3 AFFECTED ENVIRONMENT

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

- **Marine Environment**, including ambient noise in the oceans, physical environmental factors affecting acoustic propagation, ocean acoustic regimes, and oceanographic features affecting marine mammal distribution (Subchapter 3.1);
- **Marine Organisms,** including fish, sea turtles, and marine mammals (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).

3.1 Marine Environment

There have been no significant changes to the knowledge or understanding in the marine environment, acoustic propagation, or propagation modeling. The information in Subchapter 3.1 (Marine Environment) in the FOEIS/EIS remains valid, and its contents are incorporated by reference herein.

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3.2 Marine Organisms

3.2.1 Species Screening

An animal must be able to hear LF sound, and/or some organ or tissue must be capable of changing sound energy into mechanical effects in order 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.

Based on these considerations, a detailed analysis of only those organisms in the world's oceans that meet the following criteria has been undertaken:

- Does the proposed SURTASS LFA sonar geographical sphere of acoustic influence overlap the distribution of this species? If so,
- Is the species capable of being physically affected by LF sound? Are acoustic impedance mismatches large enough to enable LF sound to have a physical effect?
- Can the species hear LF sound? If so, at what thresholds?

In other words, to be evaluated for potential impact in this SEIS, the 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 evaluation process is summarized visually in Figure 3.2-1 (Species Selection Rationale) in the FOEIS/EIS. For example, phytoplankton and zooplankton species do have acoustic impedance differences from seawater due to tiny gas bubbles. However, Medwin and Clay (1998) have calculated resonance frequency ranges from 7 to 27 kHz at 100 m (328 ft). Because of the lack of acoustic impedance mismatches at low frequencies, the SURTASS LFA sonar pulse essentially would pass through them without being detected. Therefore, they do not have the potential to be physically affected by the operation of SURTASS LFA sonar, and were not evaluated for potential impacts (Croll, et al., 1999).

References to Underwater Sound Levels

1. 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.
2. References to underwater Sound Exposure Level (SEL) in this SEIS are the measure of sound energy flow per unit area expressed in dB, and are assumed to be standardized at dB re 1 μPa^2-s, unless otherwise stated.

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

3.2.1.1 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) there is no evidence of auditory capabilities 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 (lobster, shrimp, and crab) are known to sense LF sound (Offutt, 1970; Budelmann and Williamson, 1994). There are very limited data on invertebrates. Based on Budelmann and Young's measurements, the cephalopod threshold for hearing for far-field sound waves is estimated to be 146 SEL. Statocysts were analyzed when the hair cells were stimulated with water movements from different directions. The experiment indicated that cephalopod statocysts are directionally sensitive in a way that is similar to the responses of hair cells on vertebrate vestibular and lateral line systems. The hearing threshold for the American lobster has been determined to be approximately 150 SEL -- in the LF range of SURTASS LFA sonar (Offutt, 1970). Popper et al. (2003) also reviewed behavioral, physiological, anatomical, and ecological aspects of sound and vibration detection by decapod crustaceans. Decapod crustaceans are known to produce acoustic signals. Many decapods also have an array of hair-like receptors within and upon the body surface that potentially or 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).

While data are still very limited, they do suggest that some of the major cephalopods and decapods may not hear well, if they hear at all. We may cautiously suggest that given these high levels of hearing thresholds, 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 27,000 extant fish species (Nelson, 1994) only a small percentage have been studied in terms of audition or sound production (Fay, 1988; 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 nm] 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, Lamniformes, Anguilliformes, Albutleiformes, Clupeiformes, Salmoniformes, Gadiformes, Beryciformes, Scorpaeniformes, and the Perciformes families Pomacentridae, Labridae, Lutjanidae, Serranidae, Sciaenidae, Scombridae, and Haemulidae. These are the fish groups evaluated for potential impacts in this SEIS.

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. Seabirds that can occur in areas where SURTASS LFA sonar may operate are generally shallow divers. In addition, seabirds spend a very small fraction of their time submerged, and they can rapidly disperse to other areas if disturbed. Therefore, there would be no impact to seabirds, including those that may be threatened or endangered. For these reasons, seabirds have been excluded from further evaluation.

Sea Snakes

Sea snakes are excluded because they primarily inhabit inshore waters, and there is no information on the hearing sensitivity in these species.

Sea Turtles

There are seven species of marine turtles, six of which are listed as either threatened and/or endangered under the ESA. The green turtle (*Chelonia mydas*) (including the black turtle [*C. agassizi*) is listed as threatened everywhere except Florida and the Pacific coast of Mexico, where they are endangered. The loggerhead turtle (*Caretta caretta*) is listed as threatened. The hawksbill (*Eretmochelys imbricata*), Kemp's ridley (*Lepidochelys kempi*), and leatherback (*Dermochelys coriacea*) are listed as endangered species. The olive ridley (*Lepidochelys olivacea*) is threatened everywhere except the Mexican breeding stocks, which are listed as endangered. The flatback turtle (*Natator depressus)* is unlisted and is restricted to nearshore waters off Australia. Consequently, it is excluded from further analysis. It is likely that all species of sea turtles hear LF sound as adults (Ridgway et al., 1969; O'Hara and Wilcox, 1990). Therefore, the other six species of sea turtles are considered for evaluation since they are likely to hear LF sound, occur in pelagic water, and/or dive deeply.

Baleen Whales (Mysticetes)

All 11 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. However, only those that occur within the latitudes of proposed SURTASS LFA sonar operations are considered. This excludes the bowhead whale (*Balaena mysticetus*) that occurs only in Arctic waters, north of the area where the system would operate. Included for consideration are the remaining ten baleen whale species: blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), minke (*Balaenoptera acutorostrata*), Bryde's (*Balaenoptera edeni*), sei (*Balaenoptera borealis*), humpback (*Megaptera novaeangliae*), northern right (*Eubalaena glacialis*), southern right (*Eubalaena australis*), pygmy right (*Caperea marginata*), and gray (*Eschrichtius robustus*) whales.

Toothed Whales (Odontocetes)

There are at least 70 species of odontocetes (some species classifications are under study, and the exact number of beaked whales is not known) including dolphins, porpoises, beaked whales, long-finned pilot, short-finned pilot, pygmy killer, false killer, melon-headed whales, killer whales, and sperm whales. A number of these species inhabit ocean areas where SURTASS LFA sonar might operate. Many species are known to use HF clicks for echolocation. All odontocete species studied to date hear best in the mid- to high-frequency range, and so are less likely to be affected by exposure to LF sounds than mysticetes. Like mysticetes, odontocetes depend on acoustic perception and production for communication, food finding, and probably for navigation and orientation.

The following species of odontocetes do not meet the screening criteria described at the beginning of this subchapter, and thus are eliminated from further evaluation:

- Arctic specialists in the family Monodontidae including narwhal (*Monodon monoceros),* because SURTASS LFA sonar would not be employed in their range in the Arctic.

- Some porpoise species because they are coastal species with ranges well inshore of the areas where SURTASS LFA sonar would be employed, including: Burmeister's porpoise *(P. spinipinnis*), vaquita (*P. sinus),* and finless porpoise (*Neophocaena phocaenoides).*

- Dolphin species in the following families: Pontoporiidae (Chinese River dolphin [*Lipotes vexillifer],* fanciscana [*Pontoporia blainvillei]*); Iniidae (boto/Amazon River dolphin [*Inia geoffrensis]*); and Platanistidae (Ganges river dolphin [*Platanista gangetica]* and Indus River dolphin [*P. minor*]). They are eliminated because they are river dolphins that may enter coastal waters, but their ranges are well inshore of the areas where SURTASS LFA sonar would be employed.

- Dolphin species in the family Delphinidae that occur in shallow, coastal waters well inshore of the areas where SURTASS LFA sonar would be employed and are not known to hear sounds in the range of the system. This group includes Tucuxi/boto (*Sotalia fluviatilis),* Irrawaddy dolphin (*Oracella brevirostris),* Indo-Pacific humpbacked dolphin (*Sousa chinensis),* Atlantic humpbacked dolphin (S*ousa teuszii),* and humpback dolphin (*Sousa plumbea).*

Odontocetes that are further analyzed in this document are those species that have the potential to be found in deeper, offshore waters where SURTASS LFA sonar might operate. This includes pelagic dolphins, coastal dolphin species that also occur in deep water, beaked whales, killer whales, sperm whales, long-finned and short-finned pilot whales, pygmy killer whales, false killer whales, melon-headed whales, and belugas.

Seals, Sea Lions, and Walruses (Pinnipeds)

The suborder of Pinnipedia consists of "eared" seals (family Otariidae), "true" seals (family Phocidae), and walruses (family Odobenidae).

There are 14 species of otariids including sea lions and fur seals. They are found in temperate or sub-polar waters. Several of these species are listed as special status (northern sea lion, northern fur seal, and Guadalupe fur seal). All 14 species are further analyzed in this document.

There are 18 species of phocids, or "true" seals, nine of which occur in polar oceans or inland lakes and can therefore be excluded. The remaining nine phocid species, including two monk seal species that are listed as endangered, merit further evaluation. These include the Hawaiian and Mediterranean monk seals (*Monochas monachus* and *M. schauinslandi*); the northern and southern elephant seals (*Mirounga angustirostris* and *M. leonina*); the gray seal (*Halichoerus* *grypus*); three species in the genus *Phoca*: the ribbon, harbor, and spotted seals (*P. fasciata, P. vitulina,* and *P. largha*); and the hooded seal (*Cystophora csistata*).

The walrus can be excluded from further analysis since it is a polar species.

Polar Phocids Excluded from Further Analysis	
ringed (*Phoca hispida*)	
baikal (*P. sibirica)*	crabeater (*Lobodon carcinophagus*)
Caspian (*P. caspica*)	Ross (*Ommatophoca rosii*)
harp (*P. groenlandica*)	leopard (*Hydrurga leptonyx*)
bearded (*Erignathus barbatus*)	Weddell (*Leptonychotes weddelli*)

Ursids

A marine mammal, the polar bear (*Ursus maritimus*) can be excluded from further analysis since it is a polar species

Mustelids

Two of the six species of otters in the world inhabit ocean waters: the sea otter (*Enhydra lutris*) and the chungungo (*Lutra felina*). The activities of both species occur almost exclusively in shallow waters. Therefore, these species are not considered for further evaluation.

Sirenians

The world has three manatee species, West Indian (*Trichechus manatus*), Amazonian (*T. inunguis*]) and West African *T. senegalensis*) and one dugong species (*Dugong dugon*). The manatees are primarily a fresh water and estuarine species. Therefore, they are eliminated from further evaluation.

Dugongs are usually found in calm, sheltered, nutrient-rich water less than 5-m (16.4 ft) deep, generally in bays, shallow island and reef areas which are protected against strong winds and heavy seas and which contain extensive sea grass beds. However, they are not confined to inshore waters. There have been sightings near reefs up to 80 km (43.2 nm) offshore in waters up to 37 m (121.4 ft) deep. The average minimum water depth that the SURTASS LFA vessel will operate is 200 m (656.2 ft). The shallowest depth that it can operate is 100 m (328 ft). As a result of sound attenuation in shallow and shoaling water, dugongs are unlikely to be affected. Therefore, they are eliminated from further evaluation.

