.

[44] It would be impossible to test even those species most likely to be exposed to LFA to determine effects. Instead, select species must be examined and used as "reference species" (e.g., species that are very similar to, but not the same as, the species of

genus as rainbow trout. Listed species of this genus could not be tested in the Seneca Lake study since it would have been too difficult to import the fish to the experimental site in the numbers needed for study. In addition, since there is a chance that fish could escape from the experimental apparatus, it was not appropriate to use species that are not endemic to the test site. Adding new species to Seneca Lake could potentially impact the lake ecosystem in unpredictable ways.

In addition to being in the same taxonomic genus, rainbow trout are also a good reference species for listed salmonids because the species have similar, if not identical, ears and hearing sensitivity (Song and Popper, in prep). Hearing tests of hatchery-raised chinook salmon (*Oncorhynchus tshawytscha*) show that hearing sensitivity and range of hearing is very similar to that of rainbow trout (Popper et al., 2005a). Since the ears and hearing sensitivity are essentially the same for the rainbow trout and another member of the genus *Oncorhynchus* (Pacific salmons and Pacific trouts), it is likely that the rainbow trout can serve as the model species/system in other anthropogenic sound studies, as in the LFA study.

- **Experimental overview**

The facility at Seneca Lake, where the SURTASS LFA sonar study was conducted, is an acoustic free-field environment that enabled the investigators to have a highly calibrated sound source and to monitor the sound field as well as the behavior of the fish throughout the experiments. The facility has a large barge in the middle of the lake and a nearby shore support facility that has room for holding animals and conducting all hearing and other tests.

In brief, experimental fish were placed in a test tank that was 1 m (3.3 ft) on a side and made of 1.27 cm (0.5 in) thick Lexan® clear plastic sheets (Figure 4-3). The tank was designed to allow free flow of water throughout the tests to ensure that fish were at the best experimental temperature and had oxygenated water. Two video cameras external to the test tank were used to observe the behavior of the fish (with images and sounds recorded on digital tape) as the test tank was raised and lowered, and during sound presentations.

Prior to conducting experiments with live animals, calibration tests were performed on the sound field inside and around the fish test tank. These data showed that the variation in sound level was small in different regions of the test tank, indicating that the acoustic field inside was sufficiently uniform for the studies. For a single tone, the maximum RL was approximately 193 dB re 1 µPa (rms) at 196 Hz and the level was uniform within the test tank to within approximately ±3 dB. The experimental sounds were produced using a single SURTASS LFA sonar transmitter excited at 1,600 V, giving an approximate SL of 215 dB re 1 µPa at 1 m (rms). The signal used was generated electronically and was very similar to the actual sonar signal train used by the Navy. The frequency range of the signal was from 170 to 320 Hz.

All fish were from the same supplier. They were randomly assigned to one of the three experimental groups. Baseline group animals had no handling other than moving to the Seneca Lake facility. Experimental group animals were placed in the test tanks and exposed to sound. Control group animals were handled in precisely the same way as experimental animals but without the sound presentation.

concern). It is very common to use reference species in animal studies, and a great deal of relevant information can be learned from such species.

The photo shows the test tank. The braces to the left and right support the video cameras (black) used to monitor fish throughout the experiments. The small black objects suspended from cables in the test tank are an array of hydrophones used to monitor the sound throughout the experiments. An additional hydrophone (right) was used to monitor the sound outside of the tank.

Figure 4-3. Photograph of experimental tank (with rainbow trout) being lifted out of the water.

Experimental groups were exposed to one of three test signals. These included: 1) MAX: maximum sound level; 2) MAX-6, 12, or 18: the maximum signal lowered by 6, 12, or 18 dB SPL; and 3) MAX*2: the maximum signal but at twice the duration of the MAX signal.

Each test consisted of three presentations of the LFA signal separated by a quiet period. In all but the MAX*2 experiment, sound presentations were 108 sec long and separated by 9 min of silence. In the MAX*2 trials, the LFA sound duration was 216 sec with an 18 min quiet period. The longer quiet interval was required with MAX*2 in order to allow the LFA transducer to cool. The overall test sequence for each tank was: slowly lower tank to depth–transmit signal–quiet–repeat signal–quiet–repeat signal–and then slowly raise the test tank to the surface.

The test signal consisted of three hyperbolic frequency-modulated (HFM) sweeps centered at 185 Hz with a 30-Hz bandwidth, 210-Hz tone, 220-Hz tone (labeled as Tone 2), 230-Hz tone, and three more HFM sweeps centered at 295 Hz with a 30-Hz bandwidth (Figure 4-4).

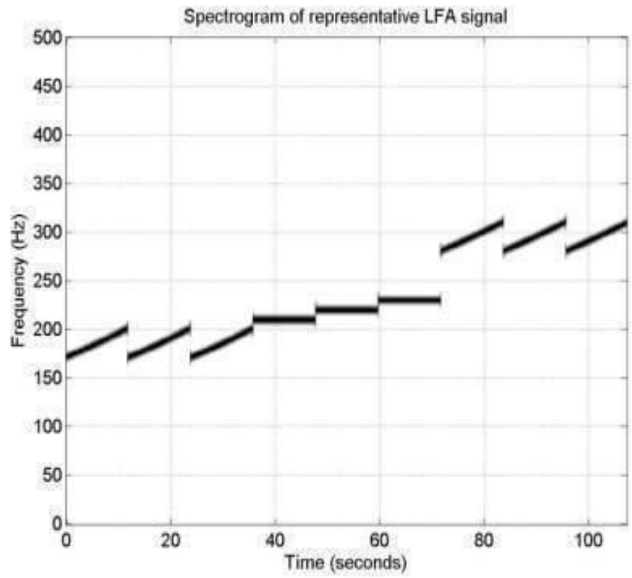
All test, control, and baseline animals were evaluated to determine hearing sensitivity using the AEP method. Fish were then sacrificed to determine any effects on inner ear structure. Additional fish from each group were sacrificed for analysis by an expert fish pathologist, who determined any effects on gross structure and tissue pathology.

- **Results of SURTASS LFA sonar study: Hearing tests**

The overall findings of the study (Popper et al., 2007) show the following with respect to effects on fish hearing:

1. No fish died as a result of exposure to the experimental source signals. Fish all appeared healthy and active until they were sacrificed or returned to the fish farm from which they were purchased.
2. Fish behavior[45] 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

[45] 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.



The signal was 108 sec long (except in MAX*2 tests where the signal was 216 sec long). Each test consisted of three presentations of this signal, separated by a 9 or 18-minute silent interval during which time the projector cooled down.

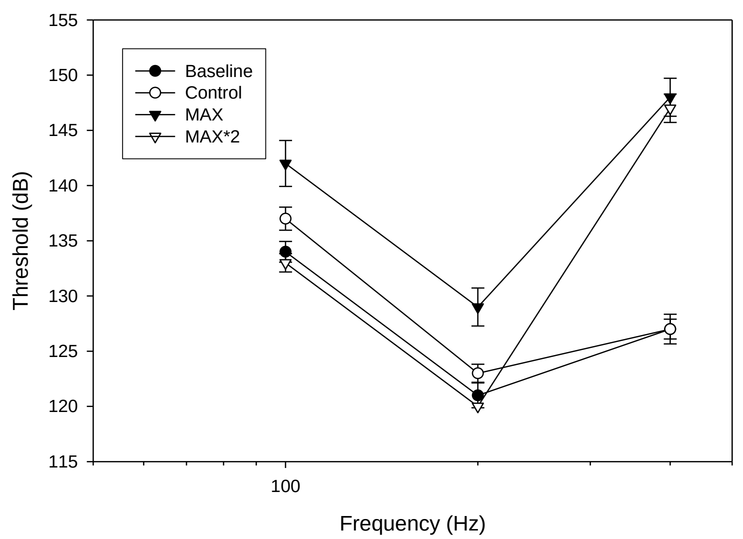
Figure 4-4. Schematic of one presentation of the LFA signal used in the SURTASS LFA sonar experiments.

showed an immediate quick "startle"[46] 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.

3. Catfish and some (but not all) specimens of rainbow trout showed 10 to 20 dB SPL of hearing loss immediately after exposure to the LFA sound when compared to baseline and control animals (Figure 4-5), 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, while it is over the complete range of frequencies (200 to 1,000 Hz) tested for catfish.
4. There is an interesting and potentially very important variation in the effects of exposure on trout. Some groups of trout showed hearing loss, while 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 their being obtained for study. The significance here is not only were there differences in the effects of sound on different species, but there may also be differences within a species, depending on environmental and other variables. However, and most importantly, under no circumstances did exposure to LFA sound result in unrecoverable hearing loss in rainbow trout, and there was no effect on any other organ systems (see below). While there is no direct evidence to support the differences in effect on different groups of rainbow trout, another study at the Laboratory of Aquatic Bioacoustics at the University of Maryland has shown that fish from the identical genetic stock (i.e., probably same

[46] 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.

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 effects of sound on fish, but also indicates that not all salmonids have their hearing affected by exposure to intense sounds.



These data are for rainbow trout and compare hearing for baseline and control animals, and animals that received MAX and MAX*2 signals. Data represent means and standard errors of the means. Note that maximum hearing loss occurred at 400 Hz where there was over a 20 dB SPL TTS. It is not clear why there was more hearing loss after MAX stimulation than MAX*2 but this could be related to signals being closer together in the former. (Note: the “thresholds” shown are not calibrated and so do not reflect the lowest sounds that fish necessarily hear at these frequencies.)

Figure 4-5. Examples of hearing data obtained in the SURTASS LFA sonar studies.

➢ ***Results of SURTASS LFA and mid-frequency sonar study: ear and non-auditory tissues***

As part of the SURTASS LFA study, and an accompanying study on the effects of mid-frequency (MF) sonar on fish (done in a manner identical to that for the SURTASS LFA), fish were examined for effects on the inner ear tissues responsible for hearing and on other non-auditory body tissues. Unlike all but one earlier study, the analysis of non-auditory tissues was carried out by an expert fish pathologist[47], whereas the analysis of inner ear tissue was conducted by an expert on fish inner ear structure[48]. Work was done to the highest standards of pathology to ensure that even the most subtle damage at the gross and cellular levels would be found.

Tissue for analysis of gross tissue pathology and histopathology (cellular structure) was taken from fish exposed to the same sounds, and under the same conditions, as fish tested for hearing changes. The tissue for inner ear studies were taken from fish sacrificed after they had been tested for hearing.[49] Preliminary results for rainbow trout were reported by Popper et al. (2007), where it was documented that there was no damage to any inner ear sensory cells and no pathology was found in any body structure at the gross and histopathologic level, including heart, brain, gills, swim bladder, kidney, or other tissues.

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[48] J. Song, Ph.D., Division of Fishes, National Museum of Natural History, Smithsonian Institution. Dr. Song’s current research focus is on understanding the new genotypical explanation of the peripheral innervation patterns for assessing morphological homologies in phylogenetic and systematic studies.

[49] This was not done for histopathology since any handling of fish in hearing tests could result in lesions (e.g., from handling during AEP tests), so a procedure was adopted to use animals from the exposure (and controls) that were not used in hearing tests.

Preliminary analysis of the LFA data was presented in a report by Kane (2007). Since the FSEIS (DoN, 2007a), more extensive analysis of exposed tissue has been completed for both the LFA and MFA studies. The results of this tissue analysis have undergone peer review and been published (Kane et al., 2010). The results from the examinations were direct and simple: 1) no pathological effects from LFA sound exposure up to 193 dB re 1 µPa (rms) RL; 2) no short- or long-term effects to ear tissue from LFA sound exposure up to 193 dB re 1 µPa (rms) RL; and 3) no pathological effects from exposure to MF sounds for 15 sec with a maximum received signal level of 210 dB re 1 µPa (rms).

- **Conclusions from SURTASS LFA sonar study**

The critical question addressed in the SURTASS LFA sonar study was whether this kind of sound source impairs the survival of fish and, more importantly, whether survival would be impaired in a normal environment when a ship using SURTASS LFA sonar is in the vicinity of a fish. In answering this question, several factors must be taken into consideration.

First, the sound level to which fish were exposed in these experiments was 193 dB re 1 µPa (rms) RL, a level that is only found within about 200 m (656 ft) of the LFA source array. Thus, the likelihood of exposure to this or a higher sound level is small, considering all the possible places a fish might be relative to the sound source. The volume of the ocean ensonified by a single SURTASS LFA sonar source at 193 dB re 1 µPa (rms) RL or higher is very small compared to the ocean area ensonified by the LFA source at lower sound levels.

Second, the LFA sound used in the study can be considered to represent a "worst-case" exposure. In effect, the exposure during the experiments was likely substantially greater than any exposure a fish might encounter in the wild. In the study described here, each fish received three exposures to a high-level LFA sound (a total of 324 sec in the MAX tests and 628 sec in the MAX*2 tests). However, under normal circumstances the SURTASS LFA sonar source is on a moving ship. A fish in one location will only receive maximum ensonification for a very few seconds (depending on ship speed and whether the fish is moving or not, and its direction of motion and speed). Prior to reaching the closest point of approach to the fish, or after the boat has moved on, the sound level would be much lower. Thus, rather than receiving 100 sec of maximum exposure, a fish would receive much less exposure. Since exposures at three to six times the maximum level did not cause damage to fish, and only what appears to be a temporary limited hearing loss, it is unlikely that a shorter exposure would result in any measurable hearing loss or non-auditory damage to fish unless they were so close to the SURTASS LFA sonar source that they received a maximum output.

Finally, it should be noted that 193 dB re 1 µPa (rms) RL had no real adverse effects on the fish tested. Even in an exposure scenario where fish were subject to the maximum output of a sonar array this exposure would be for a minimal period of time. While it was not possible to present a higher sound level to the fish in this experiment, it is very likely that a shorter exposure than 100 sec to an even higher sound level may not have adversely affected the fish. In effect, it is likely that fish could be even closer than 200 m (656 ft) to the source array and not be damaged by the sounds.

4.1.1.4 Additional Sonar Data

While there are no other data on the effects of LFA on fish, there is a recent study of some relevance, since it examined the effects on fish from sonar for the Norwegian Navy. In a report published in 2005, fish larvae and juvenile fish were exposed to simulated sonar signals in order to investigate potential effects on survival, development, and behavior (Jørgensen et al., 2005). The study used herring (*Clupea harengus*) (standard lengths 2 to 5 cm [0.79 to 2.0 in]), Atlantic cod (*Gadus morhua*) (standard length 2 and 6 cm [0.29 and 2.4 in]), saithe (*Pollachius virens*) (4 cm [1.6 in]), and spotted wolffish (*Anarhichas minor*) (4 cm [1.6 in]) at different developmental stages (Jørgensen et al., 2005). While the study's authors referred to these sonar sounds as low frequency, the Norwegian sonar signal's frequency (1.5 to

6.5 kHz) is higher than the signal used by SURTASS LFA sonar (100 to 500 Hz) and in the frequency range of U.S. Navy MFA sonar.

Fish in Jørgensen et al. (2005) were placed in plastic bags 3 m (9.8 ft) from the sonar source and exposed to between four and 100 pulses of 1-sec duration of pure tones at 1.5, 4, and 6.5 kHz. Sound levels at the location of the fish ranged from 150 to 189 dB re 1 µPa (rms) RL. The sounds were designed to mimic those of actual sonar signals used by the Norwegian Navy. The investigators found no effects on fish behavior during or after exposure to sound (other than some startle or panic movements by herring for sounds at 1.5 kHz). The investigators found no effect on behavior, growth (length and weight), or survival of fish kept as long as 34 days post-exposure (Jørgensen et al., 2005). All exposed animals were compared to controls that received similar treatment other than for exposure to the actual sound. Similar to the LFA studies (Popper et al., 2005a, 2007; Halvorsen et al., 2006; Kane et al., 2010), pathology of internal organs showed no damage as a result of sound exposure. The only exception to almost full survival was exposure of two groups of herring tested with SPLs of 189 dB re 1 µPa (rms) RL, where there was a post-exposure mortality of 20 to 30% (Jørgensen et al., 2005). While these were statistically significant losses, it is important to note that this sound level was only tested once and so it is not known if this increased mortality was due to the level of the test signal or to other unknown factors.

In another Norwegian study, but with wild fish, Doksæter et al., (2009) examined responses of killer whales and herring to what they call low frequency sonar (but 1 to 2 kHz) and mid frequency sonar (6 to 7 kHz). They monitored, using bottom-mounted echosounders, the response of over-wintering herring to sonar exposure from operational naval sonars towed above the fish. The results showed herring did not respond to either sonar, but they did show marked reaction to feeding sounds of killer whales (a predator of herring), indicating that the lack of response to sonar was because the sonar, unlike the killer whale sounds, did not bother the fish enough to evoke a behavioral reaction.

4.1.1.5 Extrapolation to Other Species

The results of the SURTASS LFA sonar study, as well as the recent studies on seismic airguns (Popper et al., 2005b; Hastings et al., 2008), should only be extrapolated to other species with considerable caution. This caution is based on potential differences among species in structure of the auditory system and hearing capabilities. As discussed below, the degree of hearing loss in a species may vary depending on the level of the signal above the hearing threshold of the fish. Other variables that may ultimately be involved in the amount of hearing loss are signal duration, frequency characteristics of the sound, and whether the sound is impulsive or coherent (including continuous sounds). The same variables may also affect the amount of non-auditory damage that might occur.

At the same time, the rainbow trout in the LFA study and the species in the seismic airgun studies differ considerably from one another in hearing structures, distribution of fish taxa, and hearing capabilities. None of these fish showed any tissue damage as a result of sound exposure, and hearing loss was relatively small (and non-existent in the Hastings et al., 2008 study) and recovery was fairly rapid. Thus, recognizing the need for caution when extrapolating among species, these results strongly indicate that SURTASS LFA sonar is likely to have a negligible impact on fish when they are exposed to underwater LFA sound signals within the decibel levels used in these studies.

Overview of Hearing Effects of Noise Exposure

In reviewing the results of their study and that of the few previous studies, Hastings et al. (1996) suggested that sounds 90 to 140 dB re 1 µPa (rms) above a fish's hearing threshold may potentially injure the inner ear of a fish. This suggestion was supported in the findings of Enger (1981) in which injury occurred only when the stimulus was 100 to 110 dB re 1 µPa (rms) above threshold at 200 to 250 Hz for the Atlantic cod. Hastings et al. (1996) derived the values of 90 to 140 dB re 1 µPa (rms) above threshold by examining the RLs that caused minimal injury in their test fish, the oscar, and then hypothesizing that extensive injury would require more energy. They suggest that RLs of 220 dB to 240 dB re 1 µPa (rms) would potentially cause extensive damage to sensory hair cells in non-specialist fish. Calculations for a hearing specialist such as the squirrelfish (*Myripristi berndti*) using the Hastings et al. (1996) values (i.e., 90 to 140 dB re 1 µPa [rms] above threshold) (see Figure 3-3) indicate RLs of 140 to 190 dB re 1 µPa (rms) continuously for at least one hour would be necessary to induce damage to inner ear sensory cells. Interestingly, exposure to about 190 dB dB re 1 μPa^2-sec SEL did not cause hearing loss in the pinecone soldier fish (*Myripristis murdjan)* (Hastings et al., 2008), a species that is likely to have hearing thresholds similar to the squirrelfish. Thereby, these results provide additional evidence to suggest that RLs of over 190 dB re 1 µPa (rms) will not result in hearing loss, much less damage to sensory cells.

The results of Smith et al. (2004a, 2004b, 2006) and Scholik and Yan (2001, 2002) provide further experimental evidence in support of the hypothesis proposed by Hastings et al. (1996). Moreover, Smith et al. (2004b) were able to use their data to hypothesize that noise-induced threshold shifts in fish may be somewhat linearly related to the sound pressure difference (SPD) between that of the noise and the baseline hearing threshold of the fish. They called this the *LIN*ear *T*hreshold *S*hift (LINTS) hypothesis. A similar finding has been reported in birds and mammals. The actual SPD required to cause TTS in a fish is very likely related to frequency since the baseline hearing threshold in fish varies by frequency. Other variables are likely to be the duration of sound exposure, whether the sound is continuous (as in the Smith et al., 2004a, 2004b experiments), or whether the sound is impulsive.

While these variables need further study, there is preliminary evidence that the LINTS hypothesis (Smith et al. 2004b) holds for impulsive as well as continuous signals. In an analysis of their airgun results, Popper et al. (2005b) found the same relationship for these sounds as found by Smith et al. (2004b) for continuous noise. Moreover, the Popper et al. (2005b) work examined several hearing generalists and, for the first time, used RLs that were sufficiently above threshold (therefore a large SPD) to result in TTS in such species. This is in contrast to the studies by Smith et al. (2004a, 2004b) and Scholik and Yan (2002) where there was no TTS in hearing generalists. Presumably, the lack of TTS in those generalists was because of an insufficiently high SPD between noise and the baseline hearing threshold.

Finally, the results from the SURTASS LFA sonar study further support the LINTS hypothesis, since both species tested generally followed predictable amounts of threshold shift based on the levels of sound exposure. This is significant since it extends the usefulness of the hypothesis beyond continuous pure tones and impulsive noise to modulated signals. At the same time, it is very likely that with a more detailed analysis of the hypothesis it will be possible to more broadly understand the effects of sounds at different frequencies, intensities, durations, and waveforms on hearing loss. However, at this point it would not be reasonable to use the LINTS hypothesis in any but the broadest sense here since there are too few data to permit ready extrapolation among species.

4.1.1.6 Behavioral Change

This issue concerns the behavior of fish near a high intensity underwater sound source, beyond effects on the ear itself. This is likely to be a much greater issue than physiological effects since it is possible that fish, as other animals, will show behavioral reactions and changes in response to sounds that are much lower than levels needed to cause hearing loss, or ear or non-auditory tissue damage. The potential behavioral impacts range from the possibility of fish avoiding the sound and thus changing their habitat (potential economic impact to subsistence fisheries) to possibly preventing fish from engaging in basic life functions such as breeding, feeding and sheltering (which could presumably result in fish stock declines).

One caveat to developing an understanding of effects of sounds on behavior is that such studies are only useful when fish are unconstrained. That is, if fish are in any kind of cage or tank, no matter what the size, it is possible that the physical barriers will result in behaviors that would not normally be encountered in the wild in response to exposure to the same type of signal. Even if the cage is large, such as in the study by Sarà et al. (2007) on behavior of bluefin tuna (*Thunnus thynnus*) in a large pen during exposure to nearby boats, there is reason to believe that the behavior of the fish could have been altered by the presence of the pen walls, and so the behavior reported, of fish swimming from boat noise, could have been an artifact of the fish "knowing" that they were confined.

Most studies that examined effects on behavior involved confined animals, and so the results must not be taken as indicative of how fish would respond in the wild. Klimley and Beavers (1998) played back a 75 Hz phase-modulated signal (37.5-Hz bandwidth) to three species of rockfish (*Sebastes flavidus*, *S. ariculatus,* and *S. mystinus*) (presumably, but not demonstrated to be, non-specialists) in a pen in Bodega Bay, CA. The RLs were 145 to 153 dB re 1 µPa (rms). The fish exhibited little movement during the playback of the low frequency signals, and the behavior did not differ from that exhibited during a control period during which the sound was not played. Fish that started out close to the sound source did not move away, nor was there any apparent movement toward the source during playback. Most fish occupied the zone closest to the sound projector the duration of the test and control periods.

Similarly, while the behavior of fish were observed during the investigations of the effects of SURTASS LFA sonar sounds on rainbow trout and channel catfish (Popper et al., 2005a), the fish were in a cage 1 m (3.3 ft) to a side, and so they were constrained from moving during sound exposure. Preliminary quantitative analysis of the results of these studies show that while rainbow trout exhibited a small response at the onset of the sounds, they quickly returned to their pre-stimulus behavior and continued this way for the duration of the sound presentation, and even when the specific components of the sound changed. Channel catfish, in contrast, generally showed an initial "startle"[50] response to the sound and then moved to the bottom of the test tank while most fish oriented themselves toward the sound source, and stayed in that position for the duration of the signal. Furthermore, they would show a "startle" response each time the specific sound changed. As soon as the sound was turned off, the fish would resume pre-stimulus patterns of swimming. At the same time, for both the Klimley and Beavers (1998) study and the more recent SURTASS LFA sonar study, how the fish might have reacted if they were able to swim away is not known.

Other studies, however, provide some evidence that the low frequency noise produced by fishing vessels and their associated gear results in fish avoiding the vessels (Maniwa, 1971; Suzuki et al., 1979; Konigaya, 1980; Soria et al., 2003; and see review in Mitson, 1995; Dalen et al., 2007a). Similar results have been found for incoherent, impulsive airgun sounds (Engås et al., 1996; McCauley et al., 2000; Engås and Løkkeborg, 2002; Slotte et al., 2004; reviewed in Dalen, 2007b). However, in each of these studies (other than McCauley et al., 2000), fish behavior was not actually observed and results were based on fish catch rates before and after presentation of sounds from a seismic airgun. Aside from the McCauley et al. (2000) study (which included fish behavior observations), it is possible that the other three studies (which used fish catch rates as a metric), may have perceived temporary changes in fish responses to trawls and long-lines, and that there was no other alteration in behavior or movements of the fish from the fishing sites. It is interesting, however that, using fish-finding sonar, Slotte et al. (2004) found that fish in the vicinity of the airguns appeared to go to greater depths after airgun exposure compared to their vertical position prior to the airgun usage. It should be noted, however, that the statistics in the fishing reports have been criticized by Gausland (2003) in a non-peer-reviewed report that suggested that declines in catch rate might be explained by other factors and that catch rates do not differ significantly from normal seasonal variation over several fishing seasons.

In one additional study, Hassel et al. (2004) examined effects of seismic airgun exposure on caged lesser sandeel (*Ammodytes marinus*). Received sound levels were not measured in the cages. Mortality for the sandeels was the same in experimental and control cages, and was attributed to deployment of the cages

[50] 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.

and handling and confinement of the animals. The authors reported a small decline in sandeel abundance in the study region shortly after the seismic activity, but this quickly returned to pre-seismic levels.

Effects of other types of sounds on caged fish were investigated by Kastelein et al. (2008), who indicated that some fish species would show a sharp startle response when suddenly presented with a sound. While none of the sounds was anything like LFA or other sonars, the critical result of the study of caged animals was that each species showed different responses (or no responses) to different sounds. While the responses may not have been typical of what might be seen in uncaged animals exposed to the same sound, the useful outcome of this study was to reinforce the issue raised by others that extrapolation between/among species with respect to response type and/or responses to different types of sounds must be done with extreme caution.

While not directly related to sonar, but of scientific interest since unrestrained fish were used, Wardle et al. (2001) used a video system mounted on a reef to examine the behaviors of fish and invertebrates after exposure to seismic airguns (maximum RL of 210 dB re 1 µPa (rms) at 16 m (53 ft) from the source and 195 dB re 1 µPa (rms) RL at 109 m (358 ft) from the source). The results showed no observable damage to any animals or changes in behavior, or that any animals left the reef during the course of the study. The aforementioned studies support the conclusions presented below.

4.1.1.7 Masking

A sound reaching a fish, even at levels lower than those that could potentially cause PTS or TTS, may have a significant impact by preventing the fish from detecting sounds that are biologically relevant, including communication sounds, sounds of prey, or sounds of predators (Myrberg, 1981; Popper et al., 2004). The obscuring of sounds of interest by interfering sounds, generally at similar frequencies is referred to as masking (Fletcher, 1929; Richardson et al., 1995b).

The studies on auditory masking in fish have been limited in the number of species studied. The results show that species that have been studied are generally affected by masking signals in much the same way as are terrestrial animals; most masking occurs when the masking sound is close in frequency to the sound being tested (Fay, 1974, 1988b; Fay and Megela-Simmons, 1999). If the masking signal is of significantly different frequency from the frequencies of importance to the fish, then much less (or no) masking may occur, although there is also some evidence that in at least some species, any noise signal may mask other signals, and that the degree of masking may be frequency-independent.

One of the problems with existing masking data is that the bulk of the studies have been done with goldfish (*Carassius auratus auratus*), a freshwater hearing specialist, where there may be a correlation between the degree of masking and how similar the masking signal and test signal are. The data on other species are much less extensive. As a result, little is known about masking in non-specialist fish. Tavolga (1967) was the first to study the effects of noise on pure-tone detection in two non-specialist fish species. He reported that the masking effect was generally a linear function of masking level, independent of frequency. His measurements were of tonal thresholds at the edges of a masking band centered at 500 Hz for the blue-striped grunt (*Haemulon sciurus*). Results suggested that there are critical bands for fish, as in mammals, and these have now been confirmed in other species (reviewed by Fay and Megela-Simmons, 1999). In addition, Buerkle (1968) studied five frequency bandwidths for Atlantic cod in the 20 to 340 Hz region. Chapman and Hawkins (1973) found that ambient noise at higher sea states in the ocean have masking effects in Atlantic cod, haddock, and pollock.

Most recently, Vasconcelos et al. (2007) examined, in a laboratory setting, whether broad-band boat noise could mask detection of hearing conspecific's sounds in the Lusitanian toadfish (*Halobatrachus didactylus*) (a sound-producing in-shore species that is never likely to encounter LFA or MFA sonar). Results of these lab-based experiments suggest that boat noise in the frequency range of best hearing in this species can result in masking. While this result confirms the idea that all fish can have hearing masked, it is difficult to extrapolate these data to determine the potential for masking in wild animals, since it is not clear in the setup used in this experiment whether the fish were subject to pressure or particle motion signals. This is particularly relevant since this species is very likely to primarily detect particle motion, and thresholds and signal levels for masking were determined in terms of pressure. Moreover, these were captive and restrained animals, so results may be questionable

Thus, based on limited data, it appears that for fish, as for mammals, masking may be most problematic in the frequency region of the signal. For SURTASS LFA sonar this would be whatever 30-Hz (approximate maximum) bandwidth signal is being transmitted (within the 100-500 Hz frequency band); although each transmitted signal changes frequency band within ten seconds, which would diminish the potential for any masking effects.

Therefore, existing evidence supports the hypothesis that masking could have an effect on fish, particularly those where predominant biological signals and best hearing frequencies occur at similar frequencies as the SURTASS LFA sonar. However, given the nominal 7.5% duty cycle and 60-second signal duration (average), masking would be temporary. Additionally, the 30-Hz (approximate maximum) bandwidth of SURTASS LFA sonar is only a small fraction of the animal's hearing range. Most fish have hearing bandwidths >30 Hz. In summary, masking effects are not expected to be severe, because the SURTASS LFA sonar bandwidth is very limited, signals do not remain at a single frequency for more than ten seconds, and the system is usually off over 90% of the time.

4.1.1.8 Conclusions for Potential Impacts on Fish (Class Osteichthyes) Stocks

If SURTASS LFA sonar operations occur in proximity to fish stocks, members of some fish species could potentially be affected by LF sounds. Even then, the impact on fish is likely to be minimal to negligible since only an inconsequential portion of any fish stock would be present within the 180-dB sound field at any given time. Moreover, recent results from direct studies of the effects of LFA sounds on fish (Popper et al., 2005a, 2007; Halvorsen et al., 2006; Kane et al., 2010) provide evidence that SURTASS LFA sonar sounds at relatively high levels (up to 193 dB re 1 µPa [rms] RL) have minimal impact on at least the species of fish that have been studied. Nevertheless, the 180-dB criterion is maintained for the analyses presented in this SEIS/SOEIS, with emphasis that this value is *highly conservative* and protective of fish.

<u>The Viability of a 180-dB Criterion</u>

Over the past two decades, regulators have sought to use a 180 dB re 1 µPa (rms) RL as the sound level at which any effect might occur on fish (though different organizations define the kind of effect that takes place at 180 dB re 1 µPa [rms] RL differently). However, recent data, and recent regulatory considerations, have substantially raised the level at which potential injury might come to fish, and this needs to be taken into consideration in terms of this analysis and future analyses of effects on fish. The basis for the increase comes from recent peer-reviewed scientific literature and regulator considerations.

<u>Recent Findings</u>

Several recent studies have shown that sounds substantially above 180 dB re 1 µPa (rms) RL have little or no effect on fish (Popper et al., 2005b, 2007; Hastings et al., 2008; Kane et al., 2010). In addition, a number of “gray literature” studies of pile driving (reviewed in Popper and Hastings, 2009b) have shown no damage to fish tissues when received sound levels are very high.

Perhaps the best of these gray literature studies was by Abbott et al. (2005) who investigated the effects of pile driving on caged fish of three species: shiner surfperch (*Cymatogaster aggregata*), Chinook salmon (*Oncorhynchus tshawytscha*), and northern anchovy (*<u>Engraulis</u> <u>mordax</u>*) at the Port of Oakland. The fish were caged at a distance of 9.75 m (32 ft) from the pile being driven and exposed to four minutes of pile driving (over 200 sound pulses) with average peak received SPL of 185-189 dB re 1 µPa. Following exposure, fish were sacrificed using excellent pathology methodology with appropriate controls. The results showed no differences in mortality or pathology between sound-exposed and control animals.

Other pile driving studies, while not nearly as well done as the Abbott et al. (2005) investigation (reviewed in Popper and Hastings, 2009b), also suggest that exposure to multiple presentations of very intense pile driving does not cause tissue damage in various species of fish. No studies have examined effects of pile driving on hearing.

Tissue damage has also been investigated in studies of seismic exposure (Popper et al., 2005b; Song et al., 2008) where fish were exposed to 5 or 20 blasts of seismic airguns with a received sound level of over 195 dB re 1 µPa (peak-to-peak). There was some temporary hearing loss in two species (discussed earlier) but not all species. No evidence of tissue damage to the swim bladder or other non-auditory tissues (though Popper et al. do point out that a qualified fish pathologist did not examine this tissue) and there was no damage to ear tissue, as evaluated by an expert (Song et al., 2008). Some damage was found to sensory hair cells in the ears of pink snapper after exposure to sounds of seismic airguns (McCauley et al., 2003). The differences in the results between the two studies are not fully understood, but may be due to the very different acoustic environments of the studies (Popper et al., 2005b). Interestingly, while McCauley et al. found some damage to sensory cells of the ears, there was no mortality (nor was there mortality in the Popper et al. [2007] study) even when fish were kept 58 days post-exposure. In the only sonar studies that examined tissue damage in other than larvae, investigations of the effects of SURTASS LFA sonar with a received sound level of 193 dB re 1 µPa (rms) resulted in no damage to auditory or non-auditory tissues (Popper et al., 2007; Kane et al., 2010) and no tissue damage was found for mid-frequency sonar at a received sound level of 210 dB re 1 µPa (rms) (Kane et al., 2010).

It is possible that sound could result in behavioral effects on fish and/or in hearing loss, as discussed previously. Popper et al. (2005b) found a very small level of hearing loss in two of three species studied, and some hearing loss was found after exposure to SURTASS LFA sonar in the hearing specialist catfish, and in some, but not all, rainbow trout (Popper et al., 2007). Most recently, Hastings et al. (2008) found no hearing loss at all in several reef fishes and minimal loss at a few frequencies in others, to cumulative SEL RL of 189 to 190 dB re 1 µPa^2-sec.

There have been no studies that examine actual behavioral changes in free-ranging fish[51] as a result of exposure to any kinds of sounds (see previous discussion). Thus, it is not yet clear if and how such sounds might change behavior.

While these results do not specifically address the issues of behavioral effects, it is clear that sound levels well above 180 dB re 1 µPa (rms) have no, or very little, physiological affect on fish. Moreover, in all cases where an effect has been shown, the effect has been the result of exposure to a much longer duration sound, and/or sounds with much sharper onsets, than the transient exposures fish would experience in encountering LFA sonar.

The major discussion related to noise criteria for fish has focused in areas related to pile driving in aquatic environments. Recommendations have been made for acceptable levels of pile driving sounds, with particular concern for accumulated exposure over many pile-driving strikes (usually about 1 second apart). While there is considerable controversy, and current rules are often not fully science-based (they tend to be far more conservative sound levels than warranted based on “best available science”), these results may be instructive as a starting point for re-setting the levels allowable for LFA sonar and fish (and considering the poor hearing sensitivity of sharks and marine turtles, for those species as well).

Current levels for pile driving allow for peak exposure of 206 dB re 1 µPa SPL for all sizes of fish (FHWG, 2008a). The basis of this is discussed in a memorandum of agreement from the FHWG of the same date (FHWG, 2008b). There are several aspects of this level that should be noted. First, these levels are for pile driving sounds with sharp onsets and very short signals as compared to LFA sonar with slow rise

[51] Studies of fish in cages or nets are not indicators of whether sound has an effect on behavior since the restraints themselves alter fish behavior.

times and longer signals. Second, the levels agreed to by the FHWG are below those recommended, based on the best available science, in a report to Caltrans by Popper et al. (2006) which was for a 208 dB re 1 μPa SPL peak exposure. Indeed, even the later report is probably too conservative since it was presented before data were available on responses to LFA (Popper et al., 2007) and seismic exposure (Hastings et al., 2008).

4.1.2 POTENTIAL IMPACTS ON FISH (CLASS CHONDRICHTHYES—CARTILAGINOUS FISH) STOCKS

There are only limited new data on the potential effects of low frequency underwater sound on sharks, rays and skates (subclass: Elasmobranchii) (see Subchapter 3.2.2.2). The most recent studies of several species of elasmobranches show hearing ranges that are comparable to earlier studies, but are measured in terms of particle motion, the stimulus parameter that is most likely the most important to animals without a swim bladder, such as elasmobranches (Casper et al., 2003; Casper and Mann, 2006 and 2007). As discussed in the FSEIS (DoN, 2007a), Casper et al. (2003) showed that the little skate, *Raja erinacea,* is able to detect sounds from 100 to over 800 Hz, with best hearing up to and possibly slightly greater than 500 Hz. More recent studies reported similar thresholds and hearing ranges for the nurse shark (*Ginglymostoma cirratum*), the yellow stingray (*Urobatis jamaicensis*) (Casper and Mann, 2006), the horn shark *Heterodontus francisci* and the white-spotted bamboo shark *Chiloscyllium plagiosum* (Casper and Mann, 2007) (see Figure 3-4). These are consistent with elasmobranch species being able to detect sounds up to 1000 Hz, with usable hearing limited to about 500 Hz.

The contents of Subchapter 4.1.2 of the FSEIS (DoN, 2007a) are incorporated herein by reference. The limited additional and updated information on the potential effects on sharks, rays, and skates from LFA sound are included in this SEIS/SOEIS, and are discussed below.

4.1.2.1 Non-Auditory Injury

In the absence of published, peer-reviewed reports on the potential for low frequency underwater sound to cause non-auditory and/or auditory (PTS) injury to elasmobranches (sharks, rays, and skates), the previous discussions regarding fish will be considered to also apply here. Recent results from direct studies of the effects of LFA sounds on fish found no damage to tissues either at the gross or cellular levels, and there were no fish mortalities (Popper et al., 2007; Kane et al., 2010) from an LFA sonar source at relative high levels (up to 193 dB re 1 μPa [rms] RL).

4.1.2.2 Permanent Loss of Hearing

Hearing capability in elasmobranches is on a par with, or poorer than, that of hearing non-specialist bony fish, and there is no evidence that any shark is a hearing specialist. Since the FSEIS (DoN, 2007a), there are no additional data on permanent hearing loss in sharks or on damage to the ears. Recent results from direct studies of the effects of LFA sounds on fish examined the long-term effects on sensory hair cells of the ear. In the species studies, even up to 96 hours post-exposure, there was no evidence of damage to sensory cells (Popper et al., 2005a, 2007; Halvorsen et al., 2006) from an LFA sonar source at relative high levels (up to 193 dB re 1 μPa [rms] RL). A very small fraction of any shark stock would be exposed to these levels, even in the absence of mitigation. While extrapolation from bony fish to elasmobranches is something that should be done with caution, since the ears and auditory systems are different, the lack of substantive effects on non-specialist bony fish may also be similar to that for sharks, rays, and skates. Therefore, the utilization of the 180-dB criterion for fish is also applied to elasmobranches (with emphasis that this value is *highly conservative* and protective of fish, sharks, rays, and skates).

4.1.2.3 Temporary Loss of Hearing

Since the FSEIS (DoN, 2007a), there are no scientific data on temporary hearing loss in sharks, rays, and skates. Therefore, because sharks are considered hearing non-specialists and assuming they have similar hearing sensitivities as non-specialist bony fish discussed previously, the potential for TTS to cause substantial deleterious effects on shark stocks due to SURTASS LFA sonar transmissions is probably very small. Moreover, because sharks are considered hearing non-specialists, the Hastings et al. (1996) suggestion, supported by the Smith et al. (2004a and 2004b) studies may potentially apply, indicating that RLs of 220 to 240 dB re 1 µPa (rms) would be required to temporarily affect their hearing capability. However, without additional studies on sharks, this suggestion must be considered speculative, and probably very conservative.

4.1.2.4 Behavioral Change (Attraction/Repulsion)

Since the FSEIS (DoN, 2007a), there are no additional scientific data on behavioral changes in sharks, rays, and skates from anthropogenic underwater sound. Some sharks are attracted to or withdraw from pulsing low frequency sounds, as discussed in Chapter 3. This attraction or repulsion behavioral response is not considered an issue of concern since: 1) the LFA signals are not "pulsed" or structured as are sounds made by struggling marine animals, and 2) the likelihood of a significant portion of any shark stock being in the vicinity of the SURTASS LFA sonar source at any one time should be considered negligible.

4.1.2.5 Behavioral Change (Migration)

As stated in the FSEIS (DoN, 2007a), there is a body of scientific evidence that oceanic sharks make directional migrations. This has been supported by recent research using tags and satellite tracking. Satellite telemetry of tagged white sharks during 1999-2005 has revealed long-distance seasonal migrations from the California coast to offshore focal areas 2,500 km (1,350 nmi) west of the Baja Peninsula, and also the Hawaiian Islands (Weng et al., 2007). Gore et al. (2008) reported transatlantic migration from off the British Isles to off the coast of Newfoundland, Canada.

In assessing the potential for SURTASS LFA sonar signals to affect shark migrations, it is noted that the LFA source frequency is between 100 and 500 Hz, a region of the acoustic spectrum where these species appear to be best able to hear sound, and can detect sounds with intensities below 180 dB re 1 µPa (rms) RL. The issue is whether one or more LFA sonar transmissions could possibly cause displacement of sharks or shark stocks from their migratory path, such that this activity might be disrupted to the extent that the sharks may be unable to re-establish their direction along the migratory path. There are no new data that contradict the conclusion in the FSEIS (DoN, 2007a) that it would be unlikely that significant impacts to shark migration would occur due to SURTASS LFA sonar operations in the open ocean.

4.1.2.6 Masking

Sharks use hearing to detect prey, and this detection ability may potentially be affected by masking. By way of example, Nelson and Johnson (1970) measured a lemon shark's (*Negaprion brevirostris*) hearing sensitivity to a 300 Hz, 130 dB SPL SL in two different sea states (sea states 1 and 2) and two different levels of vessel traffic (light and heavy). The shark's auditory threshold was decreased by 2 dB SPL for sea state 2 versus sea state 1, a level of difference that is probably not significant since it is certainly within the variation of the hearing ability of the animal. The difference caused by light versus heavy vessel traffic was 18 dB SPL (measured in sea state 1). This represented differences in masking ranges (distance from the animal that a sound or sounds would be masked) of 45 m (148 ft) for sea state 2 versus 1 (due to sea state alone) and 110 m (360 ft) for heavy versus light boat/ship traffic. Thus, it can be concluded that the masking range for sharks can be elevated by sea state and vessel traffic.

As in bony fish, masking effects could be most significant for sharks with critical bandwidths at the same frequencies as the SURTASS LFA sonar, assuming that masking mechanisms in sharks are similar to that in mammals. However, at a nominal 7.5% duty cycle and an average 60-second transmission window, any masking would probably be temporary since the intermittent nature of the signal reduces the potential impact. In summary, masking effects are not expected to be significant because the SURTASS LFA sonar bandwidth is very limited (approximately 30 Hz), signals do not remain at a single frequency for more than ten seconds, and the system is usually off over 90% of the time.

4.1.2.7 Conclusions for Potential Impacts on Fish (Class Chondrichthyes—Cartilaginous Fish) Stocks

The conclusion in Subchapter 4.1.2.7 of the FSEIS (DoN, 2007a) remains valid. Some sharks in a SURTASS LFA sonar operations area could possibly be affected by LFA sounds, but only if they were very close to the sound source. However, a negligible portion of any shark stock would be exposed to received levels at or above 180 dB re 1 µPa (rms) SPL on an annual basis due to the small size of the LFA mitigation zone (180-dB SPL sound field) relative to the open ocean areas inhabited by shark stocks. Despite the ability of sharks to detect low frequency sound and the possibility of affecting sharks that are migrating or aggregating at seamounts/islands, the potential for the SURTASS LFA sonar to affect shark stocks would not be significant.

4.2 POTENTIAL IMPACTS ON SEA TURTLE STOCKS

There are very few studies of the potential effects of underwater sound on sea turtles and most of these examined the effects of sounds of much longer duration or of different types (e.g., seismic airgun) than the SURTASS LFA sonar signals. This subchapter will provide summaries of the recent research and update the analysis of the potential effects of the proposed alternatives based on the following SURTASS LFA sonar operational parameters:

- Small number of SURTASS LFA sonar systems to be deployed;
- Geographic restrictions imposed on system employment;
- Narrow bandwidth of the SURTASS LFA sonar active signal (approximately 30 Hz);
- Slowly moving ship, coupled with low system duty cycle, would mean that a sea turtle would spend less time in the LFA mitigation zone (180-dB SPL sound field); therefore, with a ship speed of less than 5 kt, the potential for animals being in the sonar transmit beam during the estimated 7.5 to 10% of the time the sonar is actually transmitting is very low; and
- Small size of the LFA mitigation zone (180-dB SPL sound field) relative to open ocean areas.

Due to the lack of more definitive data on sea turtle stock distributions in the open ocean, it is not feasible to estimate the percentage of a stock that could be located in a SURTASS LFA sonar operations area at a potentially vulnerable depth, during an LFA sound transmission. Data on sea turtle sound production and hearing are very limited. The best available data on sea turtle hearing are presented in Chapter 3 of this document. Further, there are no new data that contradict any of the assumptions or conclusions regarding potential effects to sea turtles in Subchapter 4.2 of the FSEIS (DoN, 2007a), which is incorporated by reference herein.

4.2.1 NON-AUDITORY INJURY

There are no data on the potential for anthropogenic sound to cause injury in sea turtles. Although not directly related to SURTASS LFA sonar effects, a review of effects of explosives on turtles was done by Viada et al. (2008). For explosive structure removals in the Gulf of Mexico, NMFS specified that the area within 3,000 ft (915 m) of the platform must be clear of sea turtles. Therefore, using a value of 180-dB SPL injury threshold for sea turtles (within approximately 1,000 m [3,281 ft] of the LFA array) is conservative. The probability of a sea turtle being within the 180-dB mitigation zone is considered negligible because of the active acoustic and visual monitoring mitigation protocols, and the five SURTASS LFA sonar operational parameters listed above.

4.2.2 PERMANENT LOSS OF HEARING

Very little is known about sea turtle hearing and what, if anything, may cause a sea turtle to incur permanent loss of hearing. However, data support the premise that using a value of 180-dB injury threshold for sea turtles is conservative. A sea turtle would have to be within the LFA mitigation zone

(≥180 dB re 1 µPa [rms] RL) when the sonar was transmitting to be at risk of injury, including permanent loss of hearing (i.e., PTS).

Despite the lack of scientific data on the potential effects of low frequency sound on sea turtle hearing and on PTS in sea turtles caused by low frequency sound, the potential for SURTASS LFA sonar to cause PTS in sea turtles must be considered negligible.

4.2.3 TEMPORARY LOSS OF HEARING

As with PTS, there are no published scientific data on temporary loss of hearing in sea turtles caused by low frequency sound. As there are no new data that contradict any of the assumptions or conclusions in Subchapter 4.1.2 (Sea Turtles) in the FOEIS/EIS (DoN, 2001), its contents are incorporated by reference herein. Further, the five SURTASS LFA sonar operational parameters listed above support the conclusion that the potential for SURTASS LFA sonar to cause TTS in sea turtles must be considered to be negligible.

4.2.4 BEHAVIORAL CHANGE

Sea turtles can travel many kilometers per day in the open ocean, as shown in tagging studies (Keinath, 1993); and the use of magnetic positional information for long-range navigation has been demonstrated in several diverse animals, including sea turtles (Lohmann et al., 2007). Sea turtles make extensive migrations and movements either for foraging opportunities or to breed. Their migration tracks may extend to thousands of kilometers (Mortimer and Carr, 1987; Bowen et al., 1995; Eckert, 1998 and 1999; Avens and Lohmann, 2004).

This issue relates to the behavior of sea turtle stocks near a high intensity sound source, beyond effects on the animals' ears themselves. A change in behavior that causes prolonged displacement of animals from the site of their normal activities could be considered a deleterious effect. Displacement can occur in two dimensions: vertical and horizontal. For example, a sea turtle could move to the surface, where anthropogenic low frequency sound would be weaker, possibly exposing it to a higher degree of predation. As for horizontal displacement, this is probably of greatest importance for non-pelagic sea turtle species (green [*Chelonia mydas*], olive ridley [*Lepidochelys olivacea*], hawksbill [*Eretmochelys imbricate*], Kemp's ridley [*Lepidochelys kempi*]), for which displacement from preferred benthic habitats could be construed as more serious.

Behavioral responses to human activity have been investigated for only a few species of sea turtles: green and loggerhead (O'Hara and Wilcox, 1990; McCauley et al., 2000); and olive ridley, leatherbacks (*Dermochelys coriacea*), loggerhead, and 160 unidentified turtle (hard-shell species) (Weir, 2007). The work by O'Hara and Wilcox (1990) and McCauley et al. (2000) reported behavioral changes of sea turtles in response to seismic airguns. 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).

Weir (2007) reported observations on olive ridley, leatherbacks, loggerheads, and additional unidentified animals during a seismic operation off Angola (note, this study has only appeared on the internet, but the author indicates [pers. comm. with Dr. Arthur Popper, 2009] that this was peer reviewed). In this study, observers watched for turtles before and during seismic airgun surveys and reported on the number of animals encountered. In most of the 240 sightings of sea turtles (200 separate animals), it was not possible to comment on actual behavior since the animals were often more than 500 m (1,640 ft) from the observer, and most were just seen and not moving much on the surface. However, when diving behavior was observed, there were no differences between times when airguns were on or off. Similarly, the number of sea turtle sightings within 1,000 m (3,281 ft) of the airguns did not differ between when there was seismic survey activity or not. An important point arose from this study--that observations of sea turtles, much more than marine mammals, are significantly hampered in any but the lowest Beaufort sea state, since the animals are barely visible at the surface.

While the aforementioned studies are of some general interest, it is important to note that airguns used in those studies have an impulsive signal with a large bandwidth, high energy, and a short duration. Therefore, airgun signals cannot be directly compared with SURTASS LFA sonar, since the signal characteristics are very different, and the likelihood of effects on living tissue dissimilar as well.

Based on the hearing data, it is possible that if a sea turtle happened to be in proximity of a SURTASS LFA sonar operations area, it will hear the LF transmissions. Given that the majority of sea turtles encountered would probably be transiting in the open ocean from one site to another, the possibility of significant displacement would be unlikely. Further, the five SURTASS LFA sonar operational parameters listed above support the conclusion that the potential for SURTASS LFA sonar to cause behavioral changes in sea turtles must be considered to be negligible.

4.2.5 MASKING

One critical question to ask is whether there are sufficient anthropogenic sounds in the normal environment of sea turtles to suggest that hearing might be masked. While there have been no masking studies on marine turtles, an indirect study looked at the potential for masking by examining sounds in an area known to be inhabited by turtles. These underwater sound recordings were made in one of the major coastal foraging areas for juvenile sea turtles (mostly loggerhead, Kemp’s ridley and green sea turtles) in the Peconic Bay Estuary system in Long Island, NY (Samuel et al., 2005). The recording season of the underwater environment coincided with the sea turtle activity season in an inshore area where there is considerable boating and recreational activity, especially during the July to September timeframe. During this time period, RLs at the data collection hydrophone system in the 200 to 700 Hz band ranged from 83 dB re 1 µPa (rms) (night) up to 113 dB re 1 µPa (rms) (weekend day). Therefore, during much of the season when sea turtles are actively foraging in New York waters, they are undoubtedly exposed to these levels of noise, most of which is anthropogenic. However, there were no data collected on any behavioral changes in the sea turtles as a consequence of anthropogenic noise or otherwise during this study, so it cannot be stated whether this level of ambient sound would have any physiological and/or behavioral effects on the sea turtles.

Masking effects may occur for sea turtle species that have critical hearing bandwidths at the same frequencies as the SURTASS LFA sonar. However, masking would probably be temporary. The geographical restrictions imposed on all SURTASS LFA sonar operations would limit the potential for masking of sea turtles in the vicinity of their nesting sites. In summary, masking effects are not expected to be significant because of the nominal 7.5% duty cycle[52], the maximum 100-sec signal duration, the fact that the ship is always moving, the limited 30 Hz sonar bandwidth, and the signals not remaining at a single frequency for more than ten seconds.

4.2.6 POTENTIAL IMPACTS ON SEA TURTLES—CONCLUSIONS

Sea turtles could be affected if they are inside the LFA mitigation zone (180-dB sound field) during a SURTASS LFA sonar transmission. However, given that received levels from SURTASS LFA sonar operations would be below 180 dB re 1 µPa (rms) SPL within 22 km (12 nmi) or greater distance of any coastlines and offshore biologically important areas, effects to a sea turtle stock could occur only if a significant portion of the stock encountered the SURTASS LFA sonar vessel in the open ocean. Further, the majority of sea turtle species inhabit the earth’s oceanic temperate zones, where sound propagation is predominantly characterized by downward refraction (higher transmission loss, shorter range), rather

[52] Average duty cycle (ratio of sound “on” time to total time) of the SURTASS LFA sonar active transmission mode is less than 20%. The typical duty cycle, based on historical LFA operational parameters since 2003 is nominally 7.5 to 10%. During the remaining 80 to 92.5% of the time, LFA transmitters would be off, thus adding no sound to the water.

than ducting (lower transmission loss, longer range) which is usually found in cold-water regimes. These factors, plus the low distribution and density of sea turtles at ranges from the coast greater than 22 km (12 nmi), equate to a very small probability that a sea turtle could be found inside the LFA mitigation zone during a SURTASS LFA sonar transmission.

In the unlikely event that SURTASS LFA sonar operations coincide with a sea turtle "hot spot," the narrow bandwidth (approximately 30 Hz) of the SURTASS LFA sonar signal, the fact that the ship is always moving (coupled with low system duty cycle [estimated 7.5%], which means sea turtles would have less opportunity to be located in the LFA mitigation zone during a transmission), and the monitoring mitigation incorporated into the alternatives (visual and active acoustic [HF] monitoring) would minimize the probability of any effects on sea turtles in the vicinity. Therefore, the potential for SURTASS LFA sonar operations to expose sea turtle stocks to injurious (non-auditory and/or PTS) sound levels is considered negligible. For the same reasons, the potential for SURTASS LFA sonar to cause TTS and/or behavioral changes in sea turtles must also be considered negligible. Any masking effects would be considered temporary and not significant.

4.3 POTENTIAL IMPACTS ON MARINE MAMMALS

Potential effects on marine mammals from SURTASS LFA sonar operations include: 1) non-auditory injury; 2) permanent loss of hearing; 3) temporary loss of hearing; 4) behavioral change; and 5) masking. Richardson et al. (1995) provided the most comprehensive review of contemporary knowledge on the sources and effects of anthropogenic noise on marine mammals, and Nowacek et al. (2007) provide a more recent review of the effects of anthropogenic noise on cetaceans. Nowacek et al. (2007) included an update on the documented behavioral, acoustic and some physiological responses of cetaceans to man-made noise. They focused on literature that reported quantitatively on the sound field and some indicator of response. Southall et al. (2007) reported on the results from a panel of acoustic research experts in the behavioral, physiological, and physical disciplines. The panel's purpose was to review the expanding literature on marine mammal hearing, and physiological and behavioral responses to anthropogenic sound, with the objective of proposing exposure criteria for certain effects. More recently, Hatch et al. (2008) and Clark et al. (2009) have addressed the issue of acoustic masking and presented metrics for quantifying the influences of anthropogenic noise sources on whales that communicate in the low frequency band.

These papers, additional literature reviews, and research indicate that there are no new data that contradict any of the assumptions or conclusions in the FOEIS/EIS (DoN, 2001) and the FSEIS (DoN, 2007a). Thus, the findings presented in the SURTASS LFA sonar FOEIS/EIS and the FSEIS regarding potential impacts on marine mammals remain valid and are incorporated by reference herein. This subchapter provides a summary of the recent literature reviews and the overall potential for impacts of SURTASS LFA sonar operations on marine mammals.

4.3.1 NON-AUDITORY INJURY

Nowacek et al. (2007) and Southall et al. (2007) reviewed potential areas for non-auditory injury to marine mammals from active sonar transmissions. These include direct acoustic impact on tissue, indirect acoustic impact on tissue surrounding a structure, and acoustically mediated bubble growth within tissues from supersaturated dissolved nitrogen gas. They presented no additional or new data that contradict any of the assumptions or conclusions in the FOEIS/EIS and the FSEIS.

4.3.1.1 Direct Acoustic Impacts

Physical effects, such as direct acoustic trauma or acoustically enhanced bubble growth, require relatively intense received energy that would only occur at short distances from high-powered sonar sources (Nowacek et al., 2007; Zimmer and Tyack, 2007).