3.2.2 Fish

3.2.2.1 Background

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 27,000 extant species (Nelson, 1994). 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. Table 3.2-1 provides a listing and a general discussion of the hearing abilities of marine fish species that have been reported in the primary literature, as well as representative fresh water species that might provide some insight into hearing capabilities of marine species. The pelagic and demersal fish orders shown are of particular importance because of their demonstrated responses to LF sounds, protected status, and/or commercial importance. It is likely, however, that many other fish species produce and/or use sound for communication, but data are not available on additional species. For example, there is some reason to think that a number of deep-sea species that live where there is little or no light, such as myctophids (lanternfish) (Popper, 1980; Mann and Jarvis, 2004), macrourids (rattails - relatives of cod) (Deng et al., 2003), 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.

3.2.2.2 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). The major components of the octavolateralis system (Figure 3.2-1a) are the inner ear and the lateral line. 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 humans (Coffin et al., 2004). Both components of the octavolateralis system, the ear and the lateral line, send their signals to the brain in separate neuronal pathways. However, at some levels the two systems interact to enable the fish to detect and analyze a wide range of biologically relevant signals (Coombs et al., 1989).

Table 3.2-1. Selected Fish Orders

Fish Order	Common Name (representative of order)	Pelagic or Demersal	Hearing Characteristics[1]
Heterodontiformes	Bullhead sharks	Demersal	The horn shark, *Heterodontus francisci*, reportedly hears from 20-160 Hz (Kelly and Nelson, 1975).[2]
Lamniformes	Pelagic sharks	Pelagic	Hearing range for the bull shark, *Carcharhinus leucas*, reportedly is 100-1400 Hz (Kritzler and Wood, 1961), the lemon, *Negaprion brevirostris,* hears from 10-640 Hz (Banner, 1967; Nelson, 1967; Banner, 1972), and the hammerhead shark, *Sphyrna lewini*, from 250-750 Hz (Olla, 1962). Data from shark attraction experiments suggest hearing up to 1500 Hz in a number of species, although these data are not quantified and need to be repeated.[2]
Rajiformes	Skates and rays	Demersal	The little skate, *Raja erinacea*, hears from 100-800 Hz, with best hearing at 200 Hz at approximately 122 dB re: 1 µPa at 1 m threshold (Casper et al., 2003).
Anguilliformes	Eels	Demersal	The upper audible limit of *Anguilla anguilla* hearing is reported to be about 600 Hz (Diesselhorst, 1938[2]) with best hearing at about 100 Hz at 95 dB re: 1 µPa at 1 m threshold (Jerko et al., 1989).
Albuleiformes	Bonefish	Pelagic and demersal	The bonefish (*Albula vulpes*) is able to detect sounds from 50-700 Hz (Tavolga, 1974).

[1] It is suggested that whereas the hearing bandwidth and general sensitivity trends are generally valid, the "details" of the specific bandwidth and hearing sensitivity must be viewed with some caution. In particular, the data reported here were obtained using a wide range of methods and so some of the differences among species may reflect the experimental approach more than real differences. For example, while the lowest frequency detectable is often given, careful analysis of the original papers will show that the lower frequency is often related to the methods used to produce sounds. Thus, a lower limit of 50 or 100 Hz may reflect that the sound sources could not produce sounds below that frequency, whereas if a different sound system were used the fish may have actually been able to respond to lower frequencies. This is less of a problem with the upper frequency limits for hearing since sound systems used in most studies often could produce much higher frequencies than tested. The other caveat in these data is the actual threshold (lowest detectable sound). The "threshold" is defined as the signal that is detectable only a certain per cent of the time (e.g., often 50 percent). Moreover, thresholds may vary within an individual based upon motivation and other factors. Finally, and significantly, many of the earlier studies were done with less than ideal acoustics and whereas the thresholds reported may have been based upon pressure signals, the fish themselves may have been responding to the particle displacement component of the sound field.

[2] Data for sharks and rays, and for a number of bony fish, have only been obtained for a few specimens. Future work is needed to replicate these results on both threshold and bandwidth.

Table 3.2-1. Selected Fish Orders

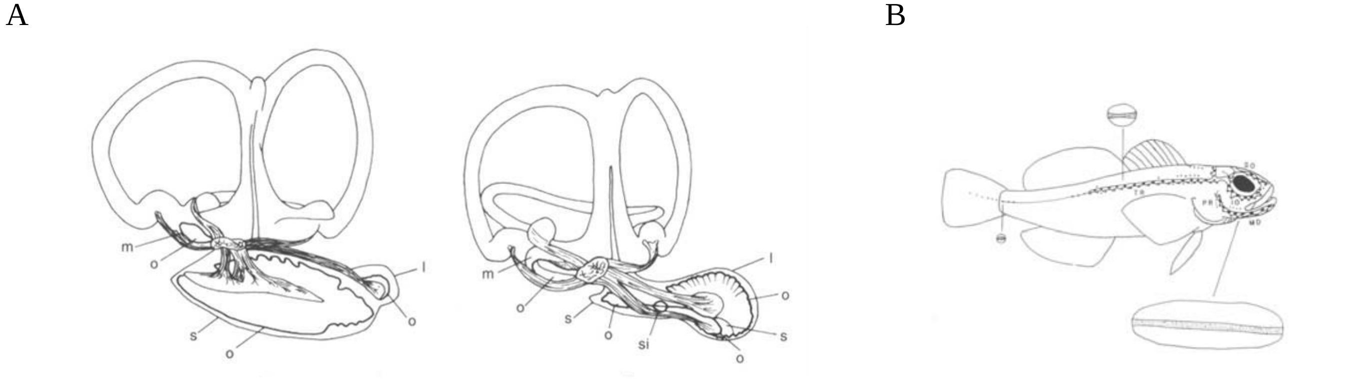
Fish Order	Common Name (representative of order)	Pelagic or Demersal	Hearing Characteristics[1]
Clupeiformes	Herrings/shads/sardines/ anchovies	Pelagic	Maximum hearing sensitivity for Pacific herring (*Clupea harengus pallasi*) is reportedly 125-500 Hz (reviewed in Croll et al., 1999), Pacific sardine (*Sardinops sagax*) best sensitivity is reported to be from 63-500 Hz (Sonalysts, 1995 – unpublished “gray” literature). Spotlined sardines (*Sardinops melanostictus*) are reported to hear from 256-2048 Hz, with maximum sensitivity near 1 kHz (Akamatsu et al., 2003). Spotted shad (*Clupanodon punctatus*) max sensitivity 125-500 Hz (Sorokin et al., 1988). All of these data are highly suspect and most clupeiforms appear to detect sounds to over 3 kHz (Mann et al., 2001) and some species in the genus *Alosa* can detect sounds to over 180 kHz (Mann et al.; 1998, Mann et al., 2001). There is a report that the twaite shad (*Alosa fallax*) avoided 200 kHz sound pulses (Gregory and Clabburn, 2003).
Salmoniformes	Salmons/trouts/ Chars	Pelagic	Some species (e.g. *Salmo salar*) are able to detect sounds from 30 Hz to about 600 Hz (Hawkins and Johnstone, 1978; Knudsen et al., 1992). Recent studies show that rainbow trout (*Oncorhynchus mykiss*) appear to be able to detect sounds to over 800 Hz (Popper et al., In Prep.).
Gadiformes	Cods/hakes/haddock/ Pollock	Pelagic and demersal	Hearing range of the cod (*Gadus morhua)* is 10-500 Hz (Chapman and Hawkins, 1973), while that of the haddock (*Melanogrammus aeglefinus*) is from 30-470 Hz (Chapman, 1973). Pollack (*Pollachius polachius*) hear about the same range of sounds (Chapman, 1973). Walleye pollock (*Theragra chalcogramma*) are reported to be able to detect sounds from 60-1000 Hz, with best hearing at 120-200 Hz (Park et al., 1995). The ling (*Molva molva*) reportedly detects sounds from 40-550 Hz (Chapman, 1973).
Pleuronectiformes	Flounders/sole/ Halibut	Demersal	*Pleuronectes platessa* and *Limanda limanda* reportedly detect sounds up to 200 Hz (Chapman and Sand, 1974), while *Pleuronectes* is able to detect sounds as low as 30 or 40 Hz (Karlsen, 1992). *Paralichthys olivaceous* detects sounds from 70 Hz to 500 Hz, with best hearing at 100 Hz (Fujieda et al., 1996). *Pleuronectes yokohamae* is able to detect sounds from 60 to 1000 Hz, with best hearing at 100 Hz (Zhang et al., 1998).

Table 3.2-1. Selected Fish Orders

Fish Order	Common Name (representative of order)	Pelagic or Demersal	Hearing Characteristics[1]
Beryciformes	Squirrelfish (Holocentridae)	Pelagic and demersal	One species of squirrelfish (*Myripriste kuntee*) can detect sounds between 100-3000 Hz with best sensitivity between 300-2000 Hz, while another (*Adioryx xantherythrus*) can only detect to about 100-1000 Hz (Coombs and Popper, 1979). The squirrelfish (*Holocentrus vexillaris*) and (*Holocentrus ascensionis*) can detect sounds from 100-1200 Hz (Tavolga and Wodinsky, 1963; Wodinsky and Tavolga, 1964). Large variability in hearing capabilities exists within this group of fish.
Batrachoidiformes	Toadfish (Batrachoididae)	Demersal	Oyster toadfish (*Opsanus tau*) reportedly detect sounds from 40-700 Hz, with best sensitivity between 40-200 Hz (Fish and Offutt, 1972) and this has been confirmed from neurophysiological studies (Fay and Edds-Walton, 1997)
Scorpaeniformes	Searobins (Triglidae)	Demersal	Slender searobin (*Prionotus scitulus*) detects sounds from 100-600 Hz, with best sensitivity from 200-400 Hz (Tavolga and Wodinsky, 1963).
Perciformes (note, this is such a diverse group of fish that they are broken down by taxonomic family)	Tunas (Scombridae)	Pelagic and demersal	Yellowfin tuna (*Thunnus albacares*) hearing range 50-1100 Hz with most sensitive hearing between 300 and 500 Hz (Iverson, 1967). This species has much better sensitivity than another tuna, the kawakawa (*Euthynnus affinis*), that has the same hearing range (Iverson, 1967).
	Damselfish (Pomacentridae)	Demersal	Various species in this family (genus *Eupomacentrus*) can detect sounds from 100 to 1200 Hz, with best hearing from 300-600 Hz (Myrberg and Spires, 1980).
	Wrasses (Labridae)	Pelagic and Demersal	Very diverse group and not likely that data for limited number of species represent variation in hearing likely to be found. However, blue-head wrasse (*Thalassoma bifasciatum*) can detect sounds from 100-1200 Hz, with best sensitivity from 200-600 Hz (Tavolga and Wodinsky, 1963).
	Sea basses (Serranidae)	Pelagic and demersal	Only data are for the red hind (*Epinephelus guttatus*) which can hear from 100-1000 Hz, with best sensitivity from 200-400 Hz (Tavolga and Wodinsky, 1963).
	Snappers (Lutjanidae)	Pelagic and demersal	Schoolmaster (*Lutjanus apodus*) hears from 100-1000 Hz, with best sensitivity from 200-600 Hz. (Tavolga and Wodinsky, 1963).
	Drums (croakers) (Sciaenidae)	Pelagic and demersal	There is broad diversity in ear structure and in hearing in this group (Ramcharitar et al., 2001, 2004; Ramcharitar and Popper, 2004). Several species can detect sounds to over 2000 Hz while others can only detect sounds to 800 Hz. Many sciaenids use sound for communication as well.