As summarized in the FSEIS, the best available scientific information shows that, while resonance can occur in marine animals, this resonance does not necessarily cause injury, and any such injury is not expected to occur below a received sound pressure level (RL) of 180 dB re 1 µPa (rms). Damage to the lungs and large sinus cavities of cetaceans from air space resonance is not regarded as a likely significant non-auditory injury because resonance frequencies of marine mammal lungs are below that of the LFA signal (Finneran, 2003). Further, biological tissues are heavily damped and tissue displacement at resonance is predicted to be exceedingly small. In addition, lung tissue damage is generally uncommon in acoustic-related strandings (Southall et al., 2007).

4.3.1.2 Gas Bubble Formation

Presently, there are discussions among researchers on whether or not marine mammals can suffer from a form of decompression sickness caused by in vivo nitrogen gas-bubble growth. Jepson et al. (2003, 2005) and Fernandez et al. (2005) reported results of necropsies of stranded beaked whales, some of which coincided with naval sonar exercises, which they interpreted as consistent with a decompression-like syndrome (Nowacek et al., 2007).

Scientists have documented bone lesions (osteonecrosis), which may be a chronic result of nitrogen bubbles, in the rib and chevron bone articulations, nasal bones, and deltoid crests of sperm whale specimens from the Atlantic and Pacific oceans dating from the late 1800s to 2003, (Moore and Early, 2004). This suggests that nonlethal pathologies related to gas bubbles may occur during the normal life span of, at least, the deep-diving sperm whale.

Houser (2007) assessed the potential for nitrogen bubble formation in a trained dolphin. Based on repetitive dives to depths of 10, 30, 50, 70, and 100 m (32.8, 98.4, 164, 230, and 328 ft), ultrasound inspections were completed on the portal and innominate veins (i.e., the left and right brachiocephalic veins). Blood samples were also taken over a 20-min period at the end of each of the 50, 70, and 100 m (164, 230, and 328 ft) dives for the assessment of nitrogen partial pressure. There were no vascular bubbles found in any post-dive ultrasound. Nitrogen partial pressures from blood samples were not significantly elevated from those of the dolphin at rest (20 min post dive). Results suggest that repetitive, prolonged dives up to 100 m (328 ft) accumulate insufficient nitrogen to generate asymptomatic intravascular bubbles in bottlenose dolphins.

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

Baird et al. (2008) investigated the variation in diving behavior from time-depth recorders on six Blainville's and two Cuvier's beaked whales. Both species demonstrated ascent rates from dives deeper than 800 m (2,625 ft) that were significantly slower than decent rates, both during the day and at night, suggesting some physiological purpose for the slower ascents. The whales also spent more time in dives to mid-water depths (100 to 600 m [328 to 1,969 ft]) during the day. At night, the whales spent more time in shallow (<100 m) dives. This diel variation[53] in behavior suggests that beaked whales may spend less time in surface waters during the day to avoid visually oriented predators, including sharks and killer whales.

Fahlman et al. (2009) modeled the effects of lung compression and collapse (pulmonary shunt) on the uptake and removal of O_2, CO_2, and N_2 in blood and tissue, and on end-dive nitrogen concentrations for breath-holding marine mammals (e.g., elephant seals, Weddell seals, and beaked whales). Fahlman et al. suggested that repeated dives might result in tissue and blood levels of nitrogen sufficient to cause symptomatic bubble formation.

Based on the current knowledge of gas exchange and physiology of marine mammals, Hooker et al. (2009) developed a mathematical model to predict blood and tissue levels of nitrogen gas for three species of beaked whales: northern bottlenose, Cuvier's, and Blainville's beaked whales. They suggested that deep-diving marine mammals live with, and manage high levels of nitrogen gas in their tissues and blood. Because of differences in dive behavior, predicted nitrogen levels were higher in Cuvier's beaked whales than in northern bottlenose whales and Blainville's beaked whales. The authors state that while the prevalence of Cuvier's beaked whale strandings after naval sonar exercises could be explained by a higher abundance of the species in the area, their results suggest that species differences in behavior and/or physiology may also play a role.

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

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

As is shown by the above discussions, the hypothesis for gas bubble formation related to beaked whale strandings is that beaked whales potentially have strong avoidance responses to sounds similar to their main predator, the killer whale (Cox et al., 2006; Southall et al., 2007; Zimmer and Tyack, 2007; Baird et al., 2008; Hooker et al., 2009). Because SURTASS LFA sonar transmissions are lower in frequency (<500 Hz) and dissimilar in characteristics from those of marine mammal predators, the above scientific studies do not provide additional evidence that SURTASS LFA sonar has caused behavioral reactions, specifically avoidance responses, in beaked whales. Thus, there are no additional or new data to

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

contradict any of the assumptions or conclusions in the FOEIS/EIS and/or the FSEIS that SURTASS LFA sonar transmissions are not expected to cause gas bubble formation or beaked whale strandings.

4.3.1.3 Injury Criteria

Southall et al. (2007) proposed injury criteria for individual LF/MF/HF marine mammal groups exposed to non-pulsed sound type, which included discrete acoustic exposures from SURTASS LFA sonar. The proposed injury criteria, which are based on onset of PTS, for LF/MF/HF cetaceans are an SEL of 215 dB re 1 μPa^2-sec and for pinnipeds in water an SEL of 203 dB re 1 μPa^2-sec. These values are then adjusted for the longer LFA signal (nominally 60 seconds), using 10 Log (T/Ti) where T is 60 sec and Ti is 1 sec. An 18-dB adjustment is made, resulting in an injury criterion for SURTASS LFA sonar of an SEL of 197 dB RL for cetaceans. For pinnipeds in water, this adjusted value would be an SEL of 185 dB re 1 μPa^2-sec RL. This provides further scientific support that the SURTASS LFA sonar injury criterion for all marine mammals of 180 dB SPL RL is conservative.

4.3.2 AUDITORY EFFECTS OF SOUND ON MARINE MAMMALS

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

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

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

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

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

Despite the increased interest in characterizing the auditory system of beaked whales, direct data on their biosonar receiving systems are sparse. Cook et al. (2006) measured AEPs in a stranded juvenile Gervais' beaked whale between 5 and 80 kHz (lowest and highest frequencies tested, respectively). Cook et al. found that the beaked whale was most sensitive to high frequency signals between 40 and 80 kHz. At 5 kHz, there was a detectable evoked potential (EP) at an SPL of 132 dB dB re 1 µPa (rms) RL, meaning that the behavioral threshold of the Gervais' beaked whale would be lower than 132 dB dB re 1 µPa (rms) SPL (Cook et al., 2006). Finneran et al. (2009) used AEP measurements to determine the upper cutoff frequency of hearing in a stranded adult Gervais' beaked whale. It was determined to be 80 to 90 kHz, which is substantially lower than that seen in dolphins (~120 to 150 kHz), but similar to killer whales. The hearing sensitivities measured by Cook et al. (2006) at 5 kHz are similar to or less than those of bottlenose dolphins, and do not support the hypothesis that these species have particularly high sensitivity at the frequencies used by MFA sonar.

There has been research into the procedures for audiograms, especially relating to the refinement of techniques for AEP methods and interpretation of results (Houser and Finneran, 2006; Finneran et al., 2007; Finneran, 2008, 2009; Mooney et al., 2009a). The results of updated literature reviews and research information on the hearing capabilities and sound production of marine mammals that potentially could be affected by SURTASS LFA sonar are provided in Chapter 3.

4.3.2.1 Permanent Loss of Hearing

The FOEIS/EIS (DoN, 2001) defined PTS as the deterioration of hearing due to prolonged or repeated exposure to sounds which accelerate the normal process of gradual hearing loss (Kryter, 1985), and the permanent hearing damage from brief exposure to extremely high sound levels (Richardson et al., 1995). PTS results in a permanent elevation in hearing threshold—an unrecoverable reduction in hearing sensitivity (Southall et al., 2007). Therefore, PTS is considered an injury.

In the initial Rule for SURTASS LFA sonar (NOAA, 2002b), NMFS stated that TTS is not an injury. Since the boundary line between TTS and PTS is neither clear, definitive, nor predictable for marine mammals, NMFS adopted the standard that 20 dB of threshold shift defines the onset of PTS (i.e., a shift of 20 dB in hearing threshold) (NOAA, 2002b). NMFS used this same standard in the second Rule (NOAA, 2007c). As discussed previously in this chapter, Southall et al. (2007) proposed injury criteria for individual LF/MF/HF marine mammals exposed to non-pulsed sound types, which included discrete acoustic exposures from SURTASS LFA sonar. The proposed injury criteria for cetaceans and pinnipeds in water are SELs of 215 dB re 1 μPa^2-sec RL and 203 dB re 1 μPa^2-sec RL, respectively. As presented earlier, an 18-dB adjustment must be made for the longer LFA signal (nominally 60 seconds) resulting in injury criteria for SURTASS LFA sonar for LF/MF/HF cetaceans of a SEL of 197 dB re 1 μPa^2-sec RL and for pinnipeds in water an SEL of 185 dB RL. The FOEIS/EIS and FSEIS injury criterion for all marine mammals was an SPL of 180 dB RL, which is noticeably lower and, therefore, more conservative, than the injury criteria proposed by Southall et al. (2007). Thus, the probability of SURTASS LFA sonar transmissions (with mitigation) causing PTS in marine mammals is considered negligible.

4.3.2.2 Temporary Loss of Hearing

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

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

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

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

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

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

SELs necessary for TTS onset for pinnipeds in water have been measured for harbor seals, California sea lions, and northern elephant seals. As reported by Southall et al. (2007), Kastak et al. (2005) presented comparative analysis of underwater TTS for pinnipeds. This indicated that in harbor seals, a TTS of ~6 dB SPL occurred with a 25-min exposure to 2.5 kHz octave-band noise of 152 dB re 1 µPa (rms) SPL (183 dB re 1 µPa^2-sec SEL); a California sea lion showed TTS-onset under the same conditions at 174 dB re 1 µPa (rms) SPL (206 dB re 1 µPa^2-sec SEL); and a northern elephant seal under the same conditions experienced TTS-onset at 172 dB re 1 µPa (rms) SPL (204 dB re 1 µPa^2-sec SEL). Finneran et al. (2003) exposed two California sea lions to single underwater pulses from an arc-gap transducer and found no measurable TTS following exposures of up to 183 dB re 1 µPa (rms) SPL (215 dB re 1 µPa^2-sec SEL).

Animals suffering from TTS over longer periods of time, such as hours to days, may be considered to have a change in a biologically significant behavior, as they may be prevented from detecting sounds that are biologically relevant, including communication sounds, sounds of prey, or sounds of predators. As noted by Mooney et al. (2009a), shorter duration sound exposures can require greater sound energy to induce TTS than longer duration exposures, and longer duration exposures can induce greater amounts of TTS. In assessing the potential for LFA sonar transmissions to cause TTS, the much shorter length of the LFA signal (1 min) versus the above studies (2 to 30 min) must be considered. The more recent scientific information presented in this subchapter support the assumptions and findings of the FOEIS/EIS and FSEIS. Therefore, they do not constitute substantial changes to the knowledge or understanding for the potential effects of LFA sonar to cause temporary loss of hearing in marine mammals. The information in the FOEIS/EIS Subchapters 1.4.2 and 4.2.7, taken in the context of temporary loss of hearing (i.e., TTS), remains valid, and the contents are incorporated by reference herein.

4.3.2.3 Behavioral Change

The primary potential deleterious effect from SURTASS LFA sonar is change in a biologically significant behavior[54]. For military readiness activities, such as the use of SURTASS LFA sonar, Level B “harassment” under the MMPA is defined as any act that disturbs or is likely to disturb a marine mammal by causing disruption of natural behavioral patterns to a point where the patterns are abandoned or significantly altered. Behaviors include migration, surfacing, nursing, breeding, feeding, and sheltering. The National Research Council (NRC, 2005) discussed biologically significant behaviors and possible effects and stated that an action or activity becomes biologically significant to an individual animal when it affects the ability of the animal to grow, survive, and reproduce. These are the effects on individuals that can have population-level consequences and affect the viability of the species (NRC, 2005).

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

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

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

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

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

Southall et al. (2007) reviewed the relatively extensive behavioral observations of low frequency cetaceans exposed to non-pulse sources. While there are clearly major areas of uncertainty, they concluded that these papers indicated that there were no (or very limited) responses to RLs of 90 dB to

120 dB re 1 µPa (rms) SPL with an increasing probability of avoidance and other behavioral effects in the 120 to 160 dB re 1 µPa (rms) SPL (RL) range. This is consistent with both the FOEIS/EIS and FSEIS.

4.3.2.4 Masking

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

Acoustic masking from low frequency ocean noise is increasingly being considered as a threat, especially to low frequency hearing specialists such as baleen whales (Clark et al., 2009). Most underwater low frequency anthropogenic noise is generated by commercial shipping, which has contributed to the increase in oceanic background noise over the past 150 years (Parks et al., 2007). This is discussed in Chapter 3. Shipping noise is primarily in the 20 to 200 Hz frequency band and is increasing yearly (Ross, 2005). Andrew et al. (2002) demonstrated an increase in oceanic ambient noise of 10 dB SPL since 1963 in the 20 to 80 Hz frequency band as sampled on the continental slope off Point Sur, California, and they ascribed this increase to increased commercial shipping. McDonald et al. (2006a) compared data sets from 1964 to 1966 and 2003 to 2004 for continuous measurements west of San Nicolas Island, California, and found an increase in ambient noise levels of 10 to 12 dB SPL in the 30 to 50 Hz band. This increase in LF background noise is likely having a widespread impact on marine mammal low frequency hearing specialists by reducing their access to acoustic information essential for conspecific communication and other biologically important activities, such as navigation and prey/predator detection. Clark et al. (2009) considered this long-term, large-scale increase in low frequency background noise a chronic impact that results in a reduction in communication space, and the loss of acoustic habitat.

Marine Mammal Behavioral Responses to Masking Sounds

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

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

SURTASS LFA Sonar Potential for Masking

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

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

Conclusions

The recent research reviewed above provides no substantial changes to the knowledge or understanding for the potential of SURTASS LFA sonar to cause acoustic masking in marine mammals that would change the information and conclusions in Subchapter 4.2.7.7 of the FOEIS/EIS and Subchapters 4.3.5, 4.3.6, and 4.6.1.2 of the FSEIS. In fact, these recent studies provide additional support for the statement in the FOEIS/EIS that broadband low frequency shipping noise is likely to be more detrimental than low duty-cycle SURTASS LFA sonar (Andrew et al., 2002; McDonald et al., 2006a; Parks et al., 2007; Clark et al., 2009). Therefore, the subchapters noted above of the FOEIS/EIS and FSEIS remain valid, and the contents are incorporated by reference herein; any masking in marine mammals due to narrowband, intermittent (low duty cycle) LFA sonar signal transmissions are expected to be minimal and unlikely.

4.3.2.5 Estimation of the Influence of LFA Signal Waveforms

As presented in Chapter 2, the typical LFA signal is not a constant tone, but rather a transmission of various waveforms that vary in frequency and duration. A complete sequence of sound transmissions is referred to as a wavetrain (also known as a "ping"). LFA wavetrains last between 6 and 100 sec with an average length of 60 sec. Within each wavetrain the duration of each continuous frequency sound transmission is no longer than 10 sec. Questions have been raised concerning the characteristics of the transmitted LFA waveform type (i.e., whether the signal is a continuous wave [CW] that is a single frequency, or a frequency-modulated [FM] waveform--one that sweeps through a range of frequencies), could potentially affect marine mammals differently. To date, no specific scientific investigation has been made into this question, and there are no papers that directly compare the results of various waveforms with potential impacts. A review of the discussion in Subchapter 4.3.2 of this document, or Southall et al. (2007), or the numerous published scientific papers on the subject, in general, show that these studies typically use either a CW waveform or a broadband “pulsed” signal as defined in Southall et al. (2007) (i.e., either an airgun, explosive or a source meant to simulate an airgun or explosive).

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

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

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

4.3.3 Potential for Mortality: Marine Mammal Mass Stranding and Unusual Mortality Events[55]

Stranding occurs when marine mammals passively (unintentionally) or purposefully come ashore either alive, but debilitated or disoriented, or dead. Although some species of marine mammals, such as pinnipeds, routinely come ashore during all or part of their life history, stranded marine mammals are differentiated by their helplessness ashore and inability to cope with or survive their stranded situation (i.e., they are outside their natural habitat and survival envelope) (Geraci and Lounsbury, 2005). In the U.S., the MMPA defines a stranding as: a) a marine mammal is dead and is (i) on a beach or shore of the U.S.; or (ii) in waters under the jurisdiction of the U.S. (including any navigable waters); or b) a marine mammal is alive and is (i) on a beach or shore of the U.S. and is unable to return to the water; (ii) on a beach or shore of the U.S. and, although able to return to the water, is in need of apparent medical attention; or (iii) in the waters under the jurisdiction of the U.S. (including any navigable waters) but is unable to return to its natural habitat under its own power or without assistance (16 U.S. Code §1421h).

Strandings of multiple marine mammals or mass strandings, however, occur only rarely. A mass stranding of marine mammals is the stranding of two or more unrelated cetaceans (i.e., not a mother-calf pair) of the same species coming ashore at the same time and place (Geraci and Lounsbury, 2005). Mass

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

strandings typically involve pelagic odontocete marine mammal species that occur infrequently in coastal waters and are usually typified by highly developed social bonds. Marine mammal strandings and mortality events are natural events that have been recorded historically from as early as 350 B.C. (Aristotle, ca. 350 B.C.), and such events continue to occur throughout the world's oceans.

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

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

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

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

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

4.3.3.1 Strandings near SURTASS LFA Sonar Operating Areas

2009 Philippines Stranding Events

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

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

Japanese Stranding Records

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

4.3.3.2 Strandings Possibly Involving Military Sonar or Beaked Whales

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

Spain (2006)

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

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

Cornwall, United Kingdom (2008)

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

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

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

4.3.3.3 Conclusions—Marine Mammal Mass Stranding and Unusual Mortality Events

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

4.3.4 Potential Impacts on Marine Mammals—Conclusions

The potential effects from SURTASS LFA sonar operations on any stock of marine mammals from injury (non-auditory or permanent loss of hearing) are considered negligible, and the potential effects on the stock of any marine mammal from temporary loss of hearing or behavioral change (significant change in a biologically important behavior) are considered minimal. Any auditory masking in marine mammals due to LFA sonar signal transmissions is not expected to be severe and would be temporary. The likelihood of LFA sonar transmissions causing marine mammals to strand is negligible.

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

The goal of the risk assessment is to analyze the proposed action and alternatives for the employment by the U.S. Navy of up to four SURTASS LFA sonar systems for routine training, testing, and military operations in the oceanic areas (see Figure 1-1). Based on current operational requirements, exercises using these sonar systems could occur in the Pacific, Atlantic, and Indian oceans, and the Mediterranean Sea. These potential operating areas are the same as those assessed in the SURTASS LFA sonar 2001 FOEIS/EIS and 2007 FSEIS (DoN, 2001 and 2007a), except for additional offshore biologically important areas (OBIA). To reduce adverse effects on the marine environment, areas would be excluded as necessary to prevent 180-dB SPL or greater within a specific geographic range of land and in OBIAs during biologically important seasons, and to prevent greater than 145-dB SPL at known recreational and commercial dive sites.

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

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

Since it was neither reasonable nor practicable to model all areas of the world's oceans in which SURTASS LFA sonar could operate, the initial risk assessment in the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001) analyzed 31 potential operating sites as discussed below.

This initial analytical process was refined to provide sensitivity and risk analyses sufficient to identify and select potential SURTASS LFA sonar mission areas with minimal marine mammal/animal activity consistent with the Navy's operational readiness requirements. These analyses were used to provide NMFS with reasonable and realistic pre- and post-operational risk estimates for marine mammal stocks in the proposed SURTASS LFA sonar operating areas. This process was documented in the SURTASS LFA Sonar FSEIS (DoN, 2007a).

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

4.4.1 MARINE MAMMAL IMPACT ANALYSIS

As previously discussed in this chapter, the types of potential effects on marine mammals from SURTASS LFA sonar operations include: 1) non-auditory injury; 2) permanent loss of hearing; 3) temporary loss of hearing; 4) behavioral change; and 5) masking. The details of how these potential effects were analyzed and details of the historical precedence and scientific justifications are provided in this chapter and Appendix C.

The first two potential effects listed above (i.e., non-auditory physical effects and permanent loss of hearing) are typically grouped together and constitute "injury effects" or Level A harassments as defined in the MMPA. Based on Southall et al. (2007), and adjusting for the longer LFA signal, the proposed injury criteria for SURTASS LFA sonar of a sound exposure level (SEL) of 197 dB re 1 μPa^2-sec received level (RL) for cetaceans. For pinnipeds in water, this adjusted value would be an SEL of 185 dB re 1 μPa^2-sec RL. Please note that due to the long duration of the LFA signal (i.e., nominally 60 seconds), the SEL criteria from Southall et al. (2007) is always the dominant of the dual criteria identified there. Additionally, based on simple spherical spreading (i.e., a transmission loss [TL] based on 20×Log10 [range in meters]) and assuming that the LFA array is a point source, a cetacean would need to approach and remain within approximately 33 m (108 ft) of the LFA source array (while a pinniped would need to be within 130 m [427 ft] of the array) for the complete 60 sec of the transmission to exceed the Southall et al. (2007) injury thresholds. Based on the mitigation procedures used during LFA sonar operations, the chances of this occurring are negligible. Therefore, no Level A harassment under the MMPA is expected.

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

4.4.2 INITIAL RISK ASSESSMENT OF POTENTIAL IMPACTS TO MARINE MAMMALS

The initial risk assessment of potential impacts to marine mammals from the operation of SURTASS LFA sonar was detailed in the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001); this detailed analysis covered the major oceanic regions of the world and analyzed 31 acoustic modeling sites (Figure 4.2-1 and Table 4.2-1 of that document). Marine mammal data were developed from the most recent NMFS stock assessment reports at the time and pertinent multinational scientific literature containing marine mammal distribution, abundance, and/or density datasets. The locations were chosen to represent reasonable sites for each of the three major underwater sound propagation regimes where SURTASS LFA sonar could be employed and included:

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

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

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

These sites represented the upper bound of effects (both in terms of possible acoustic propagation conditions, and in terms of marine mammal population and density) that could be expected from operation of the SURTASS LFA sonar system. In other words, the analyses of these 31 sites could be considered “worst-case” scenarios. Thus, if SURTASS LFA sonar operations were conducted in an area that was not acoustically modeled in the FOEIS/EIS and was lower in marine mammal abundances and densities, the potential effects would most likely be less than those obtained from the most similar site in the analyses presented. Effectively, these conservative assumptions of the FOEIS/EIS are still valid. Moreover, since there are no new data that contradict any of the assumptions or conclusions made in Subchapter 4.2 (Potential Impacts on Marine Mammals) of the FOEIS/EIS (DoN, 2001), its contents are incorporated by reference herein.

4.4.3 SENSITIVITY/RISK ASSESSMENT APPROACH

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

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

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

The Navy is required under the conditions of the current 5-year Rule and LOAs to submit classified quarterly mission reports for each SURTASS LFA sonar vessel for missions completed during the quarter in which active LFA transmissions are employed. The required elements for these reports include estimates of the percentage of marine mammal stocks affected (both for the quarter and cumulative for the year covered by the LOAs) by SURTASS LFA sonar operations based on predictive modeling, and actual operating locations, dates/times of operations, system characteristics, oceanographic environmental conditions, and animal demographics. The total annual risks for potentially affected stocks of marine mammal species are estimated by summing a particular species' risk estimates within each stock, across mission areas, for all vessels combined and are submitted to NMFS in annual unclassified reports (DoN, 2008, 2009b, and 2010). For the first three LOAs under the current rule, these risk estimates have met the regulations and conditions of the LOAs (Tables 4-1, 4-2, and 4-3).

4.4.4 Supplemental Risk Assessments

The sensitivity/risk process, discussed above, utilizes a conservative approach by integrating mission planning needs (Navy's training and operational ASW requirements) and a cautious assessment of the limited data available on specific marine mammal populations, and seasonal habitat and activity. In this supplemental analysis, 19 additional operating sites have been analyzed using the most up-to-date marine mammal abundance, density, and behavioral information available (Table 4-4). These sites were chosen because they represent, based on today's political climate, areas where SURTASS LFA sonar could potentially test, train, or operate. This analysis will provide updated modeling for the 11 sites under the current LOAs and eight additional sites, which could be requested for LOAs under the next 5-year Rule because they are in areas of potential strategic importance and/or areas of possible Fleet exercises.

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

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

Estimates of the percentage of marine mammal stocks affected by SURTASS LFA sonar operations in the 19 potential operating areas, for the seasons specified, have been derived for this document (Tables 4-5 through 4-23). The estimated stock values support the conclusion that estimates of potential effects to marine mammal stocks are below the conditions delineated by NMFS in the LOAs issued under the current Final Rule.

Table 4-1. Post-operational estimates of marine mammal stocks potentially affected by operation of SURTASS LFA sonar in all mission areas—totals for 1st year LOAs; ESA-listed species indicated by gray highlighting.

LOA 1—R/V CORY CHOUEST & USNS IMPECCABLE				
Marine Mammal Species (Seasonal Occurrence)	Stock	Number Animals in Stock	% Stock Affected (w/ mit[56]) 120 to 180 dB	% Stock Affected (w/ mit) ≥180 dB
			Annual Total	Annual Total
Fin whale	N. Pacific	9,250	0.57	0.00
Bryde's whale	Western N. Pacific	22,000	0.71	0.00
Common minke whale	Western N. Pacific	25,049	5.17	0.00
North Pacific right whale (Spring/Fall/Winter)	Western N. Pacific	922	0.17	0.00
Humpback whale (Winter only)	Western N. Pacific	394	1.48	0.00
Gray whale (Winter only)	Western N. Pacific	100	0.00	0.00
Sperm whale	N. Pacific	102,112	0.15	0.00
Kogia spp.	N. Pacific	350,553	0.09	0.00

56 With mitigation measures applied

Cuvier's beaked whale	N. Pacific	90,725	0.06	0.00
Blainville's beaked whale	N. Pacific	8,032	1.00	0.00
Ginkgo-toothed beaked whale	N. Pacific	22,799	0.37	0.00
Killer whale	Western N. Pacific	12,256	0.01	0.00
False killer whale	Western N. Pacific	16,668	2.67	0.00
False killer whale	Inshore Archipelago	9,777	0.69	0.00
Pygmy killer whale	Western N. Pacific	30,214	1.28	0.00
Melon-headed whale	Western N. Pacific	36,770	1.30	0.00
Short-finned pilot whale	Western N. Pacific	53,608	2.69	0.00
Risso's dolphin	Western N. Pacific	83,289	3.05	0.00
Common dolphin	Western N. Pacific	3,286,163	0.42	0.00
Bottlenose dolphin	Western N. Pacific	168,791	1.37	0.00
Bottlenose dolphin	Inshore Archipelago	105,138	0.70	0.00
Spinner dolphin	Western N. Pacific	1,015,059	0.01	0.00
Pantropical spotted dolphin	Western N. Pacific	438,064	0.78	0.00
Striped dolphin	Western N. Pacific	570,038	0.64	0.00
Rough-toothed dolphin	Western N. Pacific	145,729	0.84	0.00
Fraser's dolphin	Western N. Pacific	220,789	0.41	0.00
Pacific white-sided dolphin	Western N. Pacific	931,000	0.46	0.00

Table 4-2. Post-operational estimates of marine mammal stocks potentially affected by operation of SURTASS LFA sonar in all mission areas—totals for 2nd year LOAs; ESA-listed species indicated by gray highlighting.

LOA 2—USNS ABLE & USNS IMPECCABLE				
MARINE MAMMAL SPECIES (SEASONAL OCCURRENCE	**STOCK**	**NUMBER ANIMALS IN STOCK**	**% STOCK AFFECTED (W/ MIT[57]) 120 TO 180 DB**	**% STOCK AFFECTED (W/MIT) ≥180 DB**
			ANNUAL TOTAL	**ANNUAL TOTAL**
Blue whale	Western N. Pacific	1,548	0.33	0.00
Fin whale	N. Pacific	9,250	0.03	0.00
Fin whale	Hawaii	2,099	0.86	0.00
Bryde's whale	Western N. Pacific	22,000	0.17	0.00
Bryde's whale	Hawaii	469	1.09	0.00
Common minke whale	Western N. Pacific	25,049	1.00	0.00
Common minke whale	Hawaii	25,000	0.02	0.00
N. Pacific right whale (Spring/Fall/Winter)	Western N. Pacific	922	0.05	0.00
Humpback whale (Winter only)	Western N. Pacific	394	0.00	0.00
Gray whale (Winter only)	Western N. Pacific	100	0.00	0.00
Sperm whale	N. Pacific	102,112	0.06	0.00

57 With mitigation measures applied

Table 4-2. Post-operational estimates of marine mammal stocks potentially affected by operation of SURTASS LFA sonar in all mission areas—totals for 2nd year LOAs; ESA-listed species indicated by gray highlighting.

LOA 2—USNS ABLE & USNS IMPECCABLE				
Marine Mammal Species (Seasonal Occurrence	**Stock**	**Number Animals in Stock**	**% Stock Affected (w/ mit[57]) 120 to 180 dB**	**% Stock Affected (w/mit) ≥180 dB**
			Annual Total	**Annual Total**
Sperm whale	Hawaii	6,919	0.54	0.00
Kogia spp.	N. Pacific	350,553	0.01	0.00
Kogia spp.	Hawaii	24,657	0.54	0.00
Cuvier's beaked whale	N. Pacific	90,725	0.15	0.00
Cuvier's beaked whale	Hawaii	15,242	0.54	0.00
Longman's beaked whale	Hawaii	1,007	0.53	0.00
Blainville's beaked whale	N. Pacific	8,032	0.19	0.00
Blainville's beaked whale	Hawaii	2,872	0.54	0.00
Ginkgo-toothed beaked whale	N. Pacific	22,799	0.06	0.00
Killer whale	Western N. Pacific	12,256	0.08	0.00
Killer whale	Hawaii	349	0.56	0.00
False killer whale	Western N. Pacific	16,668	0.53	0.00
False killer whale	Inshore Archipelago	9,777	0.03	0.00
False killer whale	Hawaii	236	0.83	0.00
Pygmy killer whale	Western N. Pacific	30,214	0.22	0.00
Pygmy killer whale	Hawaii	956	0.82	0.00
Melon-headed whale	Western N. Pacific	36,770	0.12	0.00
Melon-headed whale	Hawaii	2,950	0.80	0.00
Short-finned pilot whale	Western N. Pacific	53,608	0.78	0.00
Short-finned pilot whale	Hawaii	8,870	0.80	0.00
Risso's dolphin	Western N. Pacific	83,289	0.51	0.00
Risso's dolphin	Hawaii	2,372	1.06	0.00
Common dolphin	Western N. Pacific	3,286,163	0.06	0.00
Bottlenose dolphin	Western N. Pacific	168,791	0.33	0.00
Bottlenose dolphin	Inshore Archipelago	105,138	0.05	0.00
Bottlenose dolphin	Hawaii	3,215	1.02	0.00
Spinner dolphin	Western N. Pacific	1,015,059	0.09	0.00
Spinner dolphin	Hawaii	3351	0.98	0.00
Pantropical spotted dolphin	Western N. Pacific	438,064	0.12	0.00
Pantropical spotted dolphin	Hawaii	8,978	0.98	0.00
Striped dolphin	Western N. Pacific	570,038	0.18	0.00
Striped dolphin	Hawaii	13,143	0.98	0.00
Rough-toothed dolphin	Western N. Pacific	145,729	0.13	0.00
Rough-toothed dolphin	Hawaii	8,709	0.98	0.00
Fraser's dolphin	Western N. Pacific	220,789	0. 07	0.00
Fraser's dolphin	Hawaii	10,226	0. 99	0.00

Table 4-2. Post-operational estimates of marine mammal stocks potentially affected by operation of SURTASS LFA sonar in all mission areas—totals for 2nd year LOAs; ESA-listed species indicated by gray highlighting.

LOA 2—USNS ABLE & USNS IMPECCABLE				
MARINE MAMMAL SPECIES (SEASONAL OCCURRENCE	STOCK	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED (W/ MIT[57]) 120 TO 180 DB	% STOCK AFFECTED (W/MIT) ≥180 DB
			ANNUAL TOTAL	ANNUAL TOTAL
Pacific White-sided dolphin	Western N. Pacific	931,000	0.05	0.00
Hawaiian monk seal	Hawaii	1,302	0.24	0.00

Table 4-3. Post-operational estimates of marine mammal stocks potentially affected by the operation of SURTASS LFA sonar in all mission areas—totals for 3rd year LOAs; ESA-listed species indicated by gray highlighting.

LOA 3—USNS ABLE & USNS IMPECCABLE				
MARINE MAMMAL SPECIES (SEASONAL OCCURRENCE	STOCK	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED (W/ MIT[57]) 120 TO 180 DB	% STOCK AFFECTED (W/ MIT) ≥180 DB
			ANNUAL TOTAL	ANNUAL TOTAL
Blue whale	North (N.) Pacific	9,250	0.03	0.00
Fin whale	N. Pacific	9,250	0.17	0.00
Sei whale	N Pacific	8,600	0.10	0.00
Bryde's whale	Western N. Pacific	22,000	0.30	0.00
Common minke whale	Western N. Pacific	25,049	1.72	0.00
N. Pacific right whale (spring/fall/winter)	Western N. Pacific	922	0.06	0.00
Humpback whale (Winter only)	Western N. Pacific	394	1.78	0.00
Sperm whale	N. Pacific	102,112	0.15	0.00
Kogia spp.	N. Pacific	350,553	0.06	0.00
Baird’s beaked whale	Western N. Pacific	8,000	0.26	0.00
Baird’s beaked whale	Western N. Pacific	8,000	0.26	0.00
Cuvier's beaked whale	N. Pacific	90,725	0.25	0.00
Blainville's beaked whale	N. Pacific	8,032	0.52	0.00
Ginkgo-toothed beaked whale	N. Pacific	22,799	0.20	0.00
Hubbs’ beaked whale	N. Pacific	22,799	0.02	0.00
Killer whale	Western N. Pacific	12,256	0.11	0.00
False killer whale	Western N. Pacific	16,668	1.79	0.00
Pygmy killer whale	Western N. Pacific	30,214	0.71	0.00
Melon-headed whale	Western N. Pacific	36,770	0.30	0.00
Short-finned pilot whale	Western N. Pacific	53,608	2.02	0.00
Risso's dolphin	Western N. Pacific	83,289	1.57	0.00
Common dolphin	Western N. Pacific	3,286,163	0.20	0.00
Bottlenose dolphin	Western N. Pacific	168,791	1.09	0.00
Spinner dolphin	Western N. Pacific	1,015,059	0.00	0.00
Pantropical spotted dolphin	Western N. Pacific	438,064	0.39	0.00
Striped dolphin	Western N. Pacific	570,038	0.43	0.00
Rough-toothed dolphin	Western N. Pacific	145,729	0.47	0.00
Fraser's dolphin	Western N. Pacific	220,789	0. 22	0.00
Pacific white-sided dolphin	Western N. Pacific	931,000	0.24	0.00

Table 4-4. Potential SURTASS LFA sonar operating areas (OPAREAs), location, and representative season that were modeled for this SEIS/OEIS.

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

Table 4-5. Estimates of the percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 1, East of Japan, summer season; ESA-listed species highlighted.

OPAREA 1—East of Japan			
Marine Mammal Species	Number Animals in Stock	% Stock Affected <180 dB	% Stock Affected (with mitigation) ≥180 dB
Blue whale	9,250	0.0182	0.0000
Fin whale	9,250	0.0221	0.0000
Sei whale	8,600	0.0661	0.0000
Bryde's whale	20,501	0.0277	0.0000
Common minke whale	25,049	0.0566	0.0000
North Pacific right whale (Spring/Fall)	922	< 0.0001	0.0000
Sperm whale	102,112	0.0060	0.0000
Kogia spp.	350,553	0.0079	0.0000
Baird's beaked whale	8,000	0.2603	0.0000
Cuvier's beaked whale	90,725	0.0427	0.0000
Gingko-toothed beaked whale	22,799	0.0157	0.0000
Hubbs' beaked whale	22,799	0.0157	0.0000
False killer whale	16,668	0.1916	0.0000
Pygmy killer whale	30,214	0.0617	0.0000
Short-finned pilot whale	53,608	0.2170	0.0000
Risso's dolphin	83,289	0.1138	0.0000
Common dolphin	3,286,163	0.0212	0.0000
Bottlenose dolphin[58]	168,791	0.0823	0.0000
Spinner dolphin	1,015,059	0.0002	0.0000
Pantropical spotted dolphin	438,064	0.0180	0.0000
Striped dolphin	570,038	0.0059	0.0000
Rough-toothed dolphin	145,729	0.0346	0.0000
Fraser's dolphin	220,789	0.0153	0.0000
Pacific white-sided dolphin	931,000	0.0070	0.0000

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

Table 4-6. Estimates of the percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 2, North Philippine Sea, fall season; ESA-listed species highlighted.

OPAREA 2—North Philippine Sea			
Marine Mammal Species	Number Animals in Stock	% Stock Affected <180 dB	% Stock Affected (with mitigation) ≥180 dB
Bryde's whale	20,501	0.0339	0.0000
Common minke whale	25,049	0.4023	0.0000
North Pacific right whale (Spring/Fall/Winter)	922	0.0055	0.0000
Sperm whale	102,112	0.0454	0.0000
Kogia spp.	350,553	0.0265	0.0000
Cuvier's beaked whale	90,725	0.0534	0.0000
Blainville's beaked whale	8,032	0.0559	0.0000
Gingko-toothed beaked whale	22,799	0.0197	0.0000
Killer whale	12,256	0.0379	0.0000
False killer whale	16,668	0.2123	0.0000
Pygmy killer whale	30,214	0.0848	0.0000
Melon-headed whale	36,770	0.0398	0.0000
Short-finned pilot whale	53,608	0.5137	0.0000
Risso's dolphin	83,289	0.3337	0.0000
Common dolphin	3,286,163	0.0168	0.0000
Bottlenose dolphin[58]	168,791	0.0548	0.0000
Spinner dolphin	1,015,059	0.0007	0.0000
Pantropical spotted dolphin	438,064	0.0429	0.0000
Striped dolphin	570,038	0.0792	0.0000
Rough-toothed dolphin	145,729	0.1109	0.0000
Fraser's dolphin	220,789	0.0411	0.0000
Pacific white-sided dolphin	931,000	0.0176	0.0000

Table 4-7. Estimates of the percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 3, West Philippine Sea, fall season; ESA-listed species highlighted.

OPAREA 3—West Philippine Sea			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Fin whale	9,250	0.0492	0.0000
Bryde's whale	20,501	0.0653	0.0000
Common minke whale	25,049	0.1880	0.0000
Humpback whale (Winter only)	1,107	< 0.0001	0.0000
Sperm whale	102,112	0.0105	0.0000
Kogia spp.	350,553	0.0099	0.0000
Cuvier's beaked whale	90,725	0.0042	0.0000
Blainville's beaked whale	8,032	0.0797	0.0000
Gingko-toothed beaked whale	22,799	0.0281	0.0000
False killer whale	16,668	0.2610	0.0000
Pygmy killer whale	30,214	0.1043	0.0000
Melon-headed whale	36,770	0.0490	0.0000
Short-finned pilot whale	53,608	0.1348	0.0000
Risso's dolphin	83,289	0.2284	0.0000
Common dolphin	3,286,163	0.0325	0.0000
Bottlenose dolphin[58]	168,791	0.0927	0.0000
Spinner dolphin	1,015,059	0.0004	0.0000
Pantropical spotted dolphin	438,064	0.0230	0.0000
Striped dolphin	570,038	0.0212	0.0000
Rough-toothed dolphin	145,729	0.0769	0.0000
Fraser's dolphin	220,789	0.0284	0.0000
Pacific white-sided dolphin	931,000	0.0211	0.0000

Table 4-8. Estimates of the percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 4, Offshore Guam, summer and fall seasons; ESA-listed species highlighted.

OPAREA 4—OFFSHORE GUAM					
		SUMMER	SUMMER	FALL	FALL
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (W/ MITIGATION) ≥180 DB	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (W/ MITIGATION) ≥180 DB
Blue whale	2,842	0.0377	0.0000	0.0338	0.0000
Fin whale	9,250	0.0376	0.0000	0.0354	0.0000
Sei whale	8,600	0.0331	0.0000	0.0330	0.0000
Bryde's whale	20,501	0.0183	0.0000	0.0197	0.0000
Common minke whale	25,049	0.0110	0.0000	0.0104	0.0000
Humpback whale (October to May)	10,103	<0.0001	0.0000	<0.0001	0.0000
Sperm whale	102,112	0.0105	0.0000	0.0104	0.0000
Kogia spp.	350,553	0.0373	0.0000	0.0315	0.0000
Cuvier's beaked whale	90,725	0.0690	0.0000	0.0679	0.0000
Longman's beaked whale	1,007	0.4112	0.0000	0.4043	0.0000
Blainville's beaked whale	8,032	0.1471	0.0000	0.1446	0.0000
Ginkgo-toothed beaked whale	22,799	0.0222	0.0000	0.0218	0.0000
Killer whale	349	0.4894	0.0000	0.4372	0.0000
False killer whale	16,668	0.0699	0.0000	0.0440	0.0000
Pygmy killer whale	30,214	0.0049	0.0000	0.0031	0.0000
Melon-headed whale	36,770	0.1222	0.0000	0.0769	0.0000
Short-finned pilot whale	53,608	0.0350	0.0000	0.0205	0.0000
Risso's dolphin	83,289	0.0141	0.0000	0.0125	0.0000
Common dolphin	3,286,163	0.0007	0.0000	0.0006	0.0000
Bottlenose dolphin[58]	168,791	0.0013	0.0000	0.0009	0.0000
Spinner dolphin	1,015,059	0.0027	0.0000	0.0025	0.0000
Pantropical spotted dolphin	438,064	0.0444	0.0000	0.0417	0.0000
Striped dolphin	570,038	0.0093	0.0000	0.0087	0.0000
Rough-toothed dolphin	145729	0.0022	0.0000	0.0021	0.0000
Fraser's dolphin	10,226	0.411	0.0000	0.3780	0.0000

Table 4-9. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 5, Sea of Japan, fall season; ESA-listed species highlighted.

OPAREA 5—Sea of Japan			
Marine Mammal Species	Number Animals in Stock	% Stock Affected <180 dB	% Stock Affected (with mitigation) ≥180 dB
Fin whale	9,250	0.2345	0.0000
Bryde's whale	20,501	0.0104	0.0000
Common minke whale	25,049	0.0291	0.0000
Common minke whale—J Stock	893	0.3261	0.0000
North Pacific right whale (Spring/Fall/Winter)	922	0.0255	0.0000
Gray whale	121	0.0011	0.0000
Sperm whale	102,112	0.0206	0.0000
Stejneger's beaked whale	8,000	0.5023	0.0000
Baird's beaked Whale	8,000	0.1076	0.0000
Cuvier's beaked Whale	90,725	0.1360	0.0000
Gingko-toothed beaked whale	22,799	0.0629	0.0000
False killer whale	9,777	0.8202	0.0000
Melon-headed whale	36,770	0.0008	0.0000
Short-finned pilot whale	53,608	0.0303	0.0000
Risso's dolphin	83,289	0.2121	0.0000
Common dolphin	3,286,163	0.0529	0.0000
Bottlenose dolphin[58]	105,138	0.0134	0.0000
Spinner dolphin	1,015,059	< 0.0001	0.0000
Pantropical spotted dolphin	219,032	0.0632	0.0000
Pacific white-sided dolphin	931,000	0.0040	0.0000
Dall's porpoise	76,720	0.9218	0.0000

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Table 4-10. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 6, East China Sea, summer season; ESA-listed species highlighted.

OPAREA 6—EAST CHINA SEA			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 dB	% STOCK AFFECTED (WITH MITIGATION) ≥180 dB
Fin whale	500	0.6200	0.0000
Bryde's whale	20,501	0.0357	0.0000
Common minke whale	25,049	0.2284	0.0000
Common minke whale—J Stock	893	2.6204	0.0000
North Pacific right whale (Winter)	922	< 0.0001	0.0000
Gray whale (Winter only)	121	< 0.0001	0.0000
Sperm whale	102,112	0.0092	0.0000
Kogia spp.	350,553	0.0056	0.0000
Cuvier's beaked whale	90,725	0.0719	0.0000
Blainville's beaked	8,032	0.1530	0.0000
Ginkgo-toothed beaked whale	22,799	0.0230	0.0000
False killer whale	9,777	0.1703	0.0000
Pygmy killer whale	30,214	0.0070	0.0000
Melon-headed whale	36,770	0.1746	0.0000
Short-finned pilot whale	53,608	0.0498	0.0000
Risso's dolphin	83,289	0.1833	0.0000
Common dolphin	3,286,163	0.0202	0.0000
Bottlenose dolphin[58]	105,138	0.0967	0.0000
Spinner dolphin	1,015,059	0.0036	0.0000
Pantropical spotted dolphin	219,032	0.0728	0.0000
Striped dolphin	570,038	0.0334	0.0000
Rough-toothed dolphin	145,729	0.0518	0.0000
Fraser's dolphin	220,789	0.0252	0.0000
Pacific white-sided dolphin	931,000	0.0041	0.0000

Table 4-11. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 7, South China Sea, fall season; ESA-listed species highlighted.

OPAREA 7—South China Sea			
Marine Mammal Species	Number Animals in Stock	% Stock Affected <180 dB	% Stock Affected (with mitigation) ≥180 dB
Fin whale	9,250	0.0352	0.0000
Bryde's whale	20,501	0.0416	0.0000
Common minke whale	25,049	0.1713	0.0000
North Pacific right whale (Winter)	922	<0.0001	<0.0001
Gray whale (Winter only)	121	<0.0001	0.0000
Sperm whale	102,112	0.0125	0.0000
Kogia spp.	350,553	0.0087	0.0000
Cuvier's beaked whale	90,725	0.0042	0.0000
Blainville's beaked whale	8,032	0.0782	0.0000
Gingko-toothed beaked whale	22,799	0.0276	0.0000
False killer whale	9,777	0.1873	0.0000
Pygmy killer whale	30,214	0.0076	0.0000
Melon-headed whale	36,770	0.1921	0.0000
Short-finned pilot whale	53,608	0.0415	0.0000
Risso's dolphin	83,289	0.2074	0.0000
Common dolphin	3,286,163	0.0210	0.0000
Bottlenose dolphin[58]	105,138	0.0796	0.0000
Spinner dolphin	1,015,059	0.3186	0.0000
Pantropical spotted dolphin	219,032	0.0646	0.0000
Striped dolphin	570,038	0.0296	0.0000
Rough-toothed dolphin	145,729	0.0467	0.0000
Fraser's dolphin	220,789	0.0257	0.0000

Table 4-12. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 8, northwest Pacific Ocean (from 25ºN to 40ºN), summer season; ESA-listed species highlighted.

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

Table 4-13. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 9, northwest Pacific Ocean, summer season; ESA-listed species highlighted.

OPAREA 9—NW Pacific (10°N to 25°N)			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Bryde's whale	20,501	0.0309	0.0000
Sperm whale	102,112	0.0034	0.0000
Kogia spp.	350,553	0.0044	0.0000
Cuvier's beaked whale	90,725	0.0197	0.0000
False killer whale	16,668	0.1965	0.0000
Melon-headed whale	36,770	0.0509	0.0000
Short-finned pilot whale	53,608	0.0373	0.0000
Risso's dolphin	83,289	0.0478	0.0000
Common dolphin	3,286,163	0.0475	0.0000
Bottlenose dolphin[58]	168,791	0.0074	0.0000
Spinner dolphin	1,015,059	0.0054	0.0000
Pantropical spotted dolphin	438,064	0.0908	0.0000
Striped dolphin	570,038	0.0340	0.0000
Rough-toothed dolphin	145,729	0.0027	0.0000

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Table 4-14. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 10, Hawaii North, summer season; ESA-listed species highlighted.

OPAREA 10—HAWAII NORTH (25ºN, 158º W)			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (WITH MITIGATION) ≥180 DB
Blue whale	1,548	0.2295	0.0000
Fin whale	2,099	0.9338	0.0000
Bryde's whale	469	1.1855	0.0000
Common minke whale	25,000	0.0128	0.0000
Humpback whale (Summer)	10,103	< 0.0001	0.0000
Sperm whale	6,919	0.5258	0.0000
Kogia spp.	24,657	1.0271	0.0000
Cuvier's beaked whale	15,242	0.6698	0.0000
Longman's beaked whale	1,007	0.6530	0.0000
Blainville's beaked	2,872	0.6697	0.0000
Killer whale	349	0.7851	0.0000
False killer whale (pelagic)	484	0.8760	0.0000
Pygmy killer whale	956	0.8870	0.0000
Melon-headed whale	2,950	0.8624	0.0000
Short-finned pilot whale	8,870	0.3718	0.0000
Risso's dolphin	2,372	0.9106	0.0000
Bottlenose dolphin	3,215	0.5087	0.0000
Spinner dolphin	3,351	0.2347	0.0000
Pantropical spotted dolphin	8,978	0.2340	0.0000
Striped dolphin	13,143	0.2341	0.0000
Rough-toothed dolphin	8,709	0.9375	0.0000
Fraser's dolphin	10,226	0.7590	0.0000
Hawaiian monk seal	1,129	0.1435	0.0000

Table 4-15. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 11, Hawaii South, spring and fall seasons; ESA-listed species highlighted.

OPAREA 11—HAWAII SOUTH (19.5°N 158.5°W)			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (WITH MITIGATION) ≥180 DB
Blue whale	1548	0.1288	0.0000
Fin whale	2099	0.4369	0.0000
Bryde's whale	469	0.5544	0.0000
Common minke whale	25000	0.0078	0.0000
Humpback whale (not summer)	10103	0.0003	0.0000
Sperm whale	6919	0.3391	0.0000
Kogia spp.	24657	0.5217	0.0000
Cuvier's beaked whale	15242	0.3985	0.0000
Longman's beaked whale	1007	0.3885	0.0000
Blainville's beaked	2872	0.3984	0.0000
Killer whale	349	0.3811	0.0000
False killer whale (pelagic)	484	0.4628	0.0000
Pygmy killer whale	956	0.4686	0.0000
Melon-headed whale	2950	0.4556	0.0000
Short-finned pilot whale	8870	0.3527	0.0000
Risso's dolphin	2372	0.4764	0.0000
Bottlenose dolphin	3215	0.3514	0.0000
Spinner dolphin	3351	0.2935	0.0000
Pantropical spotted dolphin	8978	0.2927	0.0000
Striped dolphin	13143	0.2928	0.0000
Rough-toothed dolphin	8709	0.4932	0.0000
Fraser's dolphin	10226	0.4037	0.0000
Hawaiian monk seal	1129	0.1010	0.0000

Table 4-16. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 12, Offshore Southern California, spring season; ESA-listed species highlighted.

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

Table 4-17. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 13, Western Atlantic/Jacksonville OPAREA, winter season; ESA-listed species highlighted.

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

Table 4-18. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 14, Eastern North Atlantic, summer season; ESA-listed species highlighted.

OPAREA 14—Eastern North Atlantic (NW Approaches)			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Blue whale	100	0.7726	0.0000
Fin whale	10,369	3.4018	0.0000
Sei whale	14,152	9.2473	0.0000
Common minke whale	107,205	0.6518	0.0000
Humpback whale	4,695	1.1710	0.0000
Sperm whale	6,375	2.3498	0.0000
Pygmy sperm whale	580	1.3386	0.0000
Dwarf sperm whale	580	1.3386	0.0000
Cuvier's beaked whale	3,513	1.3685	0.0000
Blainville's beaked whale	3,513	1.3685	0.0000
Sowerby's beaked whale	3,513	1.3685	0.0000
North Atlantic bottlenose whale	5,827	0.1654	0.0000
Killer whale	6,618	0.1607	0.0000
False killer whale	484	1.2615	0.0000
Long-finned pilot whale	778,000	0.0857	0.0000
Risso's dolphin	20,479	2.1137	0.0000
Common dolphin	273,150	9.1833	0.0000
Bottlenose dolphin	81,588	1.0419	0.0000
Striped dolphin	94,462	4.8839	0.0000
Atlantic white-sided dolphin	11,760	1.4759	0.0000
White-beaked dolphin	11,760	1.4759	0.0000
Harbor porpoise	341,366	1.4294	0.0000
Harbor seal	23,500	3.2031	0.0000
Gray seal	113,300	3.7559	0.0000

Table 4-19. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA potential sonar OPAREA 15, Mediterranean Sea/Ligurian Sea, summer season; ESA-listed species highlighted.

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

Table 4-20. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 16, Arabian Sea, summer season; ESA-listed species highlighted.

OPAREA 16—Arabian Sea			
Marine Mammal Species	**Number Animals in Stock**	**% Stock Affected <180 dB**	**% Stock Affected (with mitigation) ≥180 dB**
Bryde's whale	9,176	0.0134	0.0000
Humpback whale	200	1.5275	0.0000
Sperm whale	24,446	0.4530	0.0000
Dwarf sperm whale	10,541	4.1267	0.0000
Cuvier's beaked whale	27,272	0.0073	0.0000
Longman's beaked whale	16,887	0.1880	0.0000
Blainville's beaked whale	16,887	0.1880	0.0000
Ginkgo-toothed beaked whale	16,887	0.1880	0.0000
False killer whale	144,188	0.0056	0.0000
Pygmy killer whale	22,029	0.3187	0.0000
Melon-headed whale	64,600	2.7627	0.0000
Short-finned pilot whale	268,751	0.0078	0.0000
Risso's dolphin	452,125	0.0357	0.0000
Common dolphin	1,819,882	0.0373	0.0000
Bottlenose dolphin[58]	785,585	0.0393	0.0000
Spinner dolphin	634,108	0.0066	0.0000
Pantropical spotted dolphin	736,575	0.0072	0.0000
Striped dolphin	674,578	0.0437	0.0000
Rough-toothed dolphin	156,690	0.0663	0.0000

Table 4-21. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 17, Andaman Sea, summer season; ESA-listed species highlighted.

OPAREA 17—ANDAMAN SEA			
MARINE MAMMAL SPECIES	NUMBER ANIMALS IN STOCK	% STOCK AFFECTED <180 DB	% STOCK AFFECTED (WITH MITIGATION) ≥180 DB
Bryde's whale	9,176	0.0094	0.0000
Sperm whale	24,446	0.5369	0.0000
Dwarf sperm whale	10,541	1.5682	0.0000
Cuvier's beaked whale	16,867	0.1214	0.0000
Longman's beaked whale	16,867	0.1214	0.0000
Blainville's beaked whale	16,867	0.1214	0.0000
Ginkgo-toothed beaked whale	16,867	0.1214	0.0000
Killer whale	12,593	0.0079	0.0000
False killer whale	144,188	0.0017	0.0000
Pygmy killer whale	22,029	0.0970	0.0000
Melon-headed whale	64,600	0.8411	0.0000
Short-finned pilot whale	268,751	0.0079	0.0000
Risso's dolphin	452,125	0.0337	0.0000
Common dolphin	1,819,882	0.0130	0.0000
Bottlenose dolphin[58]	785,585	0.0122	0.0000
Spinner dolphin	634,108	0.0095	0.0000
Pantropical spotted dolphin	736,575	0.0104	0.0000
Striped dolphin	674,578	0.0632	0.0000
Rough-toothed dolphin	156,690	0.0724	0.0000

Table 4-22. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 18, Panama Canal, winter season; ESA-listed species highlighted.

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

Table 4-23. Estimates of percentage of marine mammal stocks potentially affected for SURTASS LFA sonar potential OPAREA 19, Northeast Australia Coast, spring season; ESA-listed species highlighted.

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

4.5 OFFSHORE BIOLOGICALLY IMPORTANT AREAS FOR SURTASS LFA SONAR OPERATIONS

The U.S. Navy plans to operate up to four SURTASS LFA sonar systems for routine training, testing, and military operations. These systems have the potential to adversely affect marine animals. In the past, Navy has applied for, and NMFS has issued, MMPA regulations and LOAs that allow for the incidental taking of marine mammals, while prescribing measures to minimize impacts. Under the Endangered Species Act (ESA), consultation was required on the issuance of MMPA regulations and LOAs. The NMFS' rulemaking for the next five-year period of authorizations will be required.[59]

To meet the least practicable adverse impacts to marine mammals under the MMPA, NMFS and the Navy developed mitigation measures to reduce the potential for adverse impacts. Given the unique operational characteristics of SURTASS LFA sonar, Navy and NMFS were able to develop a systematic process for designating marine mammal "offshore biologically important areas" (OBIA) for SURTASS LFA sonar in the initial SURTASS LFA Sonar FOEIS/EIS (DoN, 2001). Because of the majority of areas of biological importance to marine mammals and sea turtles are in coastal areas, the Navy determined it would not ensonify areas within 22 km (12 nmi) of any coastline with SURTASS LFA sonar pursuant to the FOEIS/EIS at levels at or above 180 dB dB re 1 µPa (rms). Since the Navy recognized, however, that certain areas of biological importance lie outside of these coastal areas, the Navy and NMFS developed the concept of OBIAs. OBIAs are part of a comprehensive suite of mitigation measures used in previous authorizations to minimize impacts and adverse effects to marine mammals. OBIAs were defined in the 2001 SURTASS LFA Sonar FOEIS/EIS Subchapter 2.3.2.1 as those areas of the world's oceans outside of the geographic stand-off distance (greater than 22 km [12 nmi]) from a coastline (including islands) where marine animals of concern (those animals listed under the ESA and/or marine mammals) congregate in high densities to carry out biologically important activities. These areas include migration corridors, breeding and calving grounds, and feeding grounds. This definition remains valid except as noted below. The concept of OBIAs is unique to SURTASS LFA operations in light of the unique operating characteristics of SURTASS LFA sonar, including frequency range, bandwidth, source depth, pulse length, pulse repetition rate, and duty cycle. As NMFS noted in the current Final Rule for SURTASS LFA sonar (NOAA, 2007c), "OBIAs are not intended to apply to other Navy activities and sonar operations, but rather as a mitigation measure to reduce incidental takings by SURTASS LFA sonar."