Table 3.2-1. Selected Fish Orders

Fish Order	Common Name (representative of order)	Pelagic or Demersal	Hearing Characteristics[1]
	Grunts (Haemulidae)	Demersal	Blue-striped grunt (*Haemulon sciurus*) hears from 50-1000 Hz, with best hearing from 50-500 Hz (Tavolga and Wodinsky, 1963, 1965).
	Breams and porgies (Sparidae)	Pelagic	Ringed sea-bream (*Sargus annularis*) reportedly hears from 400-1200 Hz with best hearing from 400-800 Hz (Dijkgraaf, 1952). Red sea-bream (*Pagrus major*) hears from 50-1500 Hz, with best hearing at 200 Hz (Ishioka et al., 1988; Iwashita et al., 1999). Pinfish (*Lagodon rhomboides*) hears from 100-1000 Hz, with best sensitivity at 300 Hz (Tavolga, 1974).
	Jacks and mackerels (Carangidae)	Pelagic	Horse mackerel (*Trachurus japonicus*) hears 70-3000 Hz, with best hearing at 1000-1500 Hz (Chung et al., 1995).
	Sleeper gobies (Eleotridae)	Demersal	Sleeper goby (*Dormitator latifrons*) detects frequencies from 50 to 400 Hz (Lu and Xu, 2002).
	Goatfish (Mullidae)	Dermersal	Hearing ability in *Mullus* has greatest sensitivity occurring at 450-900 Hz (Maliukina, 1960).
	Mullet (Mugilidae)	Pelagic	Hearing ability in *Mugil* has an upper frequency limit of 1600-2500 Hz, with greatest sensitivity occurring at 640 Hz (Maliukina, 1960) .
	Gobies (Gobiidae)	Demersal	Hearing ability in *Gobius* has an upper frequency limit of 800 Hz, (Dijkgraaf, 1952).
Siluriformes	Catfish	Demersal	Marine catfish (*Arius felis*) hears from 50-1000 Hz, with best hearing from 100-400 Hz (Popper and Tavolga, 1981). *Amiurus nebulosus* hears from 60-10,000 Hz with best hearing at 400-1500 Hz (Poggendorf, 1952).



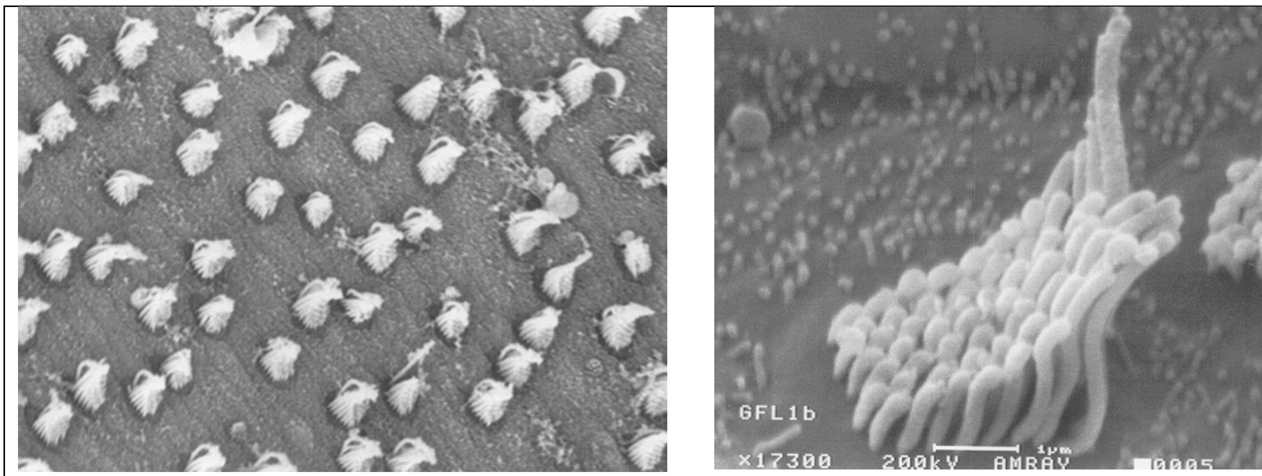
The octavolateralis system of fish includes the inner ear (A) and the lateral line system (B). (A) Drawing of the medial view of the inner ear of a zander (*Stizostedion lucioperca*) on the left and an ide (*Levciscus idus*) on the right (From Popper and Fay, 1973). l *Lagena*, m *utriculus*, o *otolith of each otolithic end organ*, s *sacculus*, si *transverse canal*. (B) Drawing of the canal and surface neuromasts on the body of the mottled sculpin (*Cottus bairdii*). The enlarged drawings show the dorsal surface of neuromasts found on the mandible, trunk, and a superficial neuromast, and stippling represents hair cells. MD *mandibular canal*; SO *supraorbital canal*; IO *infraorbital canal*; PR *preopercular canal*; TR *trunk canal*. (From Coombs, S. et al., *The Mechanosensory Lateral Line: Neurobiology and Evolution*, Springer-Verlag, New York, 1989, 301).

Figure 3.2-1a. Octavolateralis system.

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) (see Figure 3.2-1a). 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). 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). 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 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 one Hz to between 150 and 200 Hz (Coombs et al., 1992), 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). 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 styles 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). The sensory regions of the semicircular canals and otolith organs contain many sensory hair cells as shown in Figure 3.2-1b. 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).



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 enlarged from the general area shown on the left. (Information at bottom of right image shows magnification [17,300x) and other record keeping information. The scale bar is 1 µm.)

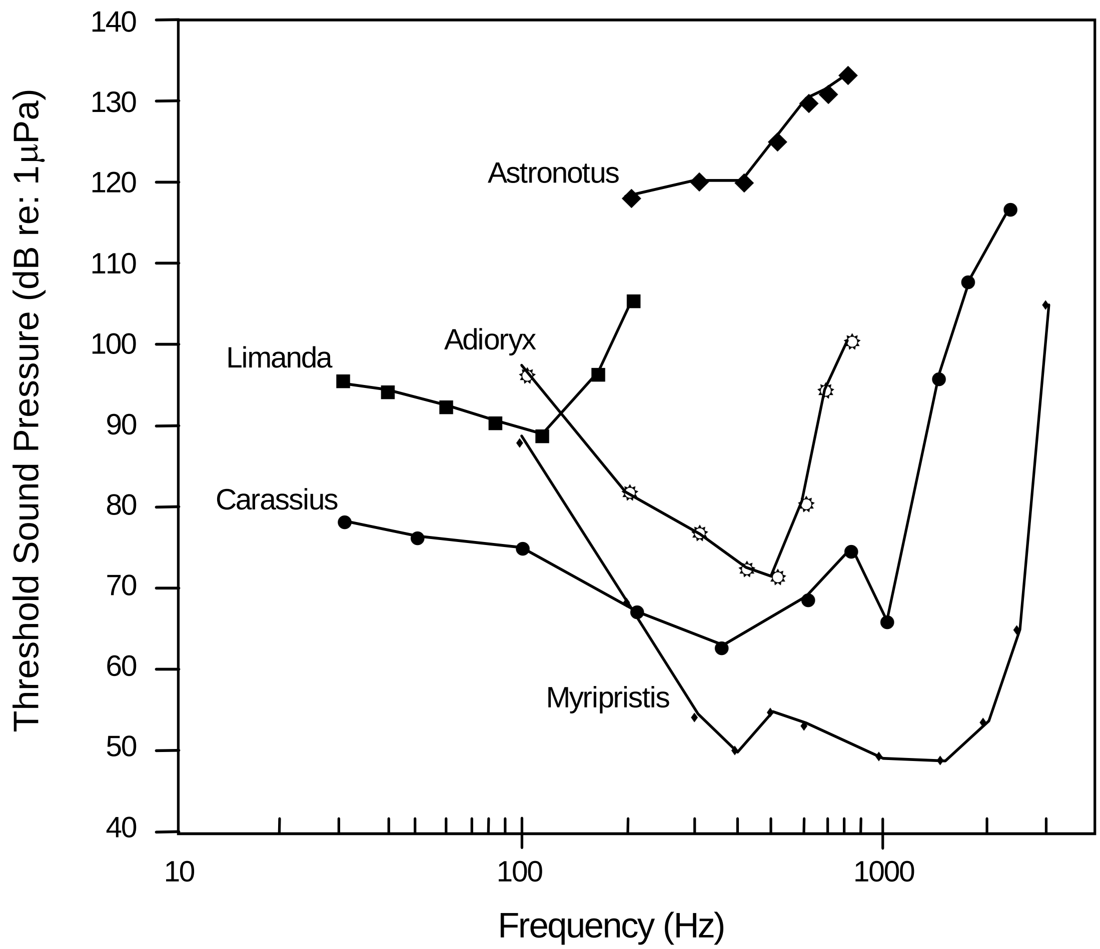
Figure 3.2-1b. Electron micrograph of the sensory surface of a fish ear.

Hearing is better understood for bony fish than for other fish, such as 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 such capabilities are called “nonspecialists” (or “generalists”). Popper and Fay (1993) suggest that in the hearing specialists, 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 bear on the ear. In nonspecialists, however, the lack of a swim bladder, or its lack of coupling to the ear, probably results in the signal from the swim bladder attenuating before it gets to the ear. As a consequence, these fish detect little or none of the pressure component of the sound (Popper and Fay, 1993).

The vast majority of fish studied to date appear to be non-specialists (Schellart and Popper, 1992; Popper et al., 2003), and only a few species known to be hearing specialists inhabit the marine environment (although lack of knowledge of specialists in the marine environment may be due more to lack of data on many marine species, rather than on the lack of there being specialists in this environment). Some of the better known marine hearing specialists are found among the Beryciformes (i.e., soldierfish and especially Holocentridae, which includes the squirrelfish) (Coombs and Popper, 1979), and Clupeiformes (i.e., herring and shad) (Mann et al., 1998, 2001). Even though there are hearing specialists in each of these taxonomic groups, most of these groups also contain numerous species that are nonspecialists. In the family Holocentridae, for example, there is a genus of hearing specialists, *Myripristis*, and a genus of nonspecialists, *Adioryx* (Coombs and Popper, 1979).