4.5.1 MARINE SPECIES CONSIDERED

In addition to considering OBIAs for marine mammals, the Navy considered whether it was appropriate to establish OBIAs for listed marine species other than marine mammals, assuming those species occur within the same ocean region and during the same time of year as the SURTASS LFA sonar operation and possess some sensory mechanism that allows it to perceive the LF sounds or possess tissue with sufficient acoustic impedance mismatch to be affected by LF sounds. Species that do not meet these criteria were excluded from consideration. Thus, many organisms would be unaffected, even if they were in areas of LF sound, because they do not have an organ or tissue with acoustic impedance different from water. Based on these factors, virtually all other species were eliminated from further consideration except for listed fish and sea turtles.

The potential impacts to fish stocks were discussed previously in this chapter, where results from recent direct studies of the effects of LFA sounds on fish (Popper et al., 2005a, 2007; Halvorsen et al., 2006; Kane et al., 2010) were presented that provided evidence that SURTASS LFA sonar sounds at relatively

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[59] Under the MMPA, the Secretary (Commerce) must issue regulations setting forth the permissible methods of taking and of other means of effecting the least practicable adverse impact, including a consideration of personnel safety, the practicality of implementation of any mitigation, and the impact on the effectiveness of the subject military readiness activity, and the requirements pertaining to the monitoring and reporting of such taking.

high levels (up to 193 dB dB re 1 µPa [rms] RL) had minimal effects on at least the species of fish that were studied. Based on examinations by an expert fish pathologist, there was no damage to fish tissues, either at the gross or cellular levels with exposures to LFA sounds up to 193 dB dB re 1 µPa (rms) RL, and there were no fish mortalities due to sound exposure (Popper et al. 2007; Kane et al., 2010).

The potential impacts to sea turtles are also discussed previously in this chapter. There are limited hearing data for sea turtle species (loggerhead, green, and Kemp's ridley) that demonstrate that these species can hear LF sound (Ketten and Bartol, 2005). The data suggest that the best hearing sensitivities of the studied sea turtles were in the LF range between 100 and 900 Hz, but the data also showed that their hearing thresholds in the LFA range (100 to 500 Hz) were from 81 to 92 dB re 1 µPa, which is similar to the hearing thresholds of marine mammals with poor LF hearing sensitivity, such as odontocetes and pinnipeds. Sea turtles would have to be well inside of the LFA mitigation zone (180-dB sound field) during a SURTASS LFA sonar transmission to be affected. Therefore, the potential impacts to fish stocks and sea turtles are considered negligible, and there is no basis for establishing OBIAs for these species.

For the purposes of initial the SURTASS LFA Sonar FOEIS/EIS (DoN, 2001), 180-dB dB re 1 µPa (rms) received level (RL) was considered as the point above which some potentially serious problems in the hearing capability of marine mammals could start to occur from exposure to an LFA signal. This value was determined based on the best, but sparse, scientific data available at the time. This conservative value was above the estimated values for onset TTS, but below the values for onset PTS, which was and is considered injury. As has already been detailed, the probability of SURTASS LFA sonar transmissions (with mitigation) causing injury in marine mammals is considered negligible. A part of the mitigation strategy to achieve this negligible impact is the establishment of OBIAs for marine mammals.

4.5.2 LFA Offshore Biologically Important Areas for Marine Mammals

The process of identifying potential marine mammal (MM) OBIAs involved an assessment by both NMFS and the Navy to identify the areas that met the biological criteria for an OBIA. For those areas that were determined to meet the biological criteria, a practicability assessment was performed. To assist in the process of identifying potential LFA OBIAs for marine mammals, NMFS convened an expert review panel of independent scientists knowledgeable about potentially affected marine mammal habitats. This panel consisted of eight subject matter experts (SMEs), each with specific expertise in geographic regions including the Atlantic Ocean, Pacific Ocean, Mediterranean Sea, Indian Ocean/Southeast Asia, and East Africa. The SMEs provided analysis of potential OBIAs in regions of the world where the Navy potentially could use the SURTASS LFA sonar systems. The initial step in the identification of LFA OBIAs for marine mammals was the development of standardized screening criteria to be used by both NMFS and the SMEs to identify preliminary OBIA nominees (Table 4-24). More details about the delineation of marine mammal OBIAs are provided in Appendix D.

4.5.2.1 Screening Criteria for OBIA Nominees for Marine Mammals

NMFS developed the following screening criteria to determine an area's eligibility to be considered as a nominee for an OBIA for marine mammals. These OBIA criteria differ from the criteria in the FOEIS/EIS (as continued in the 2007 SEIS) and the current MMPA Final Rule in two respects. First, under the 2001 FOEIS/EIS, 2007 SEIS, and the current Final Rule, an area could be designated as an OBIA only if it met a conjunctive test of being an area where: (a) marine mammals congregate in high densities, and (b) for a biologically important purpose. Under the new NMFS criteria, high density alone can be sufficient. Second, the new criteria include an additional criterion that, standing alone, could be a basis for designation; i.e., "Small, distinct populations with limited distributions."

Table 4-24. NMFS' classification methodology for OBIA recommendations for marine mammals.

RANK	LEVEL DESCRIPTION FOR HIGH DENSITY, FORAGING, BREEDING/CALVING, MIGRATION, CRITICAL HABITAT, OR SMALL DISTINCT POPULATIONS	LEVEL DESCRIPTION BOUNDARY CONSIDERATION
0	Information not provided or information presented does not meet NMFS' definition of the corresponding MM OBIA criteria or the MM OBIA criteria are not applicable.	SME did not provide boundary information.
1	Clear justification (qualitative or quantitative) for corresponding MM OBIA criteria is not available; or the SME did not provide sufficient detail to NMFS for criteria evaluation; or for high density specifically, the SME provided strong abundance/presence information, but without the comparative information that supports *high* density.	Clear justification (qualitative or quantitative) for boundary consideration is not available or SME did not provide sufficient detail to NMFS for appropriate boundary evaluation.
2	Designation inferred from analyses conducted for purposes other than quantifying the corresponding MM OBIA criteria. Designation inferred from habitat suitability models (non-peer reviewed), expert opinion, regional expertise, or gray literature.	Proposed boundary inferred from analyses conducted for purposes other than quantifying the boundary. Designation inferred from habitat suitability models (non-peer reviewed), expert opinion, regional expertise, or gray literature.
3	Designation inferred from peer-reviewed analysis, habitat suitability models (peer-reviewed), or a survey specifically aimed at investigating and supporting the corresponding MM OBIA criteria. Information presented from a single source or is generally imprecise (e.g., coefficient of variation [CV] ≥30%).	Proposed boundary inferred from peer-reviewed analysis, habitat suitability models (peer-reviewed), or a survey specifically aimed at investigating and supporting the proposed boundary.
4	Designation inferred from peer-reviewed analyses or surveys specifically aimed at investigating and supporting the corresponding OBIA criteria. Information presented is from multiple sources or is generally precise (e.g., CV <30%).	Proposed boundary is well documented and/or codified by national law or regulation (e.g., regulatory boundaries pursuant to the U.S. ESA of 1973).

Criterion 1: Outside of Coastal Standoff Distance and Non-Operational Areas

The Navy will not operate SURTASS LFA sonar pursuant to the SEIS/SOEIS in certain areas of the world as shown in Figure 1-1 (Chapter 1). Therefore, MM OBIAs will not be designated if they lie solely within these areas:

- Coastal Standoff Zone—the area within 22 km (12 nmi) of any coastline including islands and island systems.
- Non-Operational Areas:
    - Arctic—Portions of the Norwegian, Greenland, and Barents Seas north of 72°N latitude, plus Baffin Bay, Hudson Bay, the Bering Sea, and the Gulf of St. Lawrence.
    - Antarctic—South of 60°S latitude.

Criterion 2: Biologically Important

To be considered an MM OBIA nominee, an area must meet at least one of the below sub-criteria.

➢ **Sub-criterion 2a—High densities**

An area that represents a region of high density for one or more species of marine mammals will be considered. In addition to survey data, predictive habitat or density modeling may be used to identify areas of high density. The exact definition of “high density” may differ across species and should generally be treated and justified on a stock-by-stock or species-by-species basis, although combining species or stocks may be appropriate in some situations, if well justified.

In identifying high-density areas:

1. For locations/regions and species for which adequate density information is available (e.g., most waters off the U.S.), high density areas should be defined as those areas where density measurably, within a definable and justifiable area, meaningfully exceeds the average density of the species or stock in that location/region regularly or regularly within a designated time period of the year.

2. For locations/regions and species and stocks for which density information is limited or not available, high density areas should be defined (if appropriate) using some combination of the following: available data, regional expertise, and/or habitat suitability models utilizing static and/or predictable dynamic oceanographic features and other factors that have been shown to be associated with high marine mammal densities.

➢ **Sub-criterion 2b—Known, defined breeding/calving grounds, foraging grounds, and migration routes**

The area representing a location of known biologically important activities including defined breeding or calving areas, foraging grounds, concentrated migration routes, and any ESA-designated critical habitat will be considered. Although such areas may not qualify as areas of “high density” as set forth in sub-criterion 2a above, potential designation under this sub-criterion denotes that these areas are concentrated areas for the biologically important activity in question. For the purpose of this SEIS/SOEIS, “concentrated” means that more of the animals are engaged in the particular behavior at the location (and perhaps time) than are typically engaged in that behavior elsewhere.

➢ **Sub-criterion 2c—Small, distinct populations with limited distributions**

Such an area represents a location that contains a small, distinct population of marine mammals with limited distribution.

4.5.2.2 Application of Screening Criteria by SMEs and NMFS

NMFS used the screening criteria to review existing and potential marine protected areas based on the World Database on Protected Areas (WDPA) (IUCN and UNEP, 2009), Holt (2005), and prior SURTASS LFA sonar OBIAs to produce a preliminary list of LFA MM OBIA nominees. Of the 403 worldwide marine protected areas derived from these sources, NMFS compiled a preliminary listing of 27 MM OBIA nominees.

Although NMFS did not consider this list of 27 nominees to be comprehensive, it was provided to the SMEs to illustrate some of the more well-known important marine mammal areas and to lay out the format for the SME review process.[60] NMFS asked the SMEs to review the OBIA nominations; to identify less well-known areas; to use peer-reviewed literature, technical reports, and their own specific expertise and professional experience, in addition to other data sources, to justify their additions, modifications, or deletions to the list of preliminary MM OBIA nominees (Appendix D). Based on the specific criteria provided by NMFS, the SMEs provided a list of 73 recommendations to NMFS for MM OBIA nominees (Appendix D).

NMFS reviewed the SMEs' recommendations and ranked them based on the quality of the data that supported the selection of the given area based on the screening criteria. To ensure that the nominated areas were ranked consistently, NMFS assigned a rank of zero to four (i.e., 0 = lowest, 4 = highest) to reflect the robustness of the supporting documentation for each criterion for which the area was nominated. These ranking categories are:

- Rank 0: Not Eligible, not applicable
- Rank 1: Not Eligible, insufficient data
- Rank 2: Eligible for consideration, requires more data
- Rank 3: Eligible for consideration, adequate justification
- Rank 4: Eligible for consideration, strong justification.

NMFS also assigned a rank for the robustness of the supporting documentation for each proposed MM OBIA boundary (Table 4-25). These ranking categories are:

- Rank 0: SME did not provide boundary information.
- Rank 1: Clear justification (qualitative or quantitative) for boundary consideration is not available.
- Rank 2: Proposed boundary inferred from analyses conducted for purposes other than quantifying the boundary.
- Rank 3: Proposed boundary inferred from peer-reviewed analyses.
- Rank 4: Proposed boundary is well documented and/or codified by national law or regulation.

Nominee areas that received a ranking of 2 or higher for any criterion were eligible for continued consideration as an MM OBIA nominee. As a result of this process, 45 areas were ranked 2 or higher.

[60] The frequencies of the signal produced by the SURTASS LFA sonar (frequency range 100 to 500 Hz) are much lower than the frequencies of best hearing sensitivity for HF and MF marine mammal hearing groups (as defined in Southall et al., 2007). There are few known documented responses of these marine mammal hearing groups to SURTASS LFA sonar. In the initial stage and in the subsequent SME reviews, the experts identified all potential OBIA nominees that met the screening criteria, regardless of the best hearing sensitivity of the species for which the area was considered important. Further assessments were performed to eliminate areas that only met the screening criteria for HF and/or MF hearing species.

Table 4-25. The NMFS' ranking of the SMEs' list of OBIA recommendations for marine mammals.

NAME	HIGH DENSITY	FORAGING	BREEDING/ CALVING	MIGRATING	CRITICAL HABITAT	SMALL DISTINCT POPULATION	LF SPECIALIST
Georges Bank	3	4	0	4	0	0	4
Roseway Basin Right Whale Conservation Area	0	4	0	0	0	0	4
Great South Channel	0	3	0	0	4	0	4
The Gully MPA	4	3	0	0	0	0	0
Southeastern U.S. Right Whale Seasonal Habitat	0	0	4	0	4	0	4
Silver Bank and Navidad Bank	0	0	4	0	0	0	4
Coastal Waters of Gabon, Congo and Equatorial Guinea	1	1	4	4	0	2	4
Patagonian Shelf Break	0	4	0	0	0	0	4
Southern Right Whale Seasonal Habitat	0	0	4	0	0	0	4
Northern Bay of Bengal and Swatch-of-No-Ground	1	2	2	0	0	4	2
Coastal Waters off Madagascar	1	1	4	1	0	0	4
Madagascar Plateau, Madagascar Ridge, Walters Shoal	1	3	4	3	0	2	3
Central California National Marine Sanctuaries	4	4	0	4	0	0	4
Vaquita Habitat in the Northern Gulf of California	0	0	0	0	0	4	0
Southern California Bight	0	4	0	4	0	0	4
Gulf of Alaska Steller Sea Lion Critical Habitat	0	0	0	0	4	0	0
Okhotsk Sea	0	4	0	2	0	0	4
Piltun and Chayvo Offshore Feeding Grounds	0	3	0	1	0	0	3

Table 4-25. The NMFS' ranking of the SMEs' list of OBIA recommendations for marine mammals.

NAME	HIGH DENSITY	FORAGING	BREEDING/ CALVING	MIGRATING	CRITICAL HABITAT	SMALL DISTINCT POPULATION	LF SPECIALIST
Area around Ischia Island and Regno di Nettuno MPA	1	1	3	0	0	0	0
Area in the Northern Adriatic Sea	1	2	3	0	0	0	0
Northeast Slope in the Ligurian-Corsican-Provençal Basin	0	3	0	0	0	0	3
Harbor Porpoise Take Reduction Management Areas	3	3	0	3	0	0	0
Cape Hatteras Special Research Area	3	3	0	0	0	0	0
Shortland Canyon and Haldimand Canyon	3	3	0	0	0	0	0
Gulf of Thailand	1	0	1	0	0	3	0
Penguin Bank	3	0	3	0	0	0	3
Costa Rica Dome	0	3	0	0	0	0	3
Cross Seamount	0	3	0	0	0	0	0
Great Barrier Reef Between 16°S and 21°S	0	0	3	0	0	0	3
Bonney Upwelling	0	3	0	0	0	0	3
Southwest Mediterranean	1	2	2	0	0	0	0
North Alboran Sea, Gulf of Vera, Southern Almeria	1	2	2	0	0	0	0
Avenzar Bank, Câbliers Bank, and El Mansour Seamount	1	2	2	0	0	0	0
Djibouti Bank, Ville de Djibouti Bank, and Alborán Channel	1	2	2	0	0	0	0
Barcelona Canyon, Tarragona Canyon, Mallorca Chanel, Pituisas Canyon	1	2	2	0	0	0	1

Table 4-25. The NMFS' ranking of the SMEs' list of OBIA recommendations for marine mammals.

NAME	HIGH DENSITY	FORAGING	BREEDING/ CALVING	MIGRATING	CRITICAL HABITAT	SMALL DISTINCT POPULATION	LF SPECIALIST
Southern Almería, Seco de los Olivos Seamount, Alborán Island, Águilas Seamount	1	2	2	0	0	0	0
Felibres Hills, Calypso Hills, Spinola Spur, and Montpelier Canyon	1	2	2	0	0	0	2
Marseille Canyon, Cassis Canyon, Felibres Hill, Alabe Hill, Barcelona Canyon	1	2	0	0	0	0	0
Area off of Southwest Greece and Crete, Ptolemy Mountains, Cretan-Rhodes Ridge	1	2	2	0	0	0	0
Northwest of Challenger Bank	0	2	0	1	0	0	2
Sylt Outer Reef	1	0	2	0	0	0	0
Pommeranian Bay, Adler Ground, and Western Ronne Bank	0	0	2	0	0	0	0
Buenos Aires Province Coastal Area	1	2	2	0	0	2	0
Area in the Ombai Strait in the Savu Sea MPA	0	2	0	2	0	0	2
Fairweather Grounds, Southeast Alaska	0	2	0	0	0	0	2
Olympic Coast: The Prairie, Barkley Canyon, and Nitnat Canyon	0	2	0	0	0	0	2
Sardinian Seamount, Comino Trough, Sardinia, Corsica Trough	1	0	0	0	0	0	1

Table 4-25. The NMFS' ranking of the SMEs' list of OBIA recommendations for marine mammals.

NAME	HIGH DENSITY	FORAGING	BREEDING/ CALVING	MIGRATING	CRITICAL HABITAT	SMALL DISTINCT POPULATION	LF SPECIALIST
Peñiscola Canyon, Valencia Basin, Benidorm Canyon, Alicante Canyon, Águilas Seamount	1	0	0	0	0	0	1
Mediterranean Sea West of 10° E Ligurian Sea to Gibraltar Strait	1	0	0	0	0	0	1
Pelagos Cetacean Sanctuary	1	0	0	0	0	0	1
Caprera Canyon, Giglio Ridge, Oblia Terrace—Southeast of Pelagos Sanctuary	1	0	0	0	0	0	1
Area off Eastern Sicily, East of Messina Canyon	1	0	0	0	0	0	0
Area off the Gaza Strip and the Western Coast of Israel	1	0	0	0	0	0	0
Song of the Whale Surveys - Eastern Mediterranean	1	0	0	0	0	0	1
Dogger Bank	1	0	0	0	0	0	0
Continental Slope of the Northern Gulf of Mexico	1	1	0	0	0	0	0
Canary Islands Cetacean Marine Sanctuary	1	0	0	0	0	0	0
Tristan da Cunha Cetacean Sanctuary	1	0	0	0	0	0	0
Komodo National Park, Biosphere Reserve	1	0	0	0	0	0	0
Beaked Whale Habitat in the Coastal Waters off California, Washington, and Oregon	1	0	0	0	0	0	0
Southern Gulf of California	1	0	0	0	0	0	1

Table 4-25. The NMFS' ranking of the SMEs' list of OBIA recommendations for marine mammals.

NAME	HIGH DENSITY	FORAGING	BREEDING/ CALVING	MIGRATING	CRITICAL HABITAT	SMALL DISTINCT POPULATION	LF SPECIALIST
Exclusion around Japan and the Ryukyu Islands	1	0	0	0	0	0	0
The Sea of Japan	1	0	0	0	0	0	0
Exclusion in the South China Sea	1	0	0	0	0	0	0
Exclusion for the West Philippine Sea	1	0	0	0	0	0	1
Area around Quarqannah Island	0	0	0	0	0	0	0
Area Malta Island and Malta Plateau	0	0	0	0	0	0	0
Total Exclusion within the Yellow Sea / East China Sea	0	0	0	0	0	0	0
Exclusion around Taiwan	0	0	0	0	0	0	0
Total Exclusion in the Gulf of Tonkin	0	0	0	0	0	0	0
Exclusion around Wake Island	0	0	0	0	0	0	0
Exclusion for the North Philippine Sea	0	0	0	0	0	0	0
Exclusion for the East China Sea	0	0	0	0	0	0	1

4.5.2.3 Further Analysis by NMFS and the Navy

The preliminary list of 45 potential MM OBIAs was analyzed further by NMFS and the Navy. This included further analysis of the biological evidence's strength for each OBIA and further review of the proposed OBIA boundaries and, where appropriate, consideration of seasonality. Portions of this analysis are discussed in more detail below, including reasons for excluding some of the recommended OBIAs from further consideration.

<u>Southern California Bight</u>

An area in the Southern California Bight (SCB), specifically an area including Tanner and Cortes Banks (Figure 4-6), meets the biological criteria described above for designation as a SURTASS LFA sonar OBIA as a concentrated area for blue whales based on predictive modeling, or as a foraging area based on a 2000-2004 study of blue whale calls. In either case the underlying data cover a short time period. Over a longer period, the dynamic nature of blue whale distribution and the variability of prey abundance make it difficult to assign any permanence to this area as one of blue whale concentration.

Figure 4-6. Southern California Bight (SCB) OBIA boundary.

Based upon operational considerations, however, avoiding this area is impracticable. Much of this area lies within the existing Southern California (SOCAL) Range Complex, which plays a vital part in ensuring the readiness of our naval forces. The region surrounding San Diego, California, is home to the largest concentration of U.S. naval forces in the world, and the SOCAL Range Complex is the most capable and active Navy range complex in the eastern Pacific region. The Navy has used this area for over 70 years to provide a safe and realistic training and testing environment for U.S. naval forces charged with the defense of the nation. The vital training that occurs in the SOCAL Range Complex includes pre-deployment training for Carrier Strike Groups (CSG), Surface Strike Groups (SSG), and Expeditionary Strike Groups (ESG). Antisubmarine warfare (ASW) training, including possibly SURTASS LFA sonar, is a critical component of the pre-deployment training. The SOCAL Range Complex provides the uneven, mountainous underwater topography that is essential to such training, because it is similar to the kind of underwater topography that submarines use to hide or mask their presence. Therefore, it is not practicable to designate this area as an OBIA.

Stellwagen Bank NMS and the Gulf of Maine

The Gulf of Maine and adjacent waters, including the Stellwagen Bank NMS, are some of the most important areas of marine mammal prey abundance in U.S. Atlantic waters. The waters of the sanctuary and Gulf of Maine (which includes Cape Cod and Massachusetts Bays) support key prey species of cetaceans, including sand lance (small semi-pelagic fish), herring, copepods, and euphausid zooplankton. Seasonally, the prey-dense waters of the Gulf of Maine are essential North Atlantic foraging grounds for such ESA-listed cetacean species as the North Atlantic right, humpback, fin, and sei whales.

Four feeding areas of the North Atlantic right whale are located in the greater Gulf of Maine: Cape Cod Bay, Great South Channel, Bay of Fundy, and Roseway Basin. Right whales occupy these feeding grounds from late winter (January) through fall (November) while the other cetacean species are found in greatest feeding abundances in late spring through early fall. Due to this region’s importance as a baleen whale feeding ground, the portions of the U.S. Gulf of Maine including Stellwagen Bank NMS that are located outside of the 22 km (12 nmi) coastal standoff distance are eligible for inclusion as an LFA OBIA for marine mammals. OBIA #3, North Atlantic Right Whale Critical Habitat, has been expanded to include the greater Gulf of Maine and the Stellwagen Bank NMS.

Challenger Bank (off Bermuda)

An area northwest of Challenger Bank, located just west of Bermuda, was proposed as a marine mammal OBIA for SURTASS LFA sonar due its use by humpback whales as a foraging area and migration route. Humpback whales occur in and around Bermuda in the late winter and spring as they migrate northward between their North Atlantic calving and feeding grounds. Humpbacks have been sighted principally in the waters near Challenger, Plantagenet, and Sally Tucker Banks off western Bermuda and in the coastal waters off Bermuda’s southern shore during their migration, although they have also been observed elsewhere in Bermudian waters (Stone et al., 1987; Clapham and Mattila, 1990; Reeves et al., 2006). Recent photographic surveys by the Humpback Whale Research Project of Bermuda have verified that humpback whales occur from late February through mid-May on the Sally Tucker and Challenger Banks and along Bermuda’s south shore (Whales Bermuda, 2008). Additionally, the Bermudian government in 2000 established a marine mammal sanctuary encompassing all its territorial waters but placed no emphasis on specific areas within Bermuda’s waters (Hoyt, 2005). While there is no doubt that humpbacks occur seasonally at Challenger Bank and may even opportunistically feed there, the available sighting data and information are insufficient to clearly demonstrate that the Challenger Bank area individually is the most significant biologically important area in Bermudian waters for humpback whales. Therefore, it was deemed that Challenger Bank should not be nominated as an LFA OBIA for marine mammals due to the inadequate scientific basis for such a nomination.

Fairweather Grounds (Southeast Alaska)

Fairweather Grounds was recommended as a LFA OBIA for humpback whale foraging. The nomination was based on limited sighting data of humpback whale aggregations collected during the summer of 2004 by NMFS as part of the SPLASH (Structure of Populations, Levels of Abundance and Status of Humpback whales) project. Fairweather Grounds, located in the continental shelf waters of southeastern Alaska and offshore from Glacier Bay, was a former whaling ground. This area is currently an important habitat for corals, demersal fishes, and some pelagic fishes, with EFH having been designated at Fairweather Grounds for more than 10 species (NMFS, 2005), while only one of these fish species is preyed upon by humpback whales. The 15 July 2004 weekly NMFS cruise reported high densities (value undefined) of humpback whales in the area of Fairweather Grounds for three days in the summer of 2004. No humpbacks were reported for the fall 2004 survey in the same area. In the Final SPLASH report (Calambokidis, et al., 2008), no mention is made of the Fairweather Grounds as a location to be further studied or of particular relevance for humpback whales in the northeastern Pacific. Further, the stock assessment reports for Alaskan waters do not mention Fairweather Grounds as a feeding area for humpback whales (Angliss and Allen, 2009). The limited sighting data for only one season are not adequate scientific support to warrant setting aside Fairweather Grounds as an LFA OBIA for marine mammals.

Ombai Strait in the Savu Sea/Savu Sea National Marine Park

An area near the center of the Ombai Strait in the Savu Sea of Indonesia was nominated as a marine mammal LFA OBIA for blue and sperm whale foraging grounds and migration routes. Sperm whales have been both historically and presently observed in this region of Indonesia, with subsistence whaling of sperm whales continuing in small scale in villages surrounding the Savu Sea (Rudolph et al., 1997; Mustika, 2006). While there is no doubt that both sperm and blue whales occur in the Ombai Strait region of the Savu Sea and nearby island passages (Rudolph et al., 1997; Pet-Soede, 2002, Kahn and Pet, 2003), the available data, however, do not adequately support the location or seasonality proposed for the OBIA nor do the data sufficiently show what biological activities these species are performing while occupying the waters of the Savu Sea region. Sightings of both sperm and blue whales are concentrated near to shore, likely a bias of the survey collection methodology, with no sightings in the center of the Ombai Strait (Pet-Soede, 2002, Kahn and Pet, 2003). Also, the data collected in the most recent surveys from 2001 to 2003 of the region’s waters were collected principally in May with some sparse records collected in October; these data do not support the seasonality of June through September proposed for this OBIA (Pet-Soede, 2002, Kahn and Pet, 2003). For these reasons, the Ombai Strait was rejected as a marine mammal LFA OBIA

Designation of OBIAs for LF Sensitive Species

The further analysis by NMFS and the Navy included establishment of a further screening criterion, i.e., that it was appropriate to consider marine mammal OBIAs only for those species whose best hearing sensitivity is in the LF range. The LFA source is well below the range of best hearing sensitivity for odontocetes and most pinnipeds, based on the fairly extensive body of laboratory measurements (Richardson et al., 1995; Nedwell et al., 2004; Southall et al., 2007; Au and Hastings, 2008; Houser et al., 2008; Kastelein et al., 2009; and Mulsow and Reichmuth, 2010).

Observations of marine mammal responses to other types of anthropogenic sounds, such as pile driving or seismic airguns, provide little insight to the discussion here. These types of activities produce impulsive sounds which contain both a rapid onset and a broad band of frequencies, including some in the MF and HF bands, and which have been observed to elicit a behavioral response from marine mammal LF species. LFA sonar is not impulsive but consists of narrowband tonals that resemble some of the sounds produced by certain LF whales, such as humpback and right whales. Therefore, an LFA sonar sound presents a fundamentally different context compared to impulsive anthropogenic sound sources. LFA sonar signals sound like the communication sounds produced by LF whales and are not the kind of sounds that would be expected to, or that have been observed to, evoke behavioral responses in MF or HF animals.

This finding is further supported by the 1997 to 1998 SURTASS LFA Sonar Low Frequency Sound Scientific Research Program (LFS SRP) which consisted of three phases, each conducted in an area where baleen whales were engaged in a biologically important behavior (blue and fin whales feeding in Southern California Bight, gray whales migrating off the central California coast, and humpback whales mating off the Big Island, Hawaii) (Clark et al., 2001). Results from that scientific research program demonstrated that under certain conditions, some of the focal individuals (LF species) within a limited range of the LFA sources would respond to LFA sonar, but they returned to their normal activities within a short period of time (Miller et al., 2000; Croll et al., 2001a; Fristrup et al., 2003). The conclusion from these observed responses was that the probability of LFA signals affecting a significant biological behavior of the focal baleen whales was minimal. During the LFS SRP, there were numerous non-focal marine mammals (MF and HF hearing species) sighted in the vicinity of the sea tests, including short-finned pilot whales, pygmy and dwarf sperm whales, melon-headed whales, false killer whales, Cuvier's beaked whales, common dolphins, bottlenose dolphins, spinner dolphins, Risso's dolphins, and California sea lions. There were no immediately obvious responses observed from these odontocetes and pinnipeds and no immediately obvious changes in sighting rates for these species as a function of LFA source conditions during the LFS SRP. Consequently, none of these species had any obvious behavioral reaction to LFA signals at received levels similar to those that produced only minor, short-term behavioral responses in the baleen whales.

There may be some possibility that a marine mammal MF and/or HF species could detect, either acoustically or vibrotactally, and possibly respond to LFA sonar. However, the chances of injury and/or significant behavioral responses to SURTASS LFA sonar are very low to negligible, given the following:

- The MF/HF frequencies these animals are adapted to hear and produce;
- Their natural acoustic ecologies;
- Their observed lack of response to LFA sounds during the LFS SRP; and
- The kinds of sounds to which they do or do not respond.

4.5.3 SURTASS LFA SONAR OFFSHORE BIOLOGICALLY IMPORTANT AREAS

As a result of this further analysis, the NMFS and the Navy concluded that there was adequate basis to designate 21 OBIAs (Table 4-26). The Navy also reviewed the potential OBIAs to assess personnel safety, practicality of implementation, and impacts of the effectiveness on military readiness activities to include testing, training, and military operations. No issues were found that would affect the practical implementation of the LFA OBIA geographic restrictions as part of the overall mitigation and monitoring program. These OBIAs, as part of the overall mitigation measures, will reduce incidental takings by SURTASS LFA sonar and, consistent with the current 2007 Rule, are not intended to apply to other Navy activities and sonar operations.

4.5.4 COMPARISON WITH CURRENT OBIAS

As presented in Table 2-4 of the SURTASS LFA Sonar FSEIS (DoN, 2007), nine OBIAs were designated. During the 2007 rulemaking process under the MMPA, NMFS added The Gully as the tenth OBIA (Table 4-27). Current OBIAs which maintain their status as LFA OBIAs include the Costa Rica Dome, Antarctic Convergence Zone, and Hawaiian Island Humpback Whale NMS—Penguin Bank. Also, the Cordell Bank NMS, Gulf of the Farallones NMS, and Monterey Bay NMS, including the Davidson Seamount Management Zone, were combined into the Central California NMSs based on NMFS' Final Rule 15 CFR 922 revisions of November 20, 2008. The Olympic Coast NMS OBIA was expanded to include the offshore areas known as The Prairie, Barkley Canyon, and Nitnat Canyon.

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
1	Georges Bank	40°00’N, 72°30’W 39°37 N, 72°09’W 39°54’N, 71°43’W 40°02 N, 71°20’W 40°08’N, 71°01’W 40°04’N, 70°44’W 40°00’N, 69°24’W 40°16’N, 68°27’W 40°34’N, 67°13’W 41°00’N, 66°24’W 41°52’N, 65°47’W 42°20’N, 66°06’W 42°18’N, 67°23’W	Northwest Atlantic Ocean	North Atlantic right whale	Year-round
2	Roseway Basin Right Whale Conservation Area	43°05'N, 65°40'W 43°05'N, 65°03'W 42°45'N, 65°40'W 42°45'N, 65°03'W	Northwest Atlantic Ocean	North Atlantic right whale	Canadian Restriction is June through December

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
3	Great South Channel, U.S. Gulf of Maine, and Stellwagen Bank NMS[61]	41°00.000'N, 69°05.000'W 42°09.000'N, 67°08.400'W 42°53.436'N, 67°43.873'W 44°12.541'N, 67°16.847'W 44°14.911'N, 67°08.936'W 44°21.538'N, 67°03.663'W 44°26.736'N, 67°09.596'W 44°16.805'N, 67°27.394'W 44°11.118'N, 67°56.398'W 43°59.240'N, 68°08.263'W 43°36.800'N, 68°46.496'W 43°33.925'N, 69°19.455'W 43°32.008'N, 69°44.504'W 43°21.922'N, 70°06.257'W 43°04.084'N, 70°21.418'W 42°51.982'N, 70°31.965'W 42°45.187'N, 70°23.396'W 42°39.068'N, 70°30.188'W 42°32.892'N, 70°35.873'W 42°07.748'N, 70°28.257'W 42°05.592'N, 70°02.136'W 42°03.664'N, 69°44.000'W 41°40.000'N, 69°45.000'W	Northwest Atlantic Ocean/ Gulf of Maine	North Atlantic right whale	January 1 to November 14
4	Southeastern U.S. Right Whale Seasonal Habitat	Critical Habitat Boundaries are coastal waters between 31°15' N and 30°15' N from the coast out 15 nautical miles (nmi); and the coastal waters between 30°15' N and 28°00' N from the coast out 5 nmi. (50 CFR §226.13(c)) OBIA Boundaries are coastal waters between 31°15' N and 30°15' N from the 12 to 15 nmi.	Northwest Atlantic Ocean	North Atlantic right whale	15 November to 15 April

61 The expanded boundaries of OBIA #3 encompass the northern critical habitats of the North Atlantic right whale, Stellwagen Bank NMS, and areas within the Gulf of Maine.

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
5	North Pacific Right Whale Critical Habitat[62]	57°03′N, 153°00′W 57°18′N, 151°30′W 57°00′N, 151°30′W 56°45′N, 153°00′W (50 CFR §226.215)	Northeastern Pacific Ocean/Gulf of Alaska	North Pacific right whale	March through August
6	Silver Bank and Navidad Bank	Silver Bank: 20° 38.899'N, 69° 23.640'W 20° 55.706'N, 69° 57.984'W 20° 25.221'N, 70° 00.387'W 20° 12.833'N, 69° 40.604'W 20° 13.918'N, 69° 31.518'W 20° 28.680'N, 69° 31.900'W Navidad Bank: 20° 15.596'N, 68° 47.967'W 20° 11.971'N, 68° 54.810'W 19° 52.514'N, 69° 00.443'W 19° 54.957'N, 68° 51.430'W 19° 51.513'N, 68° 41.399'W	Northwestern Atlantic Ocean/Caribbean Sea	Humpback whale	December through April
7	Coastal Waters of Gabon, Congo and Equatorial Guinea	An exclusion zone following the 500-m isobath extending from 3°31.055'N, 9°12.226'E in the north offshore of Malabo southward to 8°57.470'S, 12°55.873'E offshore of Luanda	Southeastern Atlantic Ocean	Humpback whale and Blue whale	June through October
8	Patagonian Shelf Break	Between 200- and 2000-m isobaths and the following latitudes: 35°00'S, 39°00'S, 40°40'S, 42°30'S, 46°00'S, 48°50'S	Southwestern Atlantic Ocean	Southern elephant seal	Year-round

62 OBIA added after NMFS and SME initial reviews. Effective 8 May 2008, NMFS designated critical habitat for the North Pacific Right Whale in the western Gulf of Alaska off of Kodiak Island (50 CFR 226.215(c)).

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
9	Southern Right Whale Seasonal Habitat	Coastal waters between 42°00'S and 43°00'S from 12 to 15 nmi including the enclosed bays of Golfo Nuevo, Golfo San Jose and San Matias. Golfos San Jose and San Nuevo are within 22 km (12 nmi) coastal exclusion zone.	Southwestern Atlantic Ocean	Southern right whale	May through December
10	Central California National Marine Sanctuaries	Single stratum boundary created from the Cordell Bank, Gulf of the Farallones, and Monterey Bay legal boundaries. Includes Davidson Seamount Management Zone. Boundaries NOAA, 2008.	Northeastern Pacific Ocean	Blue whale and Humpback whale	June thru November
11	Antarctic Convergence Zone[63]	30°E to 80°E, 45°S 80°E to 150°E, 55°S 150°E to 50°W, 60°S 50°W to 30°E, 50°S	Southern Ocean	Blue whale, Fin whale, Sei whale, Minke whale, Humpback whale, and Southern right whale	October through March

[63] OBIA added after NMFS and SME initial reviews. The Antarctic Convergence Zone has been an OBIA since 2001 as required by the initial and current SURTASS LFA Sonar 5-Year Rules (50 CFR §216.189). There are no additional scientific data that would change this status.

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
12	Piltun and Chayvo Offshore Feeding Grounds—Sea of Okhotsk	54°09.436'N, 143°47.408'W 54°09.436'N, 143°17.354'W 54°01.161'N, 143°17.354'W 53°53.580'N, 143°13.398'W 53°26.963'N, 143°28.230'W 53°07.013'N, 143°35.481'W 52°48.705'N, 143°38.447'W 52°32.077'N, 143°37.788'W 52°21.605'N, 143°34.163'W 52°09.470'N, 143°26.582'W 51°57.686'N, 143°30.208'W 51°36.033'N, 143°42.794'W 51°08.082'N, 143°51.301'W 51°08.082'N, 144°16.742'W 51°24.514'N, 144°11.139'W 51°48.116'N, 144°10.809'W 52°03.194'N, 144°20.363'W 52°23.235'N, 144°10.150'W 52°28.674'N, 144°12.787'W 52°42.523'N, 144°10.150'W 53°12.972'N, 143°55.648'W 53°18.505'N, 143°56.637'W 53°23.041'N, 143°53.011'W 53°28.250'N, 143°53.341'W 53°44.039'N, 143°49.056'W 53°53.207'N, 143°50.045'W 53°59.819'N, 143°48.067'W	Northwestern Pacific Ocean/Sea of Okhotsk	Western Pacific gray whale	June through November

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
13	Coastal Waters off Madagascar	16°03'55.04"S, 50°27'12.59"E 16°12'23.03"S, 51°03'37.38"E 24°30'45.06"S, 48°26'00.94"E 24°15'28.07"S, 47°46'51.16"E 22°18'00.74"S, 48°14'13.52"E 20°52'24.12"S, 48°43'13.49"E 19°22'33.24"S, 49°15'45.47"E 18°29'46.08"S, 49°37'32.25"E 17°38'27.89"S, 49°44'27.17"E 17°24'39.12"S, 49°39'17.03"E 17°19'35.34"S, 49°54'23.82"E 16°45'41.71"S, 50°15'56.35"E	Western Indian Ocean	Humpback whale and Blue whale	July through September for humpback whale breeding November through December for migrating blue whales
14	Madagascar Plateau, Madagascar Ridge, and Walters Shoal	25°55'20.00"S, 44°05'15.45"E 25°46'31.36"S, 47°22'35.90"E 27°02'37.71"S, 48°03'31.08"E 35°13'51.37"S, 46°26'19.98"E 35°14'28.59"S, 42°35'49.20"E 31°36'57.96"S, 42°37'49.35"E 27°41'11.21"S, 44°30'11.01"E	Western Indian Ocean	Pygmy blue whale, Humpback whale, and Bryde's whale	November through December

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
15	Ligurian-Corsican-Provençal Basin and Western Pelagos Sanctuary	42°50.271'N, 06°31.883E 42°55.603'N, 06°43.418E 43°04.374'N, 06°52.165E 43°12.600'N, 07°10.440E 43°21.720'N, 07°19.380E 43°30.600'N, 07°32.220E 43°33.900'N, 07°49.920E 43°36.420'N, 08°05.580E 43°42.600'N, 08°22.140E 43°50.880'N, 08°34.500E 43°58.560'N, 08°47.700E 43°59.040'N, 08°56.040E 43°57.047'N, 09°03.540E 43°52.260'N, 09°08.520E 43°47.580'N, 09°13.500E 43°36.060'N, 09°16.620E 43°28.440'N, 09°05.820E 43°21.360'N, 09°02.100E 43°16.020'N, 08°57.240E 43°04.440'N, 08°47.580E 42°54.900'N, 08°35.400E 42°45.900'N, 08°27.540'E 42°36.060'N, 08°22.020'E 42°22.620'N, 08°15.849'E 42°07.202'N, 08°17.174'E 41°52.800'N, 08°15.720'E 41°39.780'N, 08°05.280'E 41°28.200'N, 08°51.600'E 42°57.060'N, 06°19.860'E	Northern Mediterranean Sea	Fin whale	July to August

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
16	Hawaiian Islands Humpback Whale NMS—Penguin Bank	21°10'02.179"N, 157°30'58.217"W 21°09'46.815"N, 157°30'22.367"W 21°06'39.882"N, 157°31'00.778"W 21°02'51.976"N, 157°30'30.049"W 20°59'52.725"N, 157°29'28.591"W 20°58'05.174"N, 157°27'35.919"W 20°55'49.456"N, 157°30'58.217"W 20°50'44.729"N, 157°42'42.418"W 20°51'02.654"N, 157°44'45.333"W 20°53'56.784"N, 157°46'04.716"W 20°56'32.988"N, 157°45'33.987"W 21°01'27.472"N, 157°43'10.586"W 21°05'20.499"N, 157°39'27.802"W 21°10'02.179"N, 157°30'58.217"W	North-Central Pacific Ocean	Humpback whale	November through April
17	Costa Rica Dome	Centered at 9°N and 88°W	Eastern Tropical Pacific Ocean	Blue whale and Humpback whale	Year-round

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
18	Great Barrier Reef Between 16°S and 21°S	16°01.829'S, 145°38.783'E 15°52.215'S, 146°20.936'E 17°28.354'S, 146°59.392'E 20°16.228'S, 151°39.674'E 20°58.381'S, 150°30.897'E 20°17.007'S, 149°38.247'E 20°10.941'S, 149°18.247'E 20°02.403'S, 149°12.623'E 19°53.287'S, 149°03.986'E 19°49.866'S, 148°52.135'E 19°53.287'S, 148°44.302'E 19°47.965'S, 148°36.870'E 19°47.205'S, 148°26.024'E 19°19.978'S, 147°39.626'E 19°14.065'S, 147°37.014'E 19°08.913'S, 147°31.993'E 19°05.667'S, 147°24.160'E 19°07.576'S, 147°18.134'E 18°51.718'S, 146°51.219'E 18°44.258'S, 146°54.031'E 18°37.175'S, 146°51.420'E 18°31.620'S, 146°43.385'E 18°27.595'S, 146°40.573'E 17°36.676'S, 146°20.488'E 17°20.484'S, 146°16.671'E 17°07.745'S, 146°13.056'E 16°49.769'S, 146°11.047'E 16°41.835'S, 146°03.817'E 16°39.706'S, 145°54.979'E	Coral Sea/Southwestern Pacific Ocean	Humpback whale and Dwarf minke whale	May through September
19	Bonney Upwelling	37°12'20.036"S, 139°31'17.703"E 37°37'33.815"S, 139°42'42.508"E 38°10'36.144"S, 140°22'57.345"E 38°44'50.558"S, 141°33'50.342"E 39°07'04.125"S, 141°11'00.733"E 37°28'33.179"S, 139°10'52.263"E	Eastern Indian Ocean	Blue whale, Pygmy blue whale, and Southern right whale	December through May

Table 4-26. Potential SURTASS LFA sonar OBIAs revised for this document.

OBIA Number	Name of Area	Location of OBIA	Water Body	Significant Species	Seasonal Restrictions
20	Northern Bay of Bengal and Head of Swatch-of-No-Ground (SoNG)	20°59.735'N, 89°07.675'E 20°55.494'N, 89°09.484'E 20°52.883'N, 89°12.704'E 20°55.275'N, 89°18.133'E 21°04.558'N, 89°25.294'E 21°12.655'N, 89°25.354'E 21°13.279'N, 89°16.833'E 21°06.347'N, 89°15.011'E	Bay of Bengal/Northern Indian Ocean	Bryde's whale (small form)	Year-round
21	Olympic Coast: The Prairie, Barkley Canyon, and Nitnat Canyon	48°30'01.995"N, 125°58'38.786"W 48°16'55.605"N, 125°38'52.052"W 48°23'07.353"N, 125°17'10.935"W 48°12'38.241"N, 125°16'42.339"W 47°58'20.361"N, 125°31'14.517"W 47°58'20.361"N, 126°06'16.322"W 48°09'46.665"N, 126°25'48.758"W Existing OBIA boundaries as defined in the 2007 Rule (50 CFR §216.184(f)).	Northeastern Pacific Ocean	Humpback whale	Existing OBIA: December, January, March, and May The Prairie, Barkley Canyon, and Nitnat Canyon June to September

Table 4-27. SURTASS LFA sonar OBIAs under Current Rule (NOAA, 2007c).

AREA NUMBER	NAME OF AREA	LOCATION OF AREA	MONTHS OF IMPORTANCE
1	200 m isobath of North American East Coast[64]	From 28°N to 50°N west of 40°W	Year-round
2	Costa Rica Dome	Centered at 9°N and 88°W	Year-round
3	Antarctic Convergence Zone	30°E to 80°E, 45°S. 80°E to 150°E, 55°S 150°E to 50°W, 60°S 50°W to 30°E, 50°S	October through March
4	Hawaiian Island Humpback Whale NMS—Penguin Bank[65]	Centered at 21°N and 157°30'W	November 1 through May 1
5	Cordell Bank NMS	Boundaries IAW 15 CFR 922.110	Year-round
6	Gulf of the Farallones NMS[65]	Boundaries IAW 15 CFR 922.80	Year-round
7	Monterey Bay NMS[65]	Boundaries IAW 15 CFR 922.130	Year-round
8	Olympic Coast NMS[65]	Within 23 nm of coast from 47°07'N to 48°30'N latitude	December, January, March and May
9	Flower Garden Banks (NMS)[65]	Boundaries IAW 15 CFR 922.120	Year-round
10	The Gully	44°13'N, 59°06'W to 43°47'N, 58°35'W to 43°35'N, 58°35'W to 43°35'N, 59°08'W to 44°06'N, 59°20'W	Year-round

Two current OBIAs were evaluated and found not to meet the criteria for designation as an LFA OBIA–Flower Garden Bank NMS and The Gully. Flower Garden Bank NMS lies approximately 185 km (100 nmi) off the coasts of Texas and Louisiana in the Gulf of Mexico. It was evaluated in NMFS' initial screening of OBIAs for marine mammals and was found ineligible because it did not meet Criterion 2. There is no evidence that more LF marine species engage in biologically important activities, such as feeding or breeding, in the Flower Garden Bank NMS than typically engage in such activities elsewhere. The Gully was removed from further consideration because the marine mammal of concern (northern bottlenose whale) does not have its best hearing sensitivity in the LF range.

Current OBIA #1 (200-m Isobath of North American East Coast) was re-designated as LFA OBIAs #1 to #4, which include:

64 OBIA boundaries encompass the critical habitats of the North Atlantic right whale, Stellwagen Bank NMS, Monitor NMS, and Gray's Reef NMS.

65 Letter from the Office of National Marine Sanctuaries, National Ocean Service, NOAA, dated 15 May 2001.

- Georges Bank (LFA OBIA #1);
- Roseway Basin Right Whale Conservation Area (LFA OBIA #2);
- Southeastern U.S. Right Whale Seasonal Habitat (NARW Critical Habitat) (LFA OBIA #4); and
- Great South Channel (LFA OBIA #3) including North Atlantic Right Whale (NARW) Critical Habitat, Stellwagen Bank NMS, areas within the Gulf of Maine.

This approach meets NMFS' biological criteria with seasonal restrictions (where appropriate) and establishes these OBIAs based on the best available science in lieu of geographic restrictions from arbitrarily established distances from shore or bathymetric features.

4.5.5 Operational Exception

The Navy reserves the right to create sound fields from SURTASS LFA transmissions at or above 180 dB dB re 1 µPa (rms) within the boundaries of the designated SURTASS LFA sonar OBIAs pursuant to the SEIS/SOEIS, including operating within an OBIA when: 1) operationally necessary to continue tracking an existing underwater contact; or 2) operationally necessary to detect a new underwater contact within the OBIA. This exception will not apply to routine training and testing with the SURTASS LFA sonar systems.

4.5.6 Coastal Standoff Range

The Navy also considered whether using a greater coastal standoff range in some locations where the shelf (≤200 m [656 ft] depth) extends farther than the current 22 km (12 nmi) coastal standoff range, is practicable. This analysis was effectively combined with the OBIA analysis outlined above, because as part of the OBIA analysis NMFS and the Navy considered the biological importance of coastal areas outside the current 22 km (12 nmi) coastal standoff range. For example, of the initial listing of 73 recommended LFA MM OBIAs by NMFS' expert panelists, 32 were either completely or partially within shelf waters and outside of the coastal standoff range. After analyses and rankings, NMFS and the Navy agreed on the proposed final 21 SURTASS LFA sonar OBIAs. Nearly all of the revised OBIAs are either located completely or partially within shelf waters but outside (or seaward of) the coastal standoff range. Therefore, the coastal standoff range for this analysis will remain at 22 km (12 nmi).

4.6 POTENTIAL IMPACTS TO SOCIOECONOMIC RESOURCES

This subchapter addresses the potential impact to commercial and recreational fisheries, other recreational activities, and research and exploration activities that could result from implementation of the alternatives under consideration.

4.6.1 Commercial and Recreational Fisheries

SURTASS LFA sonar operations are geographically restricted such that SURTASS LFA sonar RLs are less than 180 dB dB re 1 µPa (rms) RL within 22 km (12 nmi) from coastlines and at the boundaries of offshore biologically important areas during biologically important seasons, where fisheries productivity is generally high. If SURTASS LFA sonar operations occur in proximity to fish stocks, members of some fish species could potentially be affected by LF sounds. Even then, the impact on fish is likely to be minimal to negligible since only an inconsequential portion of any fish stock would be present within the 180-dB sound field at any given time. Moreover, recent results from direct studies of the effects of LFA sounds on fish (Halvorsen et al., 2006; Popper et al., 2007; Kane et al., 2010) provide evidence that SURTASS LFA sonar sounds at relatively high received levels (up to 193 dB dB re 1 µPa [rms] SPL) have minimal impact on at least the species of fish that were studied. Nevertheless, the 180-dB criterion has been maintained for the analyses presented in this SEIS/SOEIS, with emphasis that this value is *highly conservative* and protective of fish. Therefore, SURTASS LFA sonar operations are not likely to affect fish populations and, thus, are not likely to affect commercial and recreational fishing.

4.6.2 Other Recreational Activities

There are no new data that contradict any of the assumptions or conclusions regarding Subchapter 4.3.2 (Other Recreational Activities) in the FOEIS/EIS (DoN, 2001) regarding recreational swimming, snorkeling, and diving; hence, the contents of the FOEIS/EIS section are incorporated by reference herein. Whale watching typically takes places during times of year and in geographic locations where the probability of observing cetaceans will be greatest; probability of occurrence is higher because cetaceans have aggregated in specific areas to participate in some biologically important activity such as feeding or migrating. Due to the water depth and accessibility, the vast majority of recreational swimming, snorkeling, and diving occurs within 22 km (12 nmi) of shore. Since SURTASS LFA sonar operations are restricted from transmitting ≥180 dB dB re 1 µPa (rms) SPL RL within 22 km (12 nmi) from shore, more than 145 dB dB re 1 µPa (rms) SPL RL near known recreational and commercial dive sites, and in OBIAs during biologically important seasons, there is no reasonably foreseeable likelihood that operation of the sonar will affect recreational diving, snorkeling, swimming, or whale watching.

4.6.3 Research and Exploration Activities

There are no new data that contradict any of the assumptions or conclusions regarding Subchapter 4.3.3 in the FOEIS/EIS (DoN, 2001) and Subchapter 4.5.3 in the FSEIS (DoN, 2007a) regarding research and exploration activities; hence, their contents are incorporated by reference herein. SURTASS LFA sonar operations are highly unlikely to affect oceanographic research that utilize submersibles (remotely operated vehicles [ROVs], autonomous undersea vehicles [AUVs], or manned submersibles) but could potentially affect other types of oceanographic research or oil and gas exploration activities that employ underwater acoustic equipment or instruments such as air guns, hydrophones, and ocean-bottom seismometers. If transmitted near oceanographic or exploration activities using underwater acoustic instrument, SURTASS LFA sonar could possibly interfere with the acoustic instruments or saturate the hydrophones. Conversely, research and exploration activities using underwater acoustic instruments or sources could likewise interfere with SURTASS LFA sonar operations. For these reasons, SURTASS LFA sonar operations will not operate in the vicinity of known oceanographic or oil and gas exploratory operations and thus will not have an effect on these activities.

4.7 POTENTIAL CUMULATIVE EFFECTS

Cumulative effects have been defined by the Council on Environmental Quality (CEQ) as:

> "Cumulative impacts is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." (40 CFR 1508.7, 1978)

Four areas were evaluated for the incremental cumulative effects of SURTASS LFA sonar operations with "past, present, and reasonably foreseeable future actions." These include:

- Anthropogenic oceanic noise levels;
- Injury and lethal takes from anthropogenic causes;
- Socioeconomics; and
- Concurrent SURTASS LFA sonar and mid-frequency active (MFA) sonar operations.

4.7.1 Cumulative Effects from Anthropogenic Oceanic Noise

The potential cumulative effects issue associated with SURTASS LFA sonar operations is the addition of underwater sound to oceanic ambient noise levels, which in turn could affect marine animals. Anthropogenic sources of ambient noise that are most likely to have contributed to increases in ambient noise levels are commercial shipping, offshore oil and gas exploration and drilling, and naval and other use of sonar (ICES, 2005; MMC, 2007).

A report of the Interagency Task Force on Anthropogenic Sound and the Marine Environment of the Joint Subcommittee on Ocean Science & Technology (JSOST) states that the Marine Mammal Commission (MMC), National Oceanic and Atmospheric Administration (NOAA), and the U.S. Fish and Wildlife Service (USFWS) are:

> "…broadening their focus and expertise, based on the increasing realization that sound sources such as large vessels, pile driving, offshore energy development, navigational and/or imaging sonars, and oceanographic research sources may be of concern in addition to the naval and geophysical sound sources currently receiving the greatest attention. While some of these sources may lack the instantaneous output power of some of the powerful active sonars and seismic airgun sources, many of them occur in far greater numbers and cover much greater geographical ranges and deployment times than more intense, acute sounds. The potential for impact from certain lower-power but more ubiquitous sources is increasingly being considered and scientific measurements are required to inform these considerations." (Southall et al., 2009a)

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

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

4.7.1.1 Oceanic Noise Levels

Ambient noise is the typical or persistent environmental background noise that is present throughout the ocean; it is generated by both natural and anthropogenic sources. The U.S. Marine Mammal Commission, in a recently published document on underwater sound in the marine environment, classifies ambient noise into three broad categories: natural biotic, which can include marine animals, fish, and invertebrates; natural abiotic, such as seismic disturbances; and anthropogenic, which includes noise from shipping vessels and seismic surveying (Bradley and Stern, 2008). Thus, any potential for cumulative effects should be put into the context of recent changes to ambient sound levels in the world's oceans. Sources of oceanic ambient noise, both natural and man-made are presented in the SURTASS LFA sonar FOEIS/EIS Subchapter 3.1.1 as well as in Subchapter 3.1.1 of this document. Research and statements made regarding changes in oceanic noise levels before 2001 can be found in the FOEIS/EIS, Subchapter 4.4.1. The SURTASS LFA sonar FSEIS, Subchapter 4.6.1.1, complements those data with information from 2001 through 2005. These subchapters are incorporated by reference herein to this SEIS/SOEIS.

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

McDonald et al. (2006) cite commercial shipping as the most plausible explanation for the measured increases.

Commercial Shipping and Vessel Noise Sources

Subchapter 4.6.1.1 from the SURTASS LFA sonar FSEIS (DoN, 2007a) dealing with commercial shipping and vessel noise sources, remains valid and is incorporated by reference herein to this SEIS/SOEIS, except as noted below. The number of commercial vessels plying the world's oceans approximately doubled between 1965 and 2003, and the gross tonnage quadrupled, with a corresponding increase in horsepower (McDonald et al., 2006). Clark et al. (2009) demonstrated that acoustic communications space for the highly endangered North Atlantic right whale is seriously compromised by anthropogenic noise from commercial shipping traffic.