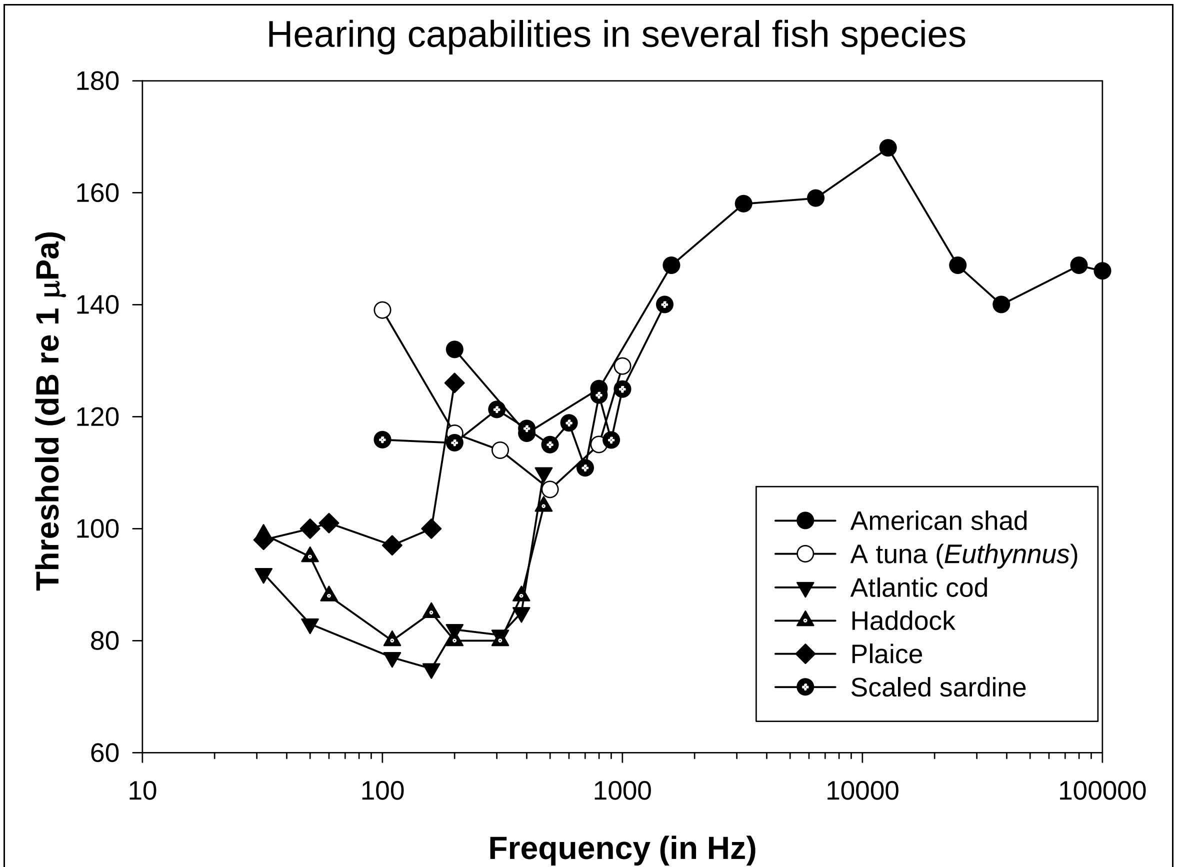
Audiograms (measures of hearing sensitivity) have been determined for over 50 fish (mostly fresh water) and four elasmobranch species (Fay, 1988a; Casper et al., 2003). An audiogram plots auditory thresholds (minimum detectable levels) at different frequencies and depicts the hearing sensitivity of the 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 hearing specialists detect sound pressure with greater sensitivity over a wider bandwidth (to 3 kHz or above) than the nonspecialists. Also, the limited behavioral data available suggest that frequency and intensity discrimination performance may not be as acute in nonspecialists (Fay, 1988a).

Behavioral audiograms for both freshwater and marine fish are presented in Figure 3.2-2a for two hearing specialists (goldfish [*Carassius auratus*] and squirrelfish [*Myripristis kuntee*]), two nonspecialists that have a swim bladder (another squirrelfish [*Adioryx xantherythrus*] and an oscar [*Astronotus ocellatus*]), and one nonspecialist without a swim bladder (lemon sole [*Limanda limanda*]). 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, hearing specialists 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 3.2-2b provides data for additional marine species.



Two hearing specialists: *Carassius auratus* (goldfish)(Fay, 1969) *and Myripristis kuntee* (squirrelfish)(Coombs and Popper, 1979); two hearing nonspecialists having a swimbladder, *Adioryx xantherythrus* (another squirrelfish)(Coombs and Popper, 1979), and *Astronotus ocellatus* (the Oscar)(Yan and Popper, 1992); and a nonspecialist without a swimbladder, *Limanda limanda* (lemon sole)(Chapman and Sand, 1974)

Figure 3.2-2a. Behavioral audiograms for marine and freshwater species.



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); Scaled sardine (*Harengula jaguana*) (Mann et al., 2001)

Figure 3.2-2b. Behavioral audiograms for selected marine species.

The specialists 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 available 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.

As for sound production in fish, 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 and Popper, 1999). Some of these sounds may involve the use of the swim bladder as an underwater resonator. Sounds produced by vibrating the swim bladder may be at a higher frequency (400 Hz) than the sounds produced by moving body parts against one another. The swim bladder drumming muscles are correspondingly specialized for rapid contractions (Zelick and Popper, 1999). Sounds are known to be used in reproductive behavior by a number of fish species, and the current data lead to the suggestion that males are the most active producers. Sound activity often accompanies aggressive behavior in fish, usually peaking during the reproductive season. Those benthic fish species that are territorial in nature throughout the year often produce sounds regardless of season, particularly during periods of high-level aggression (Myrberg, 1981).

3.2.2.3 Sharks

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 are sensitive 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 Nelson, 1975). 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 are able to 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 the band of greatest sensitivity occurring at 400 to 600 Hz. Lemon sharks responded to sounds varying in frequency 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 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 study was that of the little skate, *Raja erinacea* (Casper et al., 2003). Results suggest that this species is able to detect sounds from 100 to over 800 Hz, with best hearing up to and possibly slightly greater than 500 Hz. However, these authors, as several others working with elasmobranchs, report thresholds in terms of pressure, whereas it is highly likely that all of these species are detecting particle motion (van den Berg and Schuijf, 1983), and so the thresholds are possibly quite different than those reported since particle motion was not calibrated.

Researchers doing field studies on shark behavior found that several shark species appear to exhibit withdrawal responses to broadband noise (500-4,000 Hz, although it is not clear that sharks heard the higher frequencies in this sound). 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 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. Klimley (unpublished data) also noted the increase in tolerance of lemon sharks during successive sound playback tests. 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 of shark 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 25-500 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 they are generally obtained from studies of a single animal, and it is well known that sound detection ability (both sensitivity and hearing bandwidth) varies considerably among different species, and even among members of the same species. Moreover, it is known that hearing ability changes with age, health, and many other variables. Thus, while the thresholds reported for sharks give an indication of the sounds they 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. But 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.

3.2.2.4 Threatened and Endangered Fish Stocks

The following fish species have been listed by NMFS as threatened (T) or endangered (E) under ESA:

Threatened and Endangered Fish Stocks

- Coho salmon (*Oncorhynchus kisutch*) (T): central California coast, northern California/southern Oregon, and Oregon Coast;
- Chinook salmon (*Oncorhynchus tshawytscha*)(E): North Pacific Ocean basin;
- Sockeye salmon (*Oncorhynchus nerka*) (E): North Pacific Ocean basin;
- Cutthroat trout (Umpqua River)(*Oncorhynchus clarki clarki*) (E): U.S. and Canadian coastal zone from southeast Alaska to northern California (within 18.5 km [10 nm] of coast);
- Steelhead trout (*Oncorhynchus mykiss*) (T): Washington, Oregon, and North California coastal and inland waters;
- Shortnose sturgeon (*Acipenser brevirostrum*) (E): U.S. and Canadian North Atlantic Ocean coast;
- Gulf sturgeon (*Acipenser oxyrinchus desotoi*) (T): U.S. Gulf of Mexico coasts from Mississippi River to Tampa Bay; and
- Totoaba (*Cynoscion macdonaldi*) (E): Gulf of California.

As noted above, fish species are listed as endangered, threatened or protected in fresh water, estuarine or near-shore waters habitats, where SURTASS LFA sonar would not operate.

3.2.3 Sea Turtles

3.2.3.1 Background

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 the oceans. All sea turtles have a protected status (with respect to the U.S. Endangered Species Act [ESA] and the Convention on International Trade in Endangered Species [CITES]). Other attributes of the sea turtle species selected for study are summarized in Table 3.2-2. Following is a brief summary of each species.

The distribution of most species of sea turtle is limited by water temperature and varies by season. Most sea turtle species are distributed in water temperatures above 18 deg C (64 deg F), but they can survive in waters as cool as 10 deg C (50 deg F). If the water temperature drops below 8 to 10 deg C (46 to50 deg F), cold stunning occurs and turtles lose their ability to swim and dive, and they float to the surface (Spotila et al., 1997). Sea turtle distribution is mostly limited to between 40 deg N and 35 deg S longitude, although during warmer seasons this range is substantially expanded (Davenport, 1997). The exception to this distribution is the leatherback sea turtle, which is found from 71 deg N to 47 deg S longitude, and seems to prefer water temperatures between 14 and 16 deg C (57 and 61 deg F) for foraging, but also spends extended periods in tropical waters for breeding (Marquez, 1990; Plotkin, 1995).

Sea turtles are highly migratory and therefore have a wide geographic range in tropical, sub-tropical, and temperate waters. When they are active, they must swim to the ocean surface to breathe every 5 to 10 minutes (Keinath, 1993), but can remain underwater for 30 to 40 minutes when they are resting. Diving behaviors are discussed in the text of each sea turtle species, as well as in Table 3.2-2 of the FOEIS/EIS. Sea turtles are capable of making repetitive dives in search of food, and migrating turtles usually dive to less than 20 m (65.6 ft) (Luschi et al., 2003).

Hawksbill sea turtle *(Eretmochelys imbricata)*, green sea turtle (*Chelonia mydas*), olive ridley sea turtle (*Lepidochelys olivacea*), and Kemp's ridley sea turtle (*Lepidochelys kempi*) adults are generally coastal species, whereas the young of some or all of these species are believed to be distributed in the open ocean. Upon emerging from their nests, hatchlings rely on the light on the horizon to find the ocean. After entering the water, both magnetic orientation and the oncoming direction of sea swell guide them away from shore (Ernst et al., 1994). Marine turtle species then remain pelagic for many years and may travel through a large range of habitats before returning to coastal environments to reside (excluding the leatherback). Once in coastal waters, juvenile turtles continue to grow and move among developmental environments, migrating to different habitats at different life stages until maturity. Their pattern of movement then becomes more regular, with adult turtles migrating hundreds to thousands of miles between established foraging and breeding areas (Wyneken, 1997; Plotkin, 2003).