Oil and Gas Industry

Subchapter 4.6.1.1 from the SURTASS LFA sonar FSEIS, dealing with the oil and gas industry, remains valid and is incorporated by reference herein to this SEIS/SOEIS. In a recent study, Di Iorio and Clark (2009) found that blue whales increase their rate of social calling in the presence of seismic exploration sparkers (plasma sound sources), which presumably represented a compensatory behavior to elevated ambient noise levels from seismic surveys.

Military and Commercial Sonar

Subchapter 4.6.1.1 from the SURTASS LFA sonar FSEIS, dealing with military and commercial sonar, remains valid and is incorporated by reference herein to this SEIS/SOEIS. The statement excerpted from Southall et al. (2009a) above under "commercial shipping" also applies here—that even though naval and geophysical sound sources are currently receiving the greatest attention, other lower-power but more ubiquitous sound sources occur in far greater numbers and cover much greater geographical ranges and deployment times.

Effects of Ambient Noise Increase

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

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

The potential for cumulative effects from SURTASS LFA transmissions is analyzed in relation to overall oceanic ambient noise levels, including the potential for LFA sound to add to overall ambient levels of anthropogenic noise. Increases in ambient noise levels have the potential to cause masking and decrease the distances that underwater sound can be detected by marine animals. These effects have the potential to cause a long-term decrease in a marine mammal's efficiency at foraging, navigating, or communicating (ICES, 2005). NRC (2003) discussed acoustically-induced stress in marine mammals. NRC stated that sounds resulting from one-time exposure are less likely to have population-level effects than sounds that animals are exposed to repeatedly over extended periods of time. NRC (2005) proposed an alternative terminology for what "stress" refers to, which considers energy budgets and life-history events, based on McEwen and Wingfield (2003). It focuses on the concept of allostatic[66] load, which was adapted from the cardiovascular field and was introduced for more broad application in McEwen and Stellar (1993).

Ambient Noise Levels and Masking

Subchapter 4.6.1.2 from the SURTASS LFA sonar FSEIS, dealing with ambient noise levels and masking, remains valid and is incorporated by reference herein to this SEIS/SOEIS except as noted below. Broadband, continuous low-frequency ambient noise is more likely to affect marine mammals than narrowband, low duty cycle SURTASS LFA sonar. Moreover, the bandwidth of any SURTASS LFA sonar transmitted signal is limited (approximately 30 Hz), the average maximum pulse length is 60 seconds, signals do not remain at a single frequency for more than 10 seconds, and during an operation the system is off nominally 90 to 92.5% of the time. Most mysticete vocalizations are in the low frequency band below 1 kHz, and it is generally believed that their frequency band of best hearing is below 1 kHz, where their calls have the greatest energy (Clark, 1990; Edds-Walton, 2000; Ketten, 2000). However, with the nominal duty cycle of 7.5 to 10%, masking by LFA would only occur over a very small spatial and temporal scale. For these reasons, any masking effects from SURTASS LFA sonar are expected to be negligible.

As presented in Subchapter 4.6.1.2 of the FSEIS, 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. This is supported by the findings of Andrew et al. (2002) and McDonald et al. (2006) discussed above. Both the SURTASS LFA Sonar FOEIS/EIS and FSEIS analyzed the potential effects of four SURTASS LFA sonar systems. The use of SURTASS LFA sonar is not scheduled to increase past the originally analyzed four systems during the next five–year regulation under the MMPA. Therefore, LFA transmissions will not significantly increase anthropogenic oceanic noise in the next five years over that of the previous analyses. The findings in the SURTASS LFA Sonar FSEIS remain valid, and the cumulative effects related to the potential for masking from the proposed four SURTASS LFA sonar systems are not a reasonably foreseeable significant adverse impact on marine animals.

Stress

Subchapter 4.6.1.2 from the SURTASS LFA Sonar FSEIS, dealing with stress, remains valid and is incorporated by reference herein to this SEIS/SOEIS. Even though there are scientific data gaps concerning stress and marine animals, a sufficient understanding exists to make an informed decision regarding the proposed action. Because LFA transmissions will not significantly increase anthropogenic oceanic noise and the potential for masking is negligible, cumulative effects related to the potential for inducing stress from the proposed four SURTASS LFA sonar systems are not a reasonably foreseeable significant adverse impact on marine animals.

Synergistic Effects with Other Oceanic Noise Sources

Subchapter 4.6.1.2 from the SURTASS LFA Sonar FSEIS, dealing with synergistic effects with other oceanic noise sources, remains valid. Since the FSEIS was published in 2007, a comprehensive scientific

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

analysis has been undertaken and is highlighted below to address the potential for cumulative effects from concurrent LFA/MFA sonar operations; this study validates the earlier FSEIS assessment of SURTASS LFA sonar operations concurrent with other military and commercial sonar systems.

4.7.2 Cumulative Effects to Marine Mammals due to Injury and Lethal Takes

The second area for potential cumulative effects to marine mammal populations is through injury and lethal takes. In order to evaluate the effects of SURTASS LFA sonar operations, it is necessary to place it in perspective with other anthropogenic impacts on marine resources. Subchapter 4.6.2 from the SURTASS LFA Sonar FSEIS, dealing with bycatch and ship strikes, remains valid and is incorporated by reference herein to this SEIS/SOEIS.

4.7.2.1 Bycatch

Culik (2010) stated in his report compiled for the United Nations Environmental Programme (UNEP) Convention on Migratory Species that the major threat faced by odontocetes is by-catch in fisheries operations, which is affecting 86% of toothed whale species. Read et al. (2006) estimated the annual global bycatch for the period 1990 to 1994 to be 653,365 marine mammals (307,753 cetaceans and 345,611 pinnipeds). They also reported that the mean annual marine mammal bycatch in U.S. fisheries between 1990 and 1999 was 6,215, with the number trending downward throughout the decade due to the implementation of bycatch mitigation measures and, coincidentally, due to measures put in place to protect fisheries stocks.

Increases in underwater ambient noise levels have the potential to mask an animal's ability to detect objects, such as fishing gear, thus increasing their susceptibility to bycatch. However, because LFA transmissions are intermittent and will not significantly increase anthropogenic oceanic noise, cumulative effects from masking by LFA signals are not a reasonably foreseeable significant adverse effect on marine animals.

4.7.2.2 Ship Strikes

NMFS convened a workshop to identify and assess technologies to reduce ship strikes of large whales 8 to 10 July 2008, in Providence, RI. The workshop objectives were to: 1) identify existing or emerging technologies that might be useful in reducing ship strikes; 2) assess the feasibility of each in reducing ship strikes; and 3) identify research and development timelines needed to make a given technology useful in reducing the threat.

The outcome of the workshop was a report that stated:

> "…the problem of ship strikes is a complex one; there are no easy technological "fixes;" no technology exists, or is expected to be developed in the foreseeable future that will completely ameliorate, or reduce to zero the chances of, ship strikes of large whales; and no single technology will fit all situations. Reducing the co-occurrence of whales and vessels is likely the only sure means of reducing ship strikes, but it is not possible in many locations…Technologies applicable to reducing ship strikes are limited almost entirely to those that enhance whale detection…Depending on systems used, costs can be relatively high and false positives could be problematic…In all cases, studies are needed to confirm that any technology developed and used for this purpose are clearly capable of reducing strikes and to ensure that added environmental impacts are not introduced." (Silber et al., 2009)

A review of ship strike data found that the probability of injury or death increased with speed and generally occurred when ships were travelling at 14 kts or faster (Laist et al., 2001). Ship strikes are generally not an issue for SURTASS LFA sonar vessels because of their slow operational speed (nominally 3 kts) and transit speed (10 to 12 kts).

4.7.2.3 Lethal Whale Takes

As discussed in Chapter 3 of this document, lethal takes of whales for other activities have been authorized, including those for scientific research and subsistence whaling. Based on extensive evaluation in this document, the FOEIS/EIS, and the FSEIS, the operation of SURTASS LFA sonar with monitoring and mitigation will result in no lethal takes. This is supported by the fact that SURTASS LFA sonar has been operating since 2003 in the northwestern Pacific Ocean with no reported Level A (MMPA) harassment takes or strandings associated with its operations (DoN, 2008; 2009b; 2010). Moreover, there has been no new information or data that contradict the FOEIS/EIS and FSEIS findings that the potential effects from SURTASS LFA sonar operations on any stock of marine mammals from injury (non-auditory or permanent loss of hearing) are considered not more than negligible. Since there are no reasonably foreseeable effects from LFA operations that would lead to injury or lethal takes of marine animals, there are no cumulative effects in this area due to SURTASS LFA sonar operations.

4.7.3 Cumulative Effects to Socioeconomic Resources

Earlier in this chapter the potential effects on commercial and recreational fisheries, other recreational activities, and research and exploration activities that could result from implementation of the alternatives under consideration were addressed. The conclusion was that these activities would not be substantially affected. Therefore, the potential for cumulative effects from LFA effects on socioeconomic activities are not a reasonably foreseeable significant adverse impact.

4.7.4 Cumulative Effects from Concurrent LFA and MFA Sonar Operations

In 2007, the SURTASS LFA Sonar FSEIS stated:

> "If SURTASS LFA sonar operations were to occur concurrent with other military and commercial sonar systems, synergistic effects are not probable because of differences between these systems. In order for the sound fields to converge, the multiple sources would have to transmit exactly in phase (at the same time), requiring similar signal characteristics, such as time of transmissions, depth, frequency, bandwidth, vertical steering angle, waveform, wavetrain, pulse length, pulse repetition rate, and duty cycle. The potential for this occurring is small." (DoN, 2007a)."

This subchapter provides further analysis regarding the potential for impacts when SURTASS LFA sonar and MFA sonar are used simultaneously or in rapid succession during the same naval exercise/operation.

4.7.4.1 Potential for Combined Effects from LFA and MFA Sonar Transmissions

Although the SURTASS LFA and MFA (AN/SQS 53C and AN/SQS 56) sonars are similar in the underlying transmission types, specifically frequency-modulated (FM) sweeps and continuous wave (CW) transmissions, LFA and MFA sonars are dissimilar in other respects (Table 4-28). In addition to the dissimilarities apparent in the table, the duty cycle, (i.e., the amount of time *during sonar operations* that the sonar is actually transmitting), is different for SURTASS LFA sonar as opposed to MFA sonar. During SURTASS LFA sonar operations, LFA sonar transmits approximately 10% of the time (1 minute out of 10). During MFA sonar operations, MFA sonar transmits approximately 1.7% of the time (1 second out of

Table 4-28. Comparison of LFA and MFA sonar underwater acoustic source properties (D'Spain et al., 2006; DoN 2007a and 2008b).

	SURTASS LFA SONAR	AN/SQS 53C MFA SONAR	AN/SQS 56 MFA SONAR
Waveform[67]	FM/CW	FM/CW	FM/CW
Source Level[68]	215 dB re 1 µPa at 1 m (rms) per element	235 dB re 1 µPa at 1 m (rms)	223 dB re 1 µPa at 1 m (rms)
Pulse Length	Variable 6 to 100 sec, average 60 sec; never longer than 10 sec at a single frequency	1 to 2 sec	1 to 2 sec
Inter-pulse Time	6 to 15 min	60 to 90 sec	60 sec
Center Frequency	100-500 Hz	2.6 and 3.3 kHz	6.8, 7.5, and 8.2 kHz
Bandwidth	30 Hz	100 Hz	100 Hz
Source Depth	Array 87 to 157 m (285 to 515 ft), center 122 m (400 ft)	8 m (26.2 ft)	6 m (19.7 ft)

60)[69]. This means that for any given period of time that both SURTASS LFA and MFA sonars are operating concurrently, the LFA 60-sec transmission will be overlapped by 1. sec of MFA transmission, or 1.7% of the 60-sec LFA ping (1 sec/60 sec) (Figure 4-7). During the 10-min LFA transmission cycle, the most an animal could be simultaneously exposed from both transmissions is 1 sec for every 600 sec, or about 0.17%[70] of the time that both sonars are operating.

The previous SURTASS LFA Sonar FEIS/FOEIS and FSEIS did not attempt to quantify potential impacts from concurrent SURTASS LFA and MFA sonar operations. The simplest way to attempt such quantification would be to calculate the risk to marine mammals/animals independently for each sonar and then add the results. To address the issue of whether the combined risk from concurrent SURTASS LFA and MFA sonar operations could be more than the sum of the impacts of both systems due to potential synergistic[71] effects, the Navy has conducted additional, more sophisticated analyses. These are described briefly below and more detail can be found in Appendix E.

[67] Frequency modulated (FM), continuous wave (CW).

[68] Source levels are rms for sonars in units of dB re 1 µPa @ 1m.

[69] MFA sonar operating characteristics are based on the Navy's AN/SQS 53C sonar. The nominal sonar ping is approximately 1 second every 60 to 90 seconds (Nissen, 2011). For analysis, 1 sec/60 sec was used as it is the most conservative.

[70] MFA overlaps 1 sec for every 10 min (600 sec) of LFA duty cycle (1 sec/600 sec = 0.0017).

[71] Synergism, in general, may be defined as two or more agents working together to produce a result not obtainable by any of the agents independently.

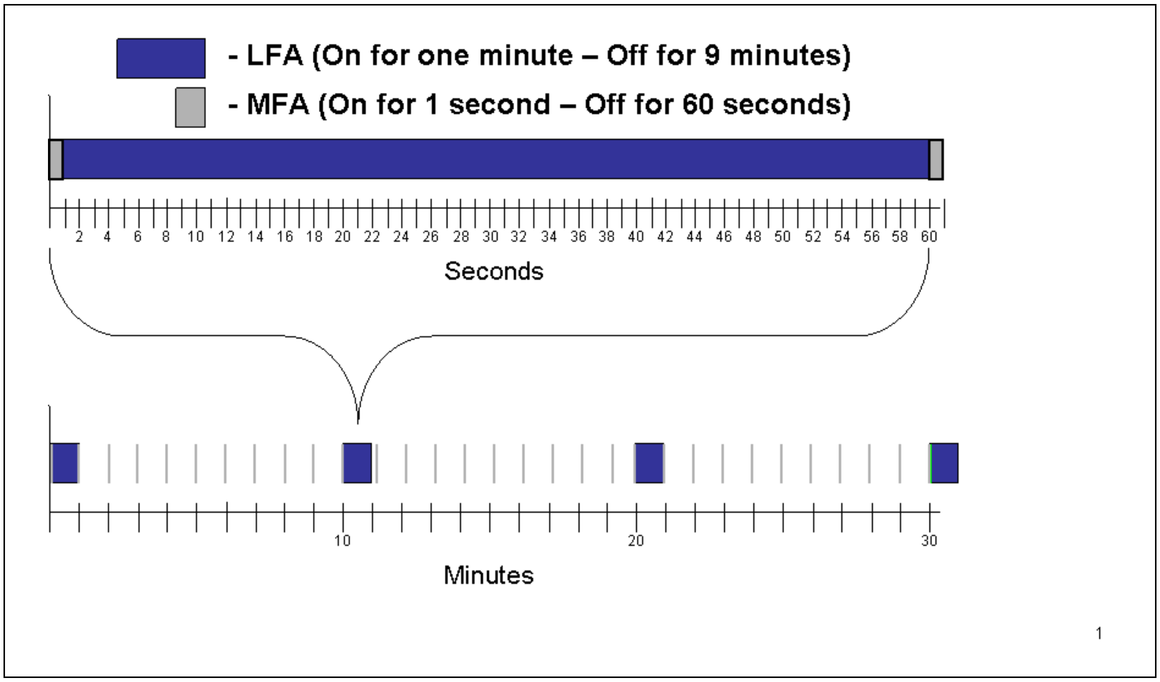

Figure 4-7. Potential for LFA and MFA sonar transmissions to overlap.

Potential for MMPA Level A Impacts from Combined Effects

The ocean volume potentially affected by Level A received levels (RLs) for each source are relatively small, being 1 km (0.54 nmi) radius or less, based on current NMFS-published Rules (NOAA, 2007c, 2009d, 2009e, and 2009f). For a variety of tactical and safety reasons, however, it is not reasonably foreseeable that SURTASS LFA and MFA sonars would operate at distances closer than 9.3 km (5 nmi) to each other. It is therefore not reasonably foreseeable that the Level A volumes for SURTASS LFA and MFA sonars would ever overlap. The statistical probability of an MFA Level B RL intensifying to a Level A RL when combined simultaneously with a SURTASS LFA sonar Level B RL is also exceedingly low (Appendix E).

Sequential, as opposed to simultaneous, exposures of a single marine mammal to a SURTASS LFA sonar transmission at a RL immediately below Level A and then an MFA transmission at a RL immediately below Level A (or vice versa), could hypothetically result in exposure above 180 dB re 1 µPa (rms) (RL). However, this hypothetical possibility is exceedingly small, given: 1) the low probability that SURTASS LFA and MFA sonars would be operating concurrently in the first place; 2) the low duty cycles of each source, even when such concurrent operations are occurring (0.17% of the time); 3) the fact that both systems would have to be operating close enough to each other for the animal to swim to both exposure points in a short enough period to have experienced, but not recovered from, the impact of the first exposure before experiencing the second exposure; 4) the fact that both the SURTASS LFA and MFA vessels are moving in two dimensions and the animal is moving in three dimensions; and 5) the fact that the exposed animal would have to elude detection by the multiple mitigation regimes for both SURTASS LFA and MFA sonars to be near enough to the Level A volumes of both sonars to experience near-Level A exposures.

Potential for MMPA Level B Effects from Combined Effects

To analyze the possibility for Level B effects of the improbable scenario (simultaneous, or near-simultaneous, MFA and LFA transmissions) occurring, the Navy used two separate methodologies, a parametric analysis and an Acoustic Integration Model© (AIM) analysis, which use the previously established risk continuum for SURTASS LFA sonar (DoN, 2001 and 2007a). The risk continuum methodology for SURTASS LFA sonar was applied here to facilitate a complex analytic process with two dissimilar sonar systems.

The risk continuum for SURTASS LFA sonar was initially developed for determining the risk from SURTASS LFA sonar (DoN, 2001). An exposure of 165 dB SPL (re 1 μPa) returns an associated risk of 0.5 (50%) from the risk continuum function; whereas 150 and 180 dB SPL (re 1 μPa) return 0.025 (2.5%) and 0.95 (95%) risk, respectively (Figure 4-8)**.**

➢ **Parametric analysis**

Parametric analysis is a methodology to describe and examine the relationship between different parameters (e.g., in this case acoustic transmission loss as a function of range and depth) and the variable (e.g., potential acoustic effect on marine mammals) that it/they influence or affect. Parametric analysis is derived from "dimensional analysis,", which is defined as:

> "…the mathematics of dimensions and quantities and provides procedural techniques whereby the variables that are assumed to be significant in a problem can be formed into dimensionless parameters, the number of parameters being less than the number of variables." (Avallone and Baumeister, 1987)

The advantage of this type of analysis is the reduction of a large number of variables into a smaller, more manageable, number of parameters. This kind of analysis has been in use for over 100 years and is well accepted in the scientific community. One example is the use of a properly scaled ship model to identify the force needed to propel the actual full-size ship through the water, including the size of the engines needed to do so. One of the key inputs is the ratio of inertia and viscous forces using the "Reynolds Number[72]," a key dimensionless number used in naval architecture, aeronautics, and anywhere fluid flow is important.

This analysis identified appropriate metrics for each of the important parameters (e.g., difference in source level [SL], distance between sources, different propagation conditions, Level B harassment criteria, etc.). Then, using such metrics, the risk for multiple animal depths and a variety of sonar separation ranges in static conditions (i.e., a series of "snapshots" of single ping risk for each source, and for the combined sources, with the source vessels in specific locations, was examined. The analysis assumed a convergence zone (CZ) propagation condition (where sound waves in the ocean refract downward and then rise back to the surface at regular intervals known as convergence zones) because it is the most probable sound propagation path that would be encountered with concurrent SURTASS LFA and MFA sonar operations. Details of this analysis are provided in Appendix E, along with discussions of other propagation conditions (i.e., bottom bounce, surface duct). In summary, this parametric analysis demonstrates that concurrent MFA/SURTASS LFA sonar operations produce a zero increase in risk over that from summing the risk of the two sources operating independently.

[72] In fluid mechanics, the Reynolds number (Re) is a dimensionless number that gives a measure of the ratio of inertial forces to viscous forces and consequently quantifies the relative importance of these two types of forces for given flow conditions.

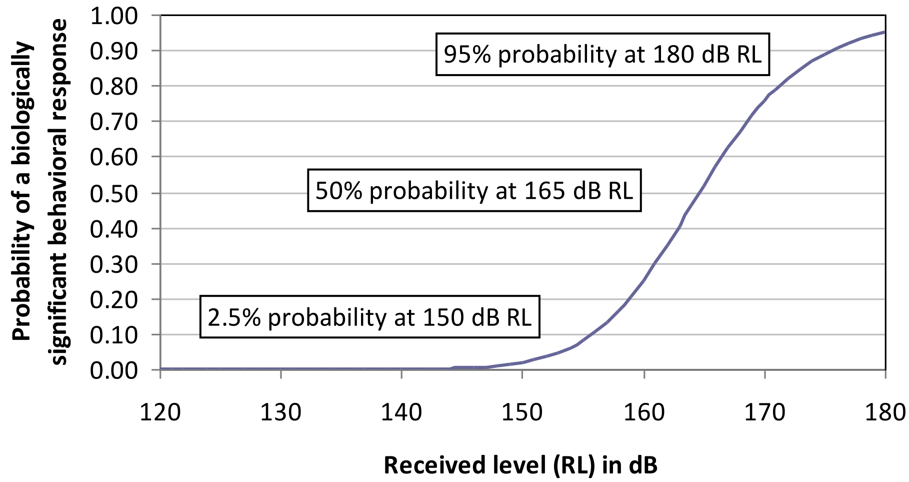

Figure 4-8. The SURTASS LFA sonar risk continuum function.

- **Acoustic Integration Model© (AIM) analysis**

This approach (similar to that used for specific operations of SURTASS LFA sonar) used AIM to develop the sound-source exposure history for individual animals in a multiple-source exposure scenario. To estimate the acoustic exposure an animal is likely to receive while the sources are transmitting, the 3-dimensional movement of animals and the acoustic fields to which they would be exposed were modeled based on nominal transmissions of the MFA and SURTASS LFA sonars. The sound fields around each source were estimated based on: 1) acoustic parameters of the SURTASS LFA sonar; 2) acoustic parameters of the MFA sonar; and 3) underwater acoustic propagation models to predict underwater sound transmissions for CZ and surface duct scenarios[73]. To estimate the risk of MMPA Level B harassment from each acoustic source, the acoustic exposures an animal receives were used to calculate a single ping equivalent, which is input into the SURTASS LFA sonar risk continuum to estimate Level B harassment (Figure 4-8). The single ping equivalent RLs were then evaluated for each source separately, and combined (Appendix E). In summary, the model analysis demonstrated that the result of concurrent MFA/SURTASS LFA sonar operations produces a zero increase in risk over that from summing the risk of the two sources operating independently.

- **Conclusion**

The results of the parametric analysis and the model analysis are consistent—concurrent MFA/SURTASS LFA sonar operations produce no risk greater than that obtained by simply adding the risks from the individual sources. Therefore, two separate analytic approaches have concluded that there is no potential increase in risk for Level B harassment from concurrent MFA/SURTASS LFA sonar operations.

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[73] See Appendix E for the technical details of the model analysis. The bottom bounce sound propagation scenario was not modeled because the potential for SURTASS LFA sonar to conduct operations in water depths that would support bottom bounce propagation as the primary sound transmission path is minimal. Moreover, for SURTASS LFA sonar operations, the bottom bounce propagation scenario would always yield higher transmission loss values (and hence shorter RL ranges) than the surface duct propagation scenario.

4.7.4.2 Overall Risk from Concurrent MFA/SURTASS LFA Sonar Operations

Analyses of the potential impacts associated with the concurrent operation of SURTASS LFA and MFA sonars during naval exercises/operations demonstrate that the overall risks of Level A and Level B impacts are no greater than the risks obtained by simply adding the risks from the individual SURTASS LFA and MFA sources. Thus, the conclusion in the SURTASS LFA Sonar FSEIS (DoN, 2007a) that the potential for this occurring is small remains valid, and should be considered very conservative.

4.7.5 SUMMARY OF CUMULATIVE EFFECTS

The operations of up to four SURTASS LFA sonars were evaluated for the potential for cumulative effects in the following foreseeable areas:

- Anthropogenic oceanic noise levels;
- Injury and lethal takes from anthropogenic causes;
- Socioeconomics; and
- Cumulative effects from concurrent LFA and MFA sonar operations.

Given the information provided in this subchapter, the potential for cumulative effects from the operations of up to four SURTASS LFA sonars has been addressed by limitations proposed for employment of the system (i.e., geographical restrictions and monitoring mitigation). Even if considered in combination with other underwater sounds, such as commercial shipping, other operational, research, and exploration activities (e.g., acoustic thermometry, hydrocarbon exploration and production), recreational water activities, commercial and military sonars, and naturally-occurring sounds (e.g., storms, lightning strikes, subsea earthquakes, underwater volcanoes, whale vocalizations, etc.), the proposed four SURTASS LFA sonar systems do not add appreciably to the underwater sounds to which fish, sea turtles and marine mammal stocks are exposed. Moreover, SURTASS LFA sonar will cause no lethal takes of marine mammals or other marine animals. Analysis of the potential impacs from concurrent LFA and MFA sonar operations demonstrates that the overall risks for Level A and Level B impacts are no greater than the risks obtained by simply adding the risks from individual LFA and MFA sources. Therefore, cumulative effects from the operation of up to four SURTASS LFA sonar systems are not a reasonably foreseeable significant adverse impact on marine animals.

4.8 EVALUATION OF ALTERNATIVES

NEPA requires federal agencies to prepare an EIS that discusses the environmental effects of a reasonable range of alternatives (including the No Action Alternative). Reasonable alternatives are those that will accomplish the purpose and meet the need of the proposed action, and are practical and feasible from a technical and economic standpoint.

This SEIS/SOEIS is the third environmental impact statement for SURTASS LFA prepared under NEPA and Executive Order 12114. Previous to this document a final environmental impact statement (under NEPA) and final overseas environmental impact statement (under Executive Order 12114) were prepared in 2001 (DoN, 2001) and supplemented in 2007 (DoN, 2007). In these documents, numerous potential alternatives have been analyzed including: acoustic and non-acoustic detection methods such as radar, laser, magnetic, infrared, electronic, electric, hydrodynamic, biological technologies, passive sonar and high- or mid-frequency active sonar; monitoring and mitigation for fish; the use of small boats and aircraft for pre-operational surveys; and an extended coastal standoff range of 46 km (25 nmi) vice 22 km (12 nmi). It has been concluded in the FOEIS/EIS (DoN, 2001) and the FSEIS (DoN, 2007) that none of these potential alternatives met the purpose and need of the proposed action to provide Naval forces with reliable long-range detection and, thus, did not provide adequate reaction time to counter potential threats. Furthermore, they were not considered practical and/or feasible for technical and economic reasons.

4.8.1 ALTERNATIVES PREVIOUSLY CONSIDERED

4.8.1.1 SURTASS LFA Sonar Offshore Biologically Important Areas (OBIAs)

SURTASS LFA Sonar OBIAs were introduced in the 2001 FOEIS/EIS as a geographic restriction to provide protection for offshore areas that were outside of the 22 km (12 nmi) coastal standoff, where species of concern (ESA listed species and/or marine mammals) congregated in high density to carry out biologically important activities. Under the 2002 5-Year Rule, there were four designated OBIAs. In the 2007 SEIS and 5-Year Rule there were ten OBIAs designated.

The current process for the identification of OBIAs is provided in Subchapter 4.5. The resulting 21 OBIAs, as presented in Table 4-26, reflect a thorough review of potential areas where SURTASS LFA sonar may be restricted from operating without significantly impacting the Navy's required ASW readiness and training evolutions.

4.8.1.2 Monitoring and Mitigation for Fish

The FSEIS (2007) examined the potential for SURTASS LFA sonar operations to affect fish stocks based on scientific results from fish controlled exposure experiments (CEEs), which exposed fish to LFA signals. These scientific results from independent scientists indicate that there were no injuries to auditory and non-auditory tissues at received levels of 193 dB re 1 µPa at 1 m (rms). The opportunity for a fish or a school of fish to be exposed to sound pressure levels from SURTASS LFA sonar transmissions that could cause injury was considered negligible. Therefore, based on scientific research, it was determined in the FSEIS (2007) that mitigation protocols for fish were not required. Thus, these protocols were not considered in the alternatives for this document.