Most adult females return to their natal beaches in order to lay eggs. The females come ashore two or more times a season to lay a hundred or more eggs in a deep nest cavity dug with the hind flippers. After filling the nests, the adult females return to the sea and generally remain near the nesting area until they have deposited their last clutch of eggs for the season.

Migratory behavior of adult sea turtles is much better understood than that of hatchlings and juveniles due to the development and use of satellite telemetry. Many females have been tracked after nesting. Some species have been tracked to a neritic environment where they sometimes stay for one to four years. The neritic environment is defined as a shallow water environment or the nearshore marine zone extending from the low-tide level to a depth of 200 m (656 ft). Juvenile sea turtles complete their development in the neritic habitat and adult sea turtles use it for feeding. Migratory routes and currents have been modeled and show that currents are often utilized during migration to increase their speed. However, the comparison between turtle migration routes and modeled data may not be accurate because the models of currents only show the average of the currents over large areas and periods of time. It is possible that the currents also produce feeding grounds (Luschi et al., 2003).

Leatherback turtles (*Dermochelys coriacea*) are listed as critically endangered under the IUCN and as endangered throughout their range under the ESA, and are protected under CITES. The primary threats to their recovery include incidental take by fisheries (particularly longline fisheries), killing of nesting females, and the collection of eggs. An estimate of population size worldwide has come from estimates of breeding females. Plotkin (1995) estimated 115,000 adult females worldwide in 1982. However, due to recent declines, it is estimated that only 20,000 to

30,000 female leatherback turtles exist (Plotkin, 1995). Leatherbacks are declining in all Pacific basin rookeries (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998a). It is also considered by most authorities to be the most endangered of the sea turtles due to the rapid decline in global population during the last 15 years (Ferraroli et al., 2004). Recent data indicate that there may be important migratory corridors and habitats used by the species in the Pacific Ocean (Morreale et al., 1996; Eckert, 1999).

They are the largest, most pelagic, and most widely distributed of any sea turtle, found between 71 deg N and 47 deg S latitude (Plotkin, 1995). In the North Atlantic, leatherback sea turtles range from Cape Sable, Nova Scotia south to Puerto Rico and the U.S. Virgin Islands. They are also found throughout the Pacific Ocean.

As stated previously, information indicates that leatherbacks inhabit regions with water temperatures between 14 and 16 deg C (57 and 61 deg F) for foraging, though they exhibit extraordinary thermal tolerance and are often observed in much colder water. They feed primarily on cnidarians, and tunicates, mostly in deeper waters, but have also been observed at the surface (Plotkin, 1995). They are deep, nearly continuous divers (Eckert et al., 1996). The deepest dive recorded was to 1,230 m (4,035 ft), but they usually dive to depths around 250 m (820 ft) (Hays et al., 2004). They rarely stop swimming and individuals have been documented to swim greater than 13,000 km (7,015 nm) per year (Eckert, 1998; Eckert, 1999).

Nesting grounds are found circumglobally between 40 deg N and 35 deg S latitude. The beaches of French Guiana and Suriname (5 deg N, 54 deg W) are the last large nesting sites in the Atlantic for leatherback turtles (Ferraroli et al., 2004). In the Atlantic, leatherback turtles have smaller nesting grounds in the U.S. Caribbean on St. Thomas, St. Croix, and St. John islands. In Puerto Rico, nesting grounds occur at Islas Culebra, Vieques, and Mona. Playas Rasaca and Brava on Isla Culebra and Sandy Point on St. Croix support the largest nesting colonies in the United States and its territories. Sandy Point Beach is designated as critical habitat under the ESA. There are no leatherback turtle nesting grounds under U.S. jurisdiction in the Pacific Ocean.

The Pacific coast of Mexico, particularly Michoacan, Guerrero, and Oaxaca, were once the largest nesting grounds of the Pacific leatherback turtles. Today, however, sea turtles do not nest there regularly. Nesting in the Pacific is widespread in the western Pacific, including China, Indonesia, Southeast Asia, and Australia (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998a).

Green turtles (*Chelonia mydas*) are protected under CITES and are listed as endangered under both the IUCN and the ESA throughout their ranges in the eastern Pacific Ocean, the Pacific coast of Mexico, as well as the breeding population in Florida. They are listed as threatened under the ESA throughout the rest of the Pacific and Atlantic oceans. Critical habitat for green turtles has been designated around Culebra Island, Puerto Rico. In the eastern Pacific, green turtles have historically been abundant. However, due to commercial exploitation, the numbers of nesting females has significantly decreased. While exploitation is a major threat to green turtles in the Pacific Ocean, their primary threats in the Atlantic Ocean are from coastal development, incidental take by commercial fisheries, and pollution (National Marine Fisheries

Service and U.S. Fish and Wildlife Service, 1991a). Green sea turtles are known to return to their natal beaches for nesting, which has made them an easy target for exploitation (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998c).

The eastern Pacific green turtle is sometimes referred to as the “black turtle,” *C. mydas agassizi*. The most recent literature states that there is still a controversy as to whether the black turtle is a subspecies of green turtles or its own species (Pritchard, 1997). Under the ESA, the black turtle is listed as a subspecies under the green sea turtle; therefore, for the purposes of this analysis, the black turtle will be considered as a subspecies of the green turtle.

Green turtles are widespread throughout tropical and subtropical waters above 20º C (51.8º F). Green sea turtles are commonly found between 15 deg N and 5 deg S latitude along the 90 deg W longitude line, between the Galapagos Islands and the Central American coast. They are the second-most sighted turtle during tuna fishing cruises. They have been reported as being as far north as British Columbia (48.15 deg N) (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998b). The black sea turtle ranges from Baja California south to Peru and west to the Galapagos Inlands (Pritchard, 1997). Their regular migration patterns, however, are unknown (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998b). They are primarily coastal as juveniles and adults, but make long pelagic migrations between foraging and breeding areas (Bjorndal, 1997; Pritchard, 1997).

Adult turtles are mainly herbivorous, eating algae and sea grasses. They are also known to eat mollusks, polychaetes, jellyfish, amphipods, sardines, and anchovies. They regularly dive to 20 m (65.6 ft) (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998b).

Green turtle nesting grounds are found in the Pacific and Atlantic oceans. In the Mediterranean Sea, nesting grounds were studied from 1979 to 2000 to assess the state of sea turtles along the coastline of Turkey (Canbolat, 2003). This study found that the Turkish coastline and Cyprus are the most important nesting areas for green sea turtles in the Mediterranean, particularly the beaches of Kazani and Akyatan. An estimated 115 to 580 female green sea turtles nest in the Mediterranean annually (Canbolat, 2003). In the United States, large numbers of nests are found on the east coast of Florida, and small numbers of nests are found throughout the U.S. Virgin Islands and Puerto Rico. The main nesting site in the eastern Pacific Ocean is located in Michoacán, Mexico, which supports approximately a third of the east Pacific green sea turtle population. Other nesting sites include Guerrero, Jalisco, Oaxaca, Chiapas, and the islands of Clarion and Socorro in Mexico and along the Central American Pacific coastline (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998b).

Loggerhead turtles (*Caretta caretta*) are listed as endangered under the IUCN, threatened under the ESA, and are protected under CITES. The primary threat to loggerhead populations is incidental capture by commercial trawlers and longline fishing nets. Coastal development is also a serious threat to their nesting (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991b).

Loggerhead turtles are large, 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 (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998d). Juvenile loggerhead sea turtles are known to forage in the Chesapeake Bay, entering in the spring and leaving in the fall, migrating south towards Cape Hatteras. Their migration may be temperature-influenced; loggerhead turtles generally occur in waters of 13.3 to 28 deg C (55 to 82 deg F) (Coles and Musick, 2000). In the spring, summer, and fall months, juvenile loggerheads are commonly found in coastal inlets, sounds, estuaries, bays, and lagoons along the eastern United States (Bolten and Witherington, 2003). Loggerhead turtles both reside and nest in subtropical to temperate areas (e.g., North Carolina to Florida, Oman, Northeastern Australia, Japan). Some stocks have long cross-basin migrations between feeding and nesting areas.

In the Pacific Ocean, loggerhead habitats include ocean and island areas around Polynesia, Micronesia, Melanesia, Indonesia, the Philippines, Australia, China, Japan, Mexico, and the United States (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998d).

Loggerhead turtles feed primarily on benthic invertebrates such as gastropods, mollusks, as well as decapod crustaceans (National Marine Fisheries Service and the U.S. Fish and Wildlife Service, 1991b; Ernst et al., 1994; Bjorndal, 1997). According to Bolten (2003), oceanic loggerheads spend 75 percent of their time in the top 5 m (16.4 ft) of the water column and 80 percent of their dives are within 2 to 5 m (6.6 to 16.4 ft). The maximum depth recorded during a dive was 233 m (764 ft) Oceanic turtles studied in the Azores swam at speeds of 0.2 m/s (0.7 ft/s) (Bolten, 2003).

Their largest known nesting beaches are in Masirah, Oman and on the Kuria Muria Islands, Oman in the Arabian Sea. More recent reports show that loggerheads are also nesting, however in smaller numbers, in the Caribbean (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991b). Atlantic loggerhead sea turtles primarily nest in Florida, but nest in smaller numbers in South Carolina, Georgia, and North Carolina (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991b). More nests are laid on Bald Head Island in North Carolina than anywhere else in the state and are therefore critically important to the stability of the northern rookery (Webster and Cook, 2001). In the Pacific, loggerhead sea turtles nest in warm temperate and subtropical regions, primarily in Japan and Australia (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998d).

The migration of all sea turtles is poorly understood, including the migration of loggerhead turtles. However, loggerhead sea turtles have been documented as traveling from eastern Florida towards the East Atlantic using the Eastern Florida Current and the Gulf Stream. Loggerheads in Japan are also known to migrate across the Pacific to California, carried by the California Current (Luschi et al., 2003). Hatchlings undertake long developmental migrations. For example, turtles hatched in Japan cross the Pacific to spend some years living off the U.S. and Mexican coasts. Hatchlings on the eastern coast of the U.S. cross the Atlantic before they return to the coastal waters near where they were hatched (Wyneken, 1997).

Hawksbill turtles *(Eretmochelys imbricata)* are listed as critically endangered under the IUCN, endangered throughout their range under the ESA, and are protected by CITES. Their numbers have declined significantly due to commercial harvesting, which uses hawksbill turtles for their shells, meat, and eggs (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1993).

They occur in tropical and subtropical waters in the Atlantic, Pacific, and Indian oceans, generally between 30 deg N and 30 deg S longitude (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998e). They are commonly found along the Gulf states, Florida and Texas in particular. Sightings north of Florida are rare; however, sightings have been made as far north as Massachusetts. Primarily near-shore reef dwellers, hawksbill turtles feed on benthic sponges, which make them highly susceptible to deteriorating coral conditions (Witzell, 1983). Hawksbill turtles are known to dive to depths of 7 to 10 m (23 to 32.8 ft) (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998e).

Some adults make long migrations between feeding and nesting areas, but juveniles are relatively sedentary on shallow reefs (Bjorndal, 1997). The most important nesting beaches in the Atlantic Ocean under U.S. jurisdiction include Mona Island in Puerto Rico, Buck Island in St. Croix, and the U.S. Virgin Islands (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1993). Mona Island has been designated as critical habitat under ESA. Hawksbills were once common in the nearshore waters from Mexico to Ecuador but are now rare or nonexistent in these areas. They have been reported in the island groups of Oceania and nest in the islands and mainland of southeast Asia, particularly China and Japan, through the Philippines, Malaysia, and Indonesia, to Papua New Guinea, Solomon Islands, and Australia. Their largest nesting grounds occur in the Torres Strait and the Republic of the Seychelles (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998e).

Olive ridley turtles (*Lepidochelys olivacea*) are the most abundant sea turtle worldwide. The global population is protected by CITES, classified as endangered under the IUCN, and listed as threatened under the ESA everywhere except the Mexican breeding stocks, which are listed as endangered. The Mexican population is severely depleted due to over-harvesting in Mexico; however, the population may be stabilizing. The main threats to olive ridley sea turtles are incidental takes by fisheries, boat collisions, and the harvesting of eggs and turtles in Central America. Harvested turtles are mostly sold for leather, bait, bone meal, and fertilizer, but also for meat (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998f).

Olive ridley turtles are found throughout the tropics and warm temperate oceans, but are concentrated around several very limited nesting beaches in Costa Rica, Mexico, and India (Musick and Limpus, 1997). It is believed that many olive ridley turtles migrate seasonally south for feeding and north for breeding and nesting. Olive ridley turtles are omnivorous, feeding on benthic organisms such as bottom fish, crab, oysters, sea urchins, snails, tunicates, shrimp, and algae and pelagic species such as jellyfish medusae, red crabs, and salps. Olive ridley turtles are recorded diving to a maximum depth of 290 m (951 ft) (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998f).

Olive ridley turtles prefer to nest around continental margins, with the largest nesting aggregation in the Indian Ocean along the northeast coast of India. The Pacific coast of Mexico and Central America, between Baja California and Peru, and particularly around Costa Rica, are the second most important nesting grounds. Most mating occurs near the nesting beaches, but copulating pairs have been seen at distances over 1,000 km (540 nm) from the nearest nesting beach. They are thought to nest throughout the year in the Eastern Tropical Pacific Ocean, with peak nesting months from September through December (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998f).

Kemp's ridley turtles (*Lepidochelys kempi*) are the rarest sea turtles worldwide and have the most restricted distribution. They are classified as critically endangered under the IUCN, as endangered throughout their range under the ESA, and are protected by CITES. The biggest threats to Kemp's ridley sea turtles have been the harvest of eggs and incidental take by the trawling industry, particularly from shrimp trawlers (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1992).

Kemp's ridley turtles are found primarily in the Gulf of Mexico and, to a lesser extent, along the Atlantic coast of the United States as far north as Long Island, New York (Musick and Limpus, 1997).

Juvenile Kemp's ridley sea turtles are known to forage in the Chesapeake Bay, entering in the spring and leaving in the fall, migrating south toward Cape Hatteras. Their migration may be temperature-influenced, generally occurring in waters greater than 11 deg C (58 deg F) (Coles and Musick, 2000). Juvenile and subadult sea turtles are found along the eastern coast of the United States and the Gulf of Mexico, traveling north with seasonal warming to feed in waters from Georgia up to New England and then migrating south again in the winter. They feed on benthic animals, primarily portunid crabs (Bjorndal, 1997). Kemp's ridley turtles are known to dive to depths of 50 m (164 ft) (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1992).

Kemp's ridley turtles exhibit mass nesting behavior where 100 to 10,000 or more females emerge from the water to nest at one time, primarily at Rancho Nuevo, Mexico in the Gulf of Mexico (only rarely has significant nesting been observed at any other beaches). There are consistent reports of large concentrations of mating adults at sea, suggesting breeding aggregations well offshore (NRC, 1990).

3.2.3.2 Sea Turtle Hearing Capabilities and Sound Production

Data on sea turtle sound production and hearing are few. There is little known about the mechanism of sound detection by turtles, including the pathway by which sound gets to the inner ear and the structure and function of the inner ear of sea turtles (Bartol and Musick, 2003). However, assumptions have been made based on research on other species of turtles. Based on the structure of the inner ear, there is some evidence to suggest that marine turtles primarily hear sounds in the low frequency range and this hypothesis is supported by the limited amount of physiological data on turtle hearing. Bartol and Musick (2003) said that the amount of pressure needed to travel through the bone channel of the ear increases with an increase in frequency. For this reason, it is believed that turtles are insensitive to high frequencies and that they primarily hear in a low frequency range. A description of the ear and hearing mechanisms can be found in Bartol and Musick (2003). The few studies completed on the auditory capabilities of sea turtles also 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).

Underwater sound was recorded 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-September timeframe. During this time period, RLs at the data collection hydrophone system in the 200-700 Hz band ranged from 83 dB (night) up to 113 dB (weekend day). Therefore, during much of the season when sea turtles are actively foraging in New York waters, their coastal habitats are flooded with underwater noise. The sea turtles are undoubtedly exposed to high levels of noise, most of which is anthropogenic. Results suggest that continued exposure to existing high levels of pervasive anthropogenic noise in vital sea turtle habitats and any increase in noise could affect sea turtle behavior and ecology (Samuel et al., 2005). However, there were no data collected on any behavioral changes in the sea turtles due to anthropogenic noise or otherwise during this study.

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

Bartol et al. (1999) measured the hearing of juvenile loggerhead sea turtles using auditory evoked potentials to LF tone bursts and found the range of hearing via Auditory Brainstem Response[3] (ABR) recordings from LF tone bursts indicated the range of hearing to be from at least 250 to 750 Hz. The lowest frequency tested was 250 Hz and the highest was 1000 Hz.

[3] ABR is a method in which recordings are made, non-invasively, of the brain response while the animal is presented with a sound. This is a method that is widely used to rapidly assess hearing in new-born humans, and which is being used more and more in studies of animal hearing, including hearing of marine mammals. The advantages of ABR 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 ABR only reflects the signal that is in the 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 ABR. 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 ABR, 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, ABR does give an excellent indication of basic hearing loss, and is an ideal method to quickly determine if there is TTS right after sound exposure when results are compared with those from controls.

More recently, Streeter and colleagues (pers. comm., 2005) were able to train a female green sea turtle to respond to acoustic signals. The results from this study showed a hearing range of at least 100 to 500 Hz (the maximum frequency that could be used in the study, as opposed to what may be a wider hearing range) with hearing thresholds of 120-130 dB RL. However, there are several important caveats to these results. First, the study was done in a relatively noisy oceanarium. Thus, the thresholds reported may have been masked by the background noise and the "absolute thresholds" (the lowest detectable signal within a noisy environment) may be several dB lower than the reported results. Second, data are for a single animal who is well into middle age (over 50 years old) and who had lived in an oceanarium all its life. While there are no data on effects of age on sea turtle hearing, data for a variety of mammals (including humans) show there is a substantial decrement in hearing with age, and this may have also happened in this animal. This too may have resulted in thresholds being higher than in younger animals (as used by Ridgway et al., 1969). Finally, the data are for one animal and so nothing is known about variability in hearing, or whether the data for this animal are typical of the species.

Table 3.2-2. Information Summary for Sea Turtles

Species	Protected Status	Distribution	Abundance/ Population	Diving Behavior And Travel Speeds
Leatherback Turtle (*Dermochelys coriacea*)	ESA endangered; CITES protected ; IUCN Critically Endangered	- Tropical and temperate pelagic waters; - Range between 71° N and 47° S - Nest between 40° N and 35° S - May aggregate at concentrations of jellyfish and areas of coastal upwelling; - Most significant nesting areas: Mexico, Costa Rica, Trinidad, Surinam/French Guiana, Indonesia, Culebra, Puerto Rico, and St. Croix U.S. VI - No nesting in the U.S. Pacific; nest mostly in China, Indonesia, Southeast Asia, and Australia -Water temps 14° to 16° C for foraging	- Recent global population estimates for mature female turtles 20,000-30,000; - Gulf of Mex: 5 turtles per 1,000 sq km	- Routinely dive to 250 m ; - Typical durations 9-15 min; - Maximum dive time 37 min.; - Maximum depth 1230 m; - Dive and swim throughout day and night; - Nearly continuous divers - During long movements or migration: 45-65 km per 24 hours; - Average swim speed: 2.21 km/h (0.614 m/s); - Hatchlings: 30 cm/sec below surface

Table 3.2-2. Information Summary for Sea Turtles				
Species	Protected Status	Distribution	Abundance/ Population	Diving Behavior And Travel Speeds
Green Turtle (*Chelonia mydas*)	ESA threatened everywhere except FL and Pac. Coast of Mexico where listed as endangered; CITES protected; IUCN Endangered	- Found throughout tropics and subtropics; - Nests on tropical beaches throughout the world; - Commonly found between 15° N and 5° S along the 90° W longitude line, between the Galapagos Islands and the Central American coast -Found in waters <20° C -Seen in waters as far north as British Columbia -Regular migrations unknown -Critical habitat around Culebra Island, Puerto Rico	- An estimated 115 to 580 female green sea turtles nest in the Mediterranean annually; - In the eastern Pacific, green turtles have historically been abundant. However, due to commercial exploitation, the numbers of nesting females has significantly decreased. - Consensus that numbers have been declining since 1950s	- Routinely dive to 20 m; - Average dive time > 40 min.; - Maximum dive time of 66 min - Average swim speed: 0.95 km/ h and have been measured at 1.4-2.2 kph; - Adults migrate between foraging grounds and nesting grounds; migrations cover distances greater than 100 km

Table 3.2-2. Information Summary for Sea Turtles				
Species	Protected Status	Distribution	Abundance/ Population	Diving Behavior And Travel Speeds
Loggerhead Turtle (*Caretta caretta*)	ESA threatened; CITES protected; IUCN Endangered	- Temperate, tropical and subtropical waters of the Atlantic, Pacific, and Indian oceans; - Relatively solitary except when aggregating on food concentrations or near nesting beaches; - About 88% of all nesting occurs on beaches in the S/E U.S., Oman, and Australia -Found in waters 13.3° - 28°C -Found around Poynesia, Micronesia, Melanesia, Indonesia, the Philippines, Australia, China, Japan, Mexico, and the United States	- In the Atlantic, a total of 127 female loggerhead sea turtles were photographed and tagged during the 1991 and 1992 nesting seasons, laying a total of 318 nests; - Estimated 250,000 females worldwide; - Estimated total population over 500,000 worldwide.	- Routinely dive to 2-5 m; - Average dive time 17-30 min.; - Maximum recorded dive is 233 m; - 75% time spent in upper 5 m of water column - Average swim speed: 1.2-1.7 km/ h and have been measured at 0.02 - 3.01 km/h - Turtles in the Azores documented at traveling at speeds of 0.2 m/s