4.8.1.3 Coastal Standoff Range

The FSEIS (2007) analyzed the differences in potential impacts from increasing the coastal standoff from 22 km (12 nmi) to 46 km (25 nmi) (a difference of 24 km [13 nmi]). Based on the analysis of the risk areas and the potential impacts to marine animals, it was concluded that increasing the coastal standoff range does decrease exposure to higher received levels for the concentrations of marine animals closest to shore (shelf species) but does so at the expense of increasing exposure levels for shelf break and pelagic species. The analysis showed that overall there is a greater risk of potential impacts to marine animals with an increase of the coastal standoff from 22 km (12 nmi) to 46 km (25 nmi). Details of this analysis are presented in Subchapter 4.8.6 of the FSEIS and are incorporated herein by reference.

In Subchapter 4.7.6, the Navy considered whether using a greater coastal standoff range in some locations where the shelf (≤200 m [656 ft] depth) extends farther than the current 22 km (12 nmi) coastal standoff range, was practicable. This analysis was effectively combined with the OBIA analysis outlined above because, as part of the OBIA analysis, NMFS and the Navy considered the biological importance of coastal areas outside the current 22 km (12 nmi) coastal standoff range. In light of these comprehensive efforts to identify and analyze areas of biological concern, and the need for broad operational flexibility, it was concluded that there is no basis for further analysis of greater coastal standoff ranges.

4.8.2 ALTERNATIVES CONSIDERED IN THIS SEIS/SOEIS

This subchapter provides a description of the proposed alternatives considered in this SEIS/SOEIS for the employment of SURTASS LFA sonar (Table 4-29).

Table 4-29. Alternatives considered in this document for SURTASS LFA sonar operation.

PROPOSED RESTRICTIONS/MONITORING	NO ACTION ALTERNATIVE	ALTERNATIVE 1	ALTERNATIVE 2
Dive Sites	NA	RL not exceed 145 dB SPL	RL not exceed 145 dB SPL
Coastline Restrictions	NA	RL <180 dB SPL within 12 nmi of coast	RL <180 dB SPL within 12 nmi of coast
FSEIS (2007) OBIAs (total 9)	NA	Yes	No
Updated OBIAs (total 21)	NA	No	Yes
Visual Monitoring	NA	Yes	Yes
Passive Acoustic Monitoring	NA	Yes	Yes
Active Acoustic Monitoring	NA	Yes	Yes
Reporting	NA	Yes	Yes

The following alternatives were considered in this SEIS/SOEIS:

- No Action Alternative;
- Alternative 1—Same as the 2007 FSEIS Preferred Alternative; and
- Alternative 2—Alternative 1 with updated OBIA list.

The analyses of these alternatives take into account the analyses contained in this SEIS/SOEIS on the issues of OBIAs (Subchapter 4.5) and larger coastal standoff distances (Subchapter 4.5.6). Alternatives 1 and 2 also include the same mitigation and monitoring measures utilized in the 2007 FSEIS Subchapters 2.4, 5.1, 5.2, and 5.3, which are incorporated herein by reference.

4.8.2.1 No Action Alternative

Under the No Action Alternative, the SURTASS LFA sonar systems would not be deployed.

4.8.2.2 Alternative 1

Alternative 1 is the same as Alternative 2 presented in Subchapter 2.6.3 of the FSEIS (DoN, 2007c), which is incorporated herein by reference.

4.8.2.3 Alternative 2 (The Preferred Alternative)

Alternative 2 is the Navy's preferred alternative. This alternative is the same as Alternative 1 but with a comprehensive update of the OBIAs, as analyzed in Subchapter 4.5. Under this alternative, there are 21 OBIAs (Table 4-26).

4.8.3 CONCLUSIONS

The following conclusions are supported by the analyses addressing the operations of up to four SURTASS LFA sonar systems in the FOEIS/EIS (DoN, 2001), which is incorporated by reference herein, the supplementary analyses undertaken in the FSEIS (DoN, 2007a), and the supplementary analyses undertaken in this SEIS/SOEIS, which also encompass the at-sea operations of up to four systems.

4.8.3.1 No Action Alternative

In summary, the No Action Alternative would avoid all environmental effects of employment of SURTASS LFA sonar. It would not, however, support the Navy's stated priority ASW need for long-range underwater threat detection. The implementation of this alternative would allow potentially hostile submarines to clandestinely threaten U.S. Fleet units and land-based targets. Without the SURTASS LFA sonar long-range surveillance capability, the reaction times to enemy submarines would be greatly reduced and the effectiveness of close-in, tactical systems to neutralize threats would be seriously, if not fatally, compromised.

4.8.3.2 Alternative 1

Under Alternative 1, as was concluded in the FOEIS/EIS, the potential effects on any stock of marine mammals from injury is considered to be negligible, and the effect on the stock of any marine mammal from significant change in a biologically important behavior is considered to be minimal. Any momentary behavioral responses and possible indirect effects on marine mammals due to potential effects on prey species are considered not to be biologically significant effects. Any auditory masking in mysticetes, odontocetes, or pinnipeds is not expected to be severe and would be temporary. Further, the potential effects on any stock of fish, sharks or sea turtles from injury is also considered to be negligible, and the effect on the stock of any fish, sharks, or sea turtles from significant change in a biologically important behavior is considered to be negligible to minimal. Any auditory masking in fish, sharks or sea turtles is expected to be of minimal significance and, if occurring, would be temporary.

4.8.3.3 Alternative 2 (The Preferred Alternative)

Under Alternative 2, additional geographic restrictions would be levied on SURTASS LFA sonar operations through the inclusion of more marine mammal OBIAs. The general summary provided in the above paragraph regarding the potential for injury to a marine animal or significant change in a biologically important behavior of a marine animal from the operation of SURTASS LFA sonar would also apply to this alternative. Potential effects to marine animals from SURTASS LFA sonar operations under this alternative would be expected to be slightly decreased when compared to Alternative 1 conclusions.

4.8.3.4 Results Summary

Table 4-30 provides a qualitative estimate of the ability of each alternative to meet the Navy's purpose and need. Alternative 2 (additional marine mammal OBIAs) would be expected to decrease to some extent the littoral areas where SURTASS LFA sonar operations could occur outside of 22 km (12 nmi). Thus, the long-range detection of threats in the littorals and Fleet training in the littorals would remain high, but may be slightly degraded compared to Alternative 1.

Table 4-30. Estimate of ability of the proposed alternatives to meet the Navy's purpose and need.

	DETECTION OF THREATS IN OPEN OCEAN	DETECTION OF THREATS IN LITTORALS	FLEET TRAINING IN OPEN OCEAN	FLEET TRAINING IN LITTORALS
No Action Alternative	N/A[74]	N/A	N/A	N/A
Alternative 1	H[75]	H	H	H
Alternative 2	H	H(1)[76]	H	H(1)

4.9 CONCLUSION OF ANALYSES OF POTENTIAL IMPACTS AND EFFECTS OF SURTASS LFA SONAR ON MARINE SPECIES

This SEIS/SOEIS is the third NEPA analysis of the potential impacts of the employment of SURTASS LFA sonar. Since the late 1990's, these public documents (DoN, 2001 and 2007a) determined that the potential impact on any stock of marine mammal from injury was considered to be negligible, and the effect on the stock of any marine mammal from significant change in a biologically important behavior was considered to be minimal. Any momentary behavioral responses and possible indirect impacts to marine mammals due to potential impacts on prey species were not considered as biologically significant effects. Any auditory masking in mysticetes, odontocetes, or pinnipeds was not expected to be severe and would be temporary. Further, the potential impact on any stock of fish, sharks or sea turtles from injury was also considered to be negligible, and the effect on the stock of any fish, sharks or sea turtles from significant change in a biologically important behavior was considered to be negligible to minimal. Any auditory masking in fish, sharks or sea turtles was expected to be of minimal significance and, if occurring, would be temporary.

During the first two analyses, the U.S. Navy sponsored independent scientific research on the potential effects of SURTASS LFA sonar on human divers, marine mammals, and fish. The Naval Submarine Medical Research Laboratory conducted a series of in-water tests and laboratory experiments that determined the damage risk threshold for Navy divers was a received level of 160 dB re 1 µPa (rms) and a safe exposure limit for recreational and commercial divers of 145 dB re 1 µPa (rms) (DoN, 2001). The Low Frequency Sound Scientific Research Program (LFS SRP) field research in 1997-98 provided important results on and insights into the types of responses of whales to SURTASS LFA sonar signals. The results of the LFS SRP confirmed that some portion of the whales exposed to the SURTASS LFA sonar responded behaviorally by changing their vocal activity, moving away from the source vessel, or both, but the responses were short-lived (Clark et al., 2001; Croll et al., 2001b). Recent scientific results from fish controlled exposure experiments (CEE) with LFA signals indicate that the opportunity for a fish or a school of fish to be exposed to sound pressure levels from SURTASS LFA sonar transmissions that could cause injury is negligible (Popper et al., 2007; Kane et al., 2010).

This chapter reviewed and updated the potential for impacts on fish, sea turtles, and marine mammals. The potential impacts to fish stocks are minimal to negligible and potential impacts to sea turtles are

[74] N/A= not applicable/does not meet.

[75] H=high level

[76] H(1) = High level but may be slightly degraded compared to Alternative 1.

considered negligible. The potential effects from SURTASS LFA sonar operations on any stock of marine mammals from injury (non-auditory or permanent loss of hearing) are considered negligible, and the potential effects on the stock of any marine mammal from temporary loss of hearing or behavioral change (significant change in a biologically important behavior) are considered minimal. Any auditory masking in marine mammals due to SURTASS LFA sonar signal transmissions is not expected to be severe and would be temporary. The likelihood of SURTASS LFA sonar transmissions causing marine mammals to strand is negligible.

This chapter also provides supplemental risk assessment analyses of 19 additional operating areas (see Table 4-4) where SURTASS LFA sonar could potentially test, train or operate during the 5-year period of the next MMPA rule. It also includes an extensive review of areas of the world to identify OBIAs for LF sensitive species, recommending 21 areas where marine mammals will be protected from 180 dB re 1 µPa (rms) (RL) from SURTASS LFA sonar. Cumulative effects for SURTASS LFA sonar operations were analyzed, including an extensive analysis of the potential for cumulative effects from concurrent LFA and MFA operations. It was concluded that the overall cumulative effects for the operation of up to four SURTASS LFA sonar systems are not a reasonably foreseeable significant adverse impact on marine mammals. Alternatives were analyzed and Alternative 2 was the Navy's preferred alternative. This is the same as the preferred alternative from the SURTASS LFA Sonar FSEIS (DoN, 2007a) with updated OBIAs.

Based on the results of the analyses in this document and the two previous NEPA EISs, operation of SURTASS LFA sonars, when employed in accordance with the mitigation measures (geographic restrictions and monitoring/reporting) detailed in Chapter 5.0, support a negative impact determination. These include:

- Potential effects on most if not all individual marine mammals are expected to be limited to Level B harassment. The Navy does not expect those effects to impact rates of recruitment or survival on the associated marine mammal species and stocks. Thus, effects on recruitment or survival are expected to be negligible.
- Navy's impact analysis does not anticipate any mortality nor any injury of marine mammals (Level A harassment) to occur as a result of LFA sonar operations, and the potential to cause strandings of marine mammals is negligible
- Potential for injury to sea turtles and fish is negligible.
- Potential for non-injurious effects (TTS, masking, modification of biological important behavior) is minimal to negligible.
- Cumulative effects are not a reasonably foreseeable adverse impact.

Since the initial LOA was issued for the operation of SURTASS LFA sonar systems in 2002, the percent of Level B incidental takes of marine mammals has consistently been below the amounts authorized in the LOAs. There have been no reported strandings and no Level A takes incidental to LFA operations.

Therefore, this document supports the Navy application under the MMPA for take authorizations incidental to the operation of SURTASS LFA sonar by providing the means of effecting the least practicable adverse impact on the species or stock and its habitat and on the availability of the species or stock for "subsistence" uses. These results will also support the interagency consultations, or Section 7 consultations, under the ESA to ensure the operations of SURTASS LFA sonar do nor jeopardize the continued existence of a species or destroy or adversely modify critical habitat.

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5.0 MITIGATION MEASURES

Mitigation, as defined by the Council on Environmental Quality (CEQ), includes measures to minimize impacts by limiting the degree or magnitude of a proposed action and its implementation. In this document, three alternatives for the operation of SURTASS LFA sonar are presented, two of which will meet, to varying degrees, the Navy's purpose and need and reduce potential impacts through the mitigation measures discussed in this chapter. The mitigation and monitoring measures presented for the SURTASS LFA sonar are similar to those in the FSEIS (DoN, 2007a).

The objective of these mitigation measures is to effect the least practicable adverse impact on marine mammal species or stocks and to avoid risk of injury to marine mammals, sea turtles, and human divers. These objectives are met by:

- Ensuring that coastal waters within 22 km (12 nmi) of shore are not exposed to SURTASS LFA sonar signal received levels (RL) ≥180 dB re 1 µPa (rms) (sound pressure level [SPL]);
- Ensuring that no offshore biologically important areas (OBIA) are exposed to SURTASS LFA sonar signal RLs ≥180 dB re 1 µPa (rms) (SPL) during biologically important seasons;
- Minimizing exposure of marine mammals and sea turtles to SURTASS LFA sonar signal RLs below 180 dB re 1 µPa (rms) (SPL) by monitoring for their presence and suspending transmissions when one of these animals enters this mitigation zone; and
- Ensuring that no known recreational or commercial dive sites are subjected to SURTASS LFA sonar signal RLs >145 dB re 1 µPa (rms) (SPL).

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

5.1 GEOGRAPHIC RESTRICTIONS

The following geographic restrictions apply to the employment of SURTASS LFA sonar:

- SURTASS LFA sonar-generated sound field would be below RLs of 180 dB re 1 µPa (rms) (SPL) within 22 km (12 nmi) of any coastlines;
- SURTASS LFA sonar-generated sound field would be below RLs of 180 dB re 1 µPa (rms) (SPL) in offshore areas outside of 22 km (12 nmi) of the coastline that have been determined by NMFS and the Navy to be biologically important (i.e., OBIAs);
- When in the vicinity of known recreational or commercial dive sites, SURTASS LFA sonar would be operated such that the sound fields at those sites would not exceed RLs of 145 dB re 1 µPa (rms) (SPL); and
- SURTASS LFA sonar operators would estimate LFA sound field RLs (SPL) prior to and during operations to provide the information necessary to modify operations, including the delay or suspension of transmissions, in order not to exceed RLs of 180 dB re 1 µPa (rms) and 145 dB re 1 µPa (rms) sound field criteria cited above.

5.1.1 OFFSHORE BIOLOGICALLY IMPORTANT AREAS

There are certain areas of the world's oceans that are biologically important to marine mammals and sea turtles. Because the majority of these areas exist within the coastal zone, SURTASS LFA sonar operations would be conducted such that the sound field is below RLs of 180 dB re 1 µPa (rms) within 22 km (12 nmi) of any coastline (including islands). Since certain areas of biological importance lie outside of these coastal areas, the Navy and NMFS developed the concept of OBIAs as described in Chapter 4. OBIAs are part of a comprehensive suite of mitigation measures used in previous authorizations to minimize impacts and adverse effects to marine mammals. LFA sonar operations would be conducted such that the LFA sound field is below RLs of 180 dB re 1 µPa (rms) in any designated OBIAs during the biologically important season for that particular area, as presented in Chapter 4 and as modified in the MMPA Rule/LOAs, as issued. The SURTASS LFA sonar sound field would be estimated in accordance with the guidelines listed below.

5.1.2 Recreational and Commercial Dive Sites

SURTASS LFA sonar operations are constrained in the vicinity of known recreational and commercial dive sites to ensure that the sound field at such sites does not exceed RLs of 145 dB re 1 µPa (rms). Recreational dive sites are generally defined as coastal areas from the shoreline out to the 40-m (130-ft) depth contour, which are frequented by recreational divers; but it is recognized that there are other sites that may be outside this boundary. The SURTASS LFA sonar sound field is estimated in accordance with the guidelines that follow.

5.1.3 Sound Field Modeling

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

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

5.1.4 Previously Considered Mitigation Measures

The following mitigation measures were considered in the previous SURTASS LFA sonar NEPA documents but not carried forward. Subchapter 5.4 of the SURTASS LFA Sonar FSEIS (DoN, 2007a) evaluated the use of small boats and aircraft for pre-operational surveys. It was concluded that these surveys were not feasible because they were not practicable, not effective, might increase the harassment of marine mammals, and were not safe to the human performers. Therefore, under the revisions to the MMPA by the NDAA FY04, pre-operational surveys were not considered as a viable mitigation option. Subchapter 4.7.6 of the SURTASS LFA FSEIS (DoN, 2007a) also analyzed increasing the coastal standoff range to 46 km (25 nmi); this analysis showed that, overall, there is a greater risk of potential impacts to marine animals with the increase of the coastal standoff range from 22 km (12 nmi) to 46 km (25 nmi). This is due to an increase in the affected area with less of the ensonified annuluses overlapping land for the 46 km (25 nmi) standoff range than for the 22 km (12 nmi) standoff range. Other discussions of mitigation measures recommended in comments are provided in the response to comments Subchapter 10.3 of the SURTASS LFA FSEIS (DoN, 2007a).

5.2 Monitoring to Prevent Injury to Marine Animals

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

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

All sightings are recorded in the log and provided as part of the Long Term Monitoring (LTM) Program (as discussed in Subchapter 2.4.2 of the SURTASS LFA sonar FOEIS/EIS [DoN, 2001]) to monitor for potential long-term environmental effects, which is incorporated herein by reference

5.2.1 VISUAL MONITORING

Visual monitoring includes daytime observations for marine mammals and sea turtles from the vessel. Daytime is defined as 30 minutes before sunrise until 30 minutes after sunset. Visual monitoring begins 30 minutes before sunrise or 30 minutes before the SURTASS LFA sonar is deployed. Monitoring continues until 30 minutes after sunset or until the SURTASS LFA sonar is recovered. Observations are made by personnel trained in detecting and identifying marine mammals and sea turtles. Marine mammal biologists qualified in conducting at-sea marine mammal visual monitoring from surface vessels train and qualify designated ship personnel to conduct at-sea visual monitoring. The objective of these observations is to maintain a track of marine mammals and/or sea turtles observed and to ensure that none approach the source close enough to enter the LFA mitigation zone as defined in Chapter 2 of this document.

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

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

Second, if the potentially affected animal is sighted anywhere within the LFA mitigation zone, the observer notifies the OIC who orders the immediate delay or suspension of SURTASS LFA sonar transmissions. All sightings are recorded in the log and provided as part of the LTM Program.

5.2.2 PASSIVE ACOUSTIC MONITORING

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

5.2.3 ACTIVE ACOUSTIC MONITORING

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

First, if a contact is detected outside the LFA mitigation zone, the HF/M3 sonar operator determines the range and projected track of the animal. If it is determined that the animal will pass within the LFA mitigation zone, the sonar operator notifies the OIC. The OIC then orders the delay or suspension of transmissions when the animal is predicted to enter the LFA mitigation zone. Second, if a contact is detected by the HF/M3 sonar within the LFA mitigation zone, the observer notifies the OIC who orders the immediate delay or suspension of transmissions. All contacts are recorded in the log and provided as part of the LTM Program.

5.2.4 RESUMPTION OF SURTASS LFA SONAR TRANSMISSIONS

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

5.3 SUMMARY OF MITIGATION

There are geographic restrictions that apply to the operation of SURTASS LFA sonar as well as three types of mitigation measures that will be applied during the operation of the sonar (Table 5-1).

Table 5-1. Summary of mitigation measures for operation of SURTASS LFA sonar.

MITIGATION MEASURE	CRITERIA	ACTIONS
Geographic Restrictions		
22 km (12 nmi) from coastline	Sound field below 180 dB re 1 µPa (rms) RL, based on SPL modeling	Delay/suspend SURTASS LFA sonar operations if sound field criterion is exceeded
Offshore biologically important areas (OBIA) during biologically important seasons	Sound field below 180 dB re 1 µPa (rms) RL, based on SPL modeling	Delay/suspend SURTASS LFA sonar operations if sound field criterion is exceeded
Recreational and commercial dive sites[77]	Sound field not to exceed 145 dB re 1 µPa (rms) RL, based on SPL modeling	Delay/suspend SURTASS LFA sonar operations if sound field criterion is exceeded
Monitoring to Prevent Injury to Marine Mammals and Sea Turtles		
Visual Monitoring	Potentially affected species near the vessel but outside of the LFA mitigation zone	Notify OIC
	Potentially affected species sighted within 2 km (1.1 nmi) and 45 degrees either side of the bow or inside of the LFA mitigation zone	Delay/suspend SURTASS LFA sonar operations
Passive Acoustic Monitoring	Potentially affected species detected	Notify OIC
Active Acoustic Monitoring	Contact detected and determined to have a track that would pass within the LFA mitigation zone	Notify OIC
	Potentially affected species detected inside of the LFA mitigation zone	Delay/suspend SURTASS LFA sonar operations

[77] Recreational dive sites generally are located in coastal areas ranging from the shoreline out to the 40-m (130-ft) depth contour.

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6.0 OTHER CONSIDERATIONS

6.1 UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

Unavoidable adverse impacts associated with the proposed action include potential effects on marine mammals, sea turtles, and fish stocks. Nearly all potential effects on marine mammals and sea turtles can be avoided due to the mitigation and monitoring methods implemented to prevent injury or harm to marine mammals and sea turtles. Additionally, the geographic restrictions on SURTASS LFA sonar use would result in negligible impacts to fish stocks on an annual basis and no impacts to commercial or recreational non-pelagic fisheries.

6.2 RELATIONSHIP OF THE PROPOSED ACTION TO FEDERAL, STATE, AND LOCAL PLANS, POLICIES, AND CONTROLS

Operation of the SURTASS LFA sonar system does not conflict with the objectives or requirements of applicable Federal, state, regional, as well as local laws, policies, and regulations (Table 6-1). SURTASS LFA sonar is currently operating under a Final Rule pursuant to the MMPA (NOAA, 2007c) and a Biological Opinion under the statutes of the ESA. All permits, approvals, and authorizations required for the operation of SURTASS LFA sonar have been obtained and are current.

Table 6-1. Summary of this document's environmental compliance with applicable Federal, state, regional, and local laws, policies, and regulations.

PLANS, POLICIES, AND CONTROLS	RESPONSIBLE AGENCY	STATUS OF COMPLIANCE
National Environmental Policy Act (NEPA) (42 USC §§4321, et. seq.) Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (40 CFR §§1500-1508) DoN Procedures for Implementing NEPA (32 CFR §775)	Navy with NMFS as a cooperating agency	This document has been prepared in accordance with NEPA, CEQ regulations, and the Navy's NEPA procedures. Public participation and review is being conducted in accordance with NEPA. The proposed action would not result in significant impacts.
Executive Order (EO) 12114, Environmental Effects Abroad of Major Federal Actions	Navy with NMFS as a cooperating agency	This document has been prepared in accordance with EO 12114, which requires environmental consideration for major Federal actions that may affect the environment outside of U.S. territorial waters. The proposed action would not result in significant impacts to the environment.

Table 6-1. Summary of this document's environmental compliance with applicable Federal, state, regional, and local laws, policies, and regulations.

PLANS, POLICIES, AND CONTROLS	RESPONSIBLE AGENCY	STATUS OF COMPLIANCE
Endangered Species Act (ESA) (16 USC §§1531, et seq.)	U.S. Fish and Wildlife Service (USFWS) NMFS	This SEIS/SOEIS analyzes potential effects to marine species listed under the ESA. The Navy has consulted under Section 7 with the NMFS on the potential of the proposed action to affect listed species.
The National Marine Sanctuaries Act (16 USC §§1431, et seq.)	NOAA	The proposed action would have no effect on sanctuary resources in the offshore environment of SURTASS LFA operating areas. Review of agency actions under Section 304 is not required.
Marine Mammal Protection Act (16 USC §§1431, et seq.)	USFWS NMFS	This SEIS/SOEIS analyzes the potential effects to marine mammals, some of which are also listed under the ESA. The Navy has been issued Letters of Authorization by the NMFS regarding effects on marine mammals.
EO 12962, Recreational Fisheries	Navy	EO 12962 requires the fulfillment of certain duties to promote the health and access of the public to recreational fishing areas. The proposed action complies with these duties.
Act to Prevent Pollution from Ships (APPS) (33 USC §§1901, et seq.)	Navy	The Navy and Marine Corps complies with the discharge regulations set forth under the requirements of the APPS.
EO 13158, Marine Protected Areas (MPAs)	Navy and NMFS	EO 13158 requires the avoidance of harm to the natural or cultural resources protected as MPAs and the identification of any actions that may affect those resources. The proposed action complies with these requirements.

Table 6-1. Summary of this document's environmental compliance with applicable Federal, state, regional, and local laws, policies, and regulations.

PLANS, POLICIES, AND CONTROLS	RESPONSIBLE AGENCY	STATUS OF COMPLIANCE
EO 13547, Stewardship of the Ocean, Our Coasts, and the Great Lakes	Navy	EO 13547 requires the development of coastal and marine spatial plans that build upon and improve existing Federal, State, tribal, local, and regional decision-making and planning processes. This and other mandates of EO 13547 have been met in this SEIS/SOEIS by using the best available data for all analyses, by conducting an analysis of potential and cumulative effects, and by defining OBIAs. Analyses of potential effects have been conducted in an integrated, systematic manner that incorporates cumulative effects from potential additional sound sources in the marine environment. In addition, OBIAs were defined within a marine spatial planning framework.

6.3 RELATIONSHIP BETWEEN SHORT-TERM USE OF MAN'S ENVIRONMENT AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The NEPA requires analysis of the relationship between a proposed action's short-term effects on the environment and any effects on the maintenance and enhancement of the long-term productivity of the affected environment. The Navy supports research that increases knowledge about marine mammals, sea turtles, and marine fishes and helps to develop methods to reduce or eliminate the potential for effects on these species that may be associated with the operation of SURTASS LFA sonar. While some short-term environmental effects may be associated with the use of SURTASS LFA sonar, no long-term environmental effects that would lead to decreased productivity, permanently reduce the range of beneficial environmental uses, or pose long-term risk to the health, safety, or general welfare of the public are reasonably expected.

6.4 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

Section 102(c)(v) of NEPA requires that an EIS identify any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented. Although operating SURTASS LFA sonar immeasurably enhances national security by allowing the Navy to ascertain submarine threats at long-range, nonrenewable resources would be used during the design, construction, and operation of SURTASS LFA sonar vessels and sonar systems. Nonrenewable resources such as petroleum-based fuel and steel would be irretrievably and irreversibly committed through the implementation of the proposed action.

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7.0 PUBLIC REVIEW PROCESS AND RESPONSE TO COMMENTS

Public involvement in the review of draft SEISs is stipulated in 40 CFR Part 1503.1 of the Council on Environmental Quality's (CEQ) regulations implementing the NEPA and in OPNAVINST 5090.1C. These regulations and guidance provide for active solicitation of public comment via public comment periods and public hearings. This chapter has been prepared to document the public involvement process in preparation of this SEIS/SOEIS and also presents the response to questions and comments raised by individual commenters during the public comment period on the Draft SEIS/SOEIS.

7.1 PUBLIC REVIEW PROCESS

On January 21, 2009, the Navy, with the NMFS as a cooperating agency, published a Notice of Intent (NOI) in the *Federal Register* to prepare a SEIS/SOEIS for the employment of SURTASS LFA sonar (DoN, 2009a). The NOI described the decision of the Deputy Assistant Secretary of the Navy (Environment) (DASN(E)) to further the purposes of NEPA, support the issuance of a new Final Rule under the MMPA for the taking of marine mammals incidental to operation of SURTASS LFA sonar systems, and to continue the Navy's commitment to environmental stewardship by preparing an additional supplemental analysis for operation of SURTASS LFA sonar. The DASN(E) called for the additional supplemental analysis to focus on potential OBIAs in regions of the world's oceans where the sonar systems might be used for routine training, testing, and military operations, as well as the potential for cumulative impacts associated with the use of other active sonar systems, and the potential for a larger coastal standoff distance, where operationally practicable. In the NOI, the Navy and NMFS solicited scoping comments on the above topics to include OBIAs, greater coastal standoff, and cumulative effects. At the end of the 45-day scoping period, no comments were received (DoN, 2009a).

7.1.1 FILING AND DISTRIBUTION OF THE DRAFT SEIS/SOEIS

Commencing with the filing of the Draft SEIS/SOEIS with the U.S. EPA, copies of the SURTASS LFA Sonar Draft SEIS/SOEIS have been distributed to agencies and officials of the federal, state, and local governments, citizens groups and associations, and other interested parties.

7.1.2 PUBLIC REVIEW PERIOD AND PUBLIC HEARINGS

A 60-day public review and comment period on the Draft SEIS/SOEIS will commence when the Notice of Availability (NOA) is published in the *Federal Register*. Public hearings will be held as necessary.

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