Table 3.2-2. Information Summary for Sea Turtles				
Species	Protected Status	Distribution	Abundance/ Population	Diving Behavior And Travel Speeds
Hawksbill Turtle (*Eretmochelys imbricata*)	ESA endangered; CITES protected; IUCN Critically Endangered	- Worldwide tropical and subtropical waters in the Atlantic, Pacific, and Indian oceans; -Found along the Gulf states, Florida and Texas in particular and as far north as Massachusetts - Hatchlings pelagic, but older juveniles and adults live in clear shallow waters over reefs; - Range of 30° N to 30° S -Most important beaches at Mona Island in Puerto Rico, Buck Island in St. Croix, and U.S. Virgin Islands -Reported around island groups of Oceania, China, Japan, Philippines, Malaysia, Indonesia, Papua New Guinea, Solomon Islands, and Australia	Population estimates not available	- Routinely dive to 7-10 m; - Average dive time 56 min.; - Dive during day and night - Average swim speed: 0.74 km/h

Table 3.2-2. Information Summary for Sea Turtles

Species	Protected Status	Distribution	Abundance/ Population	Diving Behavior And Travel Speeds
Olive Ridley Turtle (*Lepidochelys olivacea*)	ESA threatened (Mexican population endangered); CITES protected; IUCN Endangered	- Worldwide tropical and warm temperate waters; - While large juveniles and adults reside primarily within 100 km of the coast, and aggregate in large concentrations in coastal waters during the nesting season, olive ridleys will often range far out to sea (>100 km) in certain areas of the world (e.g. Eastern Tropical Pacific and Indian Ocean).	Most abundant sea turtle worldwide, though population estimates not available	- Average dive time 29-54 min.; - Maximum recorded dive is 290 m - Average swim speed: 1.2-3.6 km/ h
Kemp's Ridley Turtle (*Lepidochelys kempi*)	ESA endangered; CITES protected; IUCN Critically Endangered	-Primarily in Gulf of Mexico but also along the east coast of the United States -As far north as Long Island, New York -Found in waters >11°C	Most rare sea turtle in the world, though population estimates not available	- Routinely dive to 50 m; - Average dive time 13-18 min.; - Average swim speed: 1.0-1.4 km/ h

3.2.4 Cetaceans

Cetaceans (whales, dolphins, and porpoises in the order Cetacea) are the most aquatically adapted marine mammals found in all the world's seas and oceans. They vary in distribution and abundance in a variety of aquatic habitats, from freshwater to bathypelagic. Cetaceans are ecologically diverse and range in size from approximately one meter (3 ft) to 33 m (108 ft) in length (Ballance, 2002).

The order Cetacea includes over 80 species and are classified under two suborders: baleen whales, or Mysticeti; and toothed whales, dolphins and porpoises, or Odontoceti (Fordyce, 2002). Mysticetes are distinguished by their large body size and specialized feeding method using keratinous baleen plates to strain a large quantity of small food organisms from seawater.

In comparison, odontocetes show greater foraging diversity. Toothed whales are capable of emitting high frequency sound and receiving echoes by the process of echolocation. They have the ability to select individual prey items and use echolocation for foraging and navigation purposes.

Fossil records dating back to the Middle Eocene, show cetaceans existing more than 50 million years ago (Fordyce, 2002). Cetaceans evolved from terrestrial ancestors and formed lineages through a long-term change in structure based on adaptations to the aquatic environment. The evolution of Cetacea was potentially influenced by the physical evolution of the oceans with emphasis on the global distribution and abundance of food resources and geographical changes in habitat.

Cetaceans have evolved to exploit virtually all productive marine, estuarine, and many riverine habitats. Many cetaceans feed upon fish, squid or crustaceans in pelagic waters. Several species undergo seasonal north-south migrations that track peaks in prey availability, but others may reside year-round in areas bounded by tens of kilometers.

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 several hundred years. The reduction in population abundance causes need for concern towards the potential risk of extinction. The ESA, along with CITES and IUCN, designate a protected status generally based on natural or manmade factors affecting the continued existence of species.

Cetaceans are generally long-lived with estimates of longevity ranging from 2 to over 20 decades (George et al., 1999; Chivers, 2002). There are several methods for determining the age of cetaceans. A common method of determining age in mysticetes is by analyzing tissues collected during postmortem examination, examining the growth layers of the horny epithelium which forms on the external surface of the tympanum in the external auditory meatus. However, this method does not work for all cetaceans. Age can also be estimated by counting the oscillations in the stable carbon isotopes in the baleen. However, this method only works for bowhead whales greater than 11 years of age. Another method was developed to determine age by measuring the degree of racemization of aspartic acid, an amino acid in the eye lens and teeth (George et al., 1999). Age determination is important to ascertain if a cetacean is sexually mature. Age of sexual maturity ranges from a few years in smaller species to more than a decade in some larger species. Female cetaceans give birth to a single calf annually every few years, depending on species. Long maturation intervals and low annual reproductive capacity limit the ability of cetaceans to recover from depressed population levels.

Social systems range from relatively solitary to large social groups. Whales form aggregations for feeding, protection, and for social reasons. The size of the aggregations may correlate with resource availability and predation pressure (Balance, 2002).

Hearing and sound production is highly developed in all cetacean species studied to date. Cetaceans rely heavily on sound and hearing for communication and sensing their environment (Norris, 1969; Watkins and Wartzok 1985; Frankel, 2002). 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 of most cetacean species (Ketten, 1994).

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. The function of sound production is not completely understood, but may be used for communication, navigation and food finding in some species (Ellison et al., 1987; George et al., 1989; Clark, 1994; Tyack and Clark, 1997; Clark and Ellison, 2004).

3.2.4.1 Mysticete Species

The mysticetes, which potentially could be affected by SURTASS LFA sonar, include four families containing 12 species. Of the 12 species, 11 species will be considered for evaluation (see text box below). Mysticetes can be distinguished by their lack of functional teeth and paired blowholes. Baleen whales include the largest animal ever to live on earth, the blue whale, which can reach over 30 m (100 ft) in length and 170 tons (154,221 kg) in weight (Bannister, 2002).

All mysticetes produce low frequency sounds, although no direct measurements of auditory (hearing) thresholds have been made (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. However, it is not known if mysticete low-frequency sounds are used for other functions such as orientation, navigation, or detection of predators and prey.

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 1,000 Hz (Ketten, 2000).

Table 3.2-3 provides species-specific information on the protected status (according to the ESA, CITES, and IUCN), distribution, abundance, diving behavior, hearing and sound production of mysticetes.

Mysticetes

Family: Balaenopteridae (Rorquals)
Blue whale (*Balaenoptera musculus*)
Fin whale (*B. physalus*)
Sei whale (*B. borealis*)
Bryde's whale (*B. edeni*)
Minke whale (*B. acutorostrata*)
Humpback whale (*Megaptera novaeangliae*)

Family: Eschrichtiidae
Gray whale (*Eschrichtius robustus*)

Family: Balaenidae (Right whales)
North Atlantic right whale (*Eubalaena glacialis*)
North Pacific right whale (*E. japonica*)
Southern right whale (*E. australis*)

Family: Neobalaenidae
Pygmy right whale (*Caperea marginata)*

Balaenopteridae (Rorquals)

The family Balaenopteridae contains five whales of the genus *Balaenoptera*: blue whale (*B. musculus)*, fin whale (*B. physalus*), Bryde's whale (*B. edeni*), sei whale (*B. borealis*) and minke whale (*B. acutorostrata*). The humpback whale (*Megaptera novaeangliae*) is also part of Balaenopteridae. Balaenopterids are also known as "rorquals" (Bannister, 2002).

The **blue whale (*Balaenoptera musculus*)** is currently 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 about 11,200-13,000 individuals (Maser et al., 1981; U.S. Department of Commerce, 1983). The most recent regional stock assessments estimate approximately 1,500 animals in the eastern North Pacific (Carretta et al., 2005) and 300 animals in the western North Atlantic (Waring et al., 2002).

Blue whales occur in all oceans of the world. They are primarily pelagic but are often found along continental shelf breaks during feeding (Yochem and Leatherwood, 1985; Sigurjonsson, 1995). Traditionally, it was assumed that distribution and movement patterns consisted of seasonal migrations between higher latitudes for foraging and lower latitudes for mating and calving (Mackintosh, 1965; Lockyer, 1984). However, data from the Pacific indicate that some summer feeding takes place at low latitudes in "upwelling-modified" waters and that some whales remain year-round in low latitudes (Yochem and Leatherwood, 1985; Reilly and Thayer, 1990; Clark and Charif, 1998). No specific breeding areas are known for this species.

NMFS reported on one blue whale population that feeds in California waters from June through November and migrates south to waters off Mexico and as far south as the Costa Rica Done (10 deg N) in the winter and spring. The best estimate of abundance for this blue whale population is

1,744 individuals. The minimum population estimate is 1,384 (National Marine Fisheries Service, 2005).

Similar to the report from NMFS, Calambokidis and Barlow (2004) report that blue whales feed off of California from May through November and migrate to waters off Mexico as far as 6 deg N at the Costa Rica Dome in the winter and spring. Blue whales can be found year-round at the Costa Rica Dome and in the Eastern Tropical Pacific. However, it is unknown if there are any non-migratory population segments of the blue whales at the Costa Rica Dome. The estimated summer abundances using the capture-recapture method for the California, Oregon, and Washington study area were highly variable, ranging from 525 to 1,244 individuals. However, these estimates seem low compared to abundance estimates from past years. Estimates based on pooled three-year periods with one sample from systematic surveys that covered both coastal and offshore waters showed more realistic abundance estimates ranging from 1,167 to 2,357 individuals. The estimated summer abundance using the line-transect method for the California, Oregon, and Washington study area is 3,000 individuals (Calambokidis and Barlow, 2004).

The swimming and diving behavior of blue whales has been relatively well characterized. The average surface speed for a blue whale is 4.5 km/h (2.4 knots) (with a maximum speed of 7.2 km/h (3.9 knots) (Mate et al., 1999). Dive times range from 4 to 15 min (Laurie, 1933; Croll et al., 2001b). Dive depths average 140 m (460 ft). Blue whales typically make 5 to 20 shallow dives at 12 to 20-second intervals followed by a deep dive of 3 to 30 min (Yochem and Leatherwood, 1985; Croll et al., 1999). The dive depth of foraging blue whales averages 67.6 m (222 ft) (Croll et al., 2001b). Blue whales foraging off California were found to have a mean dive duration ranging from 4 to near 10 min (Strong, 1990). Blue whales feed almost exclusively on euphausiids, or krill (Fiedler et al., 1998; Sears, 2002).

There is no direct measurement of auditory threshold for the hearing sensitivity of blue whales (Ketten, 2000; Thewissen, 2002). In one of the only studies to date, no change in blue whale vocalization pattern or movement relative to an LFA sound source was observed for RLs of 70 to 85 dB (Aburto et al., 1997).

Blue whales produce a variety of LF sounds in a 10 to 200 Hz band (Edds, 1982; Thompson and Friedl, 1982; Alling and Payne, 1991; Clark and Fristrup, 1997; Rivers, 1997; Stafford et al., 1998, 1999a, 1999b; Stafford et al., 2001; Frankel, 2002). These low frequency calls may be used as communicative signals, as it is difficult to determine actual demonstrations of communication in the strict sense of the term (McDonald et al., 1995). Short sequences of rapid frequency-modulated (FM) calls below 90 Hz are associated with animals in social groups (Moore et al., 1999; Mellinger and Clark, 2003). The most typical signals are very long, patterned sequences of tonal infrasonic sounds in the 15 to 20 Hz range. The seasonality and structure of the sounds suggest that these are male song displays for attracting females and/or competing with other males.

Blue whales produce long, patterned hierarchically organized sequences of sounds (song). These occur throughout mose of the year with peak period of singing overlapping with the general period of functional breeding. Blue whales also produce a variety of transient sound (that is, 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), which 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).

Croll et al. (2001a) studied the effects of anthropogenic low-frequency noise on the foraging ecology of blue and fin whales off San Nicolas Island, California. Blue and fin whales produce long, intense patterned sequences of signals in the band of 10 to 100 Hz. These signals have been recorded over ranges of hundreds of miles. This study examined the response of blue and fin whales to human-produced low-frequency sounds at RLs greater than 120 dB produced by SURTASS LFA sonar. The blue and fin whale sightings did not appear to be randomly distributed and did not appear to be related to the sound source. No clear trends appeared in vocalization rates. There was no significant change in vocal activity in the study area or obvious responses of blue or fin whales in the presence of low frequency sound. It is possible that the brief interruption of normal behavior or short-term physiological responses to LF noise at RLs of approximately 140 dB have few implications on survival and reproductive success. Long-term effects, however, could have more significant effects, but these effects are harder to identify and quantify (Croll et al.,2001a).

The call characteristics of blue whales vary geographically and seasonally (Stafford et al., 2001). In temperate waters, intense bouts of long, patterned sounds are very common from fall through spring, but these also occur to a lesser extent during the summer in high latitude feeding areas. The blue whale is one of the loudest baleen whales with estimated SLs as high as 180 to 190 dB (Cummings and Thompson, 1971; Aroyan et al., 2000).

The **fin whale** (***Balaenoptera physalus***) is listed endangered under the ESA, depleted under the MMPA, protected under CITES, and classified as endangered by the IUCN. The global population estimate is about 100,000-150,000 (Maser et al., 1981; U.S. Department of Commerce, 1983). Recent regional stock assessments report approximately 2,500 animals in the eastern North Pacific and 2,800 animals in the western North Atlantic (Waring et al., 2004; Carretta et al., 2005).

Fin whales are widely distributed and found in all oceans of the world. They are primarily found in temperate and cold waters with animal densities slightly higher on the outside of the continental slope than inside. Like blue whales, it is assumed that distribution and movement patterns consist of seasonal migrations between higher latitudes for foraging and lower latitudes for mating and calving (Mackintosh, 1965; Lockyer, 1984). Panigada (1999) studied fin whale distribution in the Ligurian Sea. The study primarily covered the continental shelf and the offshore waters of the Western Ligurian Sea which maintains low surface temperatures and enhances strong up-welling currents. Whales were found to aggregate in small groups. The whales appeared to be evenly distributed in the study area to exploit food resources (Panigada, 1999). Specific breeding areas are unknown and mating is assumed to occur in pelagic waters, presumably some time during the winter when whales are in mid-latitudes. Foraging grounds tend to be near coastal upwelling areas and recent data indicate that some whales remain year-round at high latitudes (Clark and Charif, 1998).

Swimming speeds average between 1 to 16 km/h (Watkins, 1981). Fin whales have a mean dive time of 4.2±1.67 min at depths averaging 60 m (197 ft) (Panigada, 1999; Croll et al., 2001a). Maximum dive depths have been recorded deeper than 360 m (1,181 ft) (Charif et al., 2002). Similar to blue whales, fin whales typically make 5-20 shallow dives at 13-20 second intervals, followed by a deep dive of 1.5-15 min (Strong, 1990; Croll et al., 1999). Fin whales forage at dive depths close to 100 m (328 ft) deep. Foraging dive times range from 5 to 8 min and fin whales feed primarily upon planktonic crustaceans (particularly euphausiids), fish and squid (Gambell, 1985a; Aguilar, 2002).

There is no direct measurement of auditory threshold for the hearing sensitivity of fin whales (Ketten, 2000; Thewissen, 2002).

Fin whales produce a variety of LF sounds in the 10 to 200 Hz band (Watkins, 1981; Watkins et al., 1987; Edds, 1988; Thompson et al., 1992). Short sequences of rapid FM calls in the 20-70 Hz band are associated with animals in social groups (Watkins, 1981; Edds, 1988; McDonald et al., 1995). The most typical signals are long, patterned sequences of low and infrasonic pulses in the 18-35 Hz range (Patterson and Hamilton, 1964; Watkins et al., 1987; Clark et al., 2002). This sound is referred to as a “20-Hz pulse.” The seasonality of the pattern of bouts suggests that these are male reproductive displays or displays associated with food resources (Watkins et al., 1987; Clark et al., 2002; Croll et al., 2002) while the individual counter-calling sounds suggest that the more variable calls are contact calls (McDonald et al., 1995).

Croll et al. (2001a) studied the effects of anthropogenic low-frequency noise on the foraging ecology of blue and fin whales off San Nicolas Island, California. This study is described above in the blue whale section.

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 very 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 fins also produce higher frequency down sweeps ranging from 100 to 30 Hz (Frankel, 2002). Estimated SLs are as high as 180 to 190 dB (Patterson and Hamilton, 1964; Watkins et al., 1987; Thompson et al., 1992; McDonald et al., 1995; Charif et al., 2002; Croll et al., 2002).

The **sei whale** (***Balaenoptera borealis***) is currently endangered under the ESA, depleted under the MMPA, protected under CITES, and classified as endangered by the IUCN. Allen (1980) estimated the abundance of sei whales as 14,000 for the North Pacific and 37,000 for the Southern Hemisphere populations. The status of the North Atlantic population is estimated at near 10,000 in the central and northeastern Atlantic Ocean (Horwood, 2002).

Sei whales are primarily found in temperate zones of all oceans. As with other members of the family *Balaenopteridae*, they are assumed to migrate to the subpolar higher latitudes where they feed during the late spring through early fall and then migrate to lower latitudes where they breed and calve during the fall through winter (Mackintosh, 1965; Lockyer, 1984). 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 California to the Gulf of Alaska in the east and from Japan to the Bering Sea in the west. Specific breeding grounds are not known for this species.

Swim speeds have been recorded at 4.6 km/h (2.5 knots). Dive times range from 0.75 min 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, 1985b). They feed predominantly on copepods in the higher latitudes and schooling fish in the lower latitudes (Jonsgård and Darling, 1977; Rice, 1977; Nemoto and Kawamura, 1977; Kawamura, 1994; Sigurjonsson, 1995).

There is no direct measurement of auditory threshold for the hearing sensitivity of sei whales (Ketten, 2000; Thewisson, 2002).

Few sounds have been recorded from sei whales. Knowlton et al. (1991) and Thompson et al. (1979) recorded rapid sequences of FM pulses in the 1.5 to 3.0 kHz range near groups of feeding sei whales during the summer off eastern Canada. Seasonal and geographical differences and sound level range have not been identified for sei whales.

The **Bryde's whale (*Balaenoptera edeni*)** is currently protected under CITES and classified as a data deficient species by the IUCN. In the western North Pacific, abundance estimates are approximately 24,000 (IWC, 1997). Estimates for Bryde's whales occurring in eastern tropical Pacific waters are 13,000 (Wade and Gerrodette, 1993). Fifty six whales were sighted in the northern Gulf of Mexico in 2003 (Waring et al., 2004). Population estimates for most other regions are not available.

Bryde's whales are found in low densities throughout the tropical and subtropical waters of the world (Omura, 1959; Kato, 2002). They are most commonly encountered in waters between 40 deg N and 40 deg S latidude, with average water temperatures of 16.3 deg C (61.3 deg F) (Kato, 2002). 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 have also been known to breed off South Africa (Best, 1960; 1975). Foraging grounds are not well known for this species.

The swim speed of a Bryde's whale has been recorded at 20 km/h (10.8 knots) (Cummings, 1985), and they dive for as long as 20 min, although dive depths are not known. Bryde's whales feed primarily on euphausiids, copepods, and schooling fish such as sardines, herring, pilchard, and mackerel (Best, 1960; Nemoto and Kawamura, 1977; Cummings, 1985; Tershy, 1992; Tershy et al., 1993).

There is no direct measurement of auditory threshold for the hearing sensitivity of Bryde's whales.

Bryde's whales are known to produce a variety of LF sounds in the 20 to 900 Hz band (Cummings, 1985; Edds et al., 1993; Olson et al., 2003), and animals off California produce moaning sounds concentrated at 124 to 250 Hz. A pulsed moan has also been recorded in frequencies ranging from 100 to 900 Hz. Olson 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 700-900 Hz (Edds et al., 1993). The function of these sounds is unknown, but is assumed to be used for communication. SLs range between 152 to 174 dB (Frankel, 2002).

The **minke whale (*Balaenoptera acutorostrata*)** is protected under CITES and classified as IUCN lower risk/near threatened species. Populations are estimated at 200,000 in the Southern Hemisphere. Minke whale population estimates range from 60,500 to 186,000 (best estimate 113,000) in the North Atlantic and 17,000 to 28,000 in the North Pacific. Regional stock assessments report approximately 4,000 animals off the Canadian east coast and 1,015 animals of the coasts of California, Oregon, and Washington (Waring et al., 2004; Carretta et al., 2005). NMFS (2003) estimates that there are 1,015 minke whales (based off of surveys from 1996 through 2001) off the coasts of California, Oregon, and Washington, with a minimum estimate of 585 (National Marine Fisheries Service, 2003).

Three stocks of minke whales are recognized in the North Pacific by the IWC. The first stock is the Sea of Japan/East China Sea stock, the second is the western Pacific stock, west of 180 deg longitude, and the third is referred to as the "remainder" stock. 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 shelves, 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. Minke whales occur year-round off California and in the Gulf of California. They are also present in the summer and fall along the Baja California peninsula (National Marine Fisheries Service, 2003).

Minke whales are difficult to sight, as they produce small blows that are not easily observed. They are typically pelagic and encountered in small groups, but are found throughout all oceans of the world, particularly in the North Atlantic (Stewart and Leatherwood, 1985). As with other balaenopterids, minke whales migrate to higher latitudes where they feed during the late spring through early fall and to lower latitudes where they breed during the fall through winter. Breeding appears to take place during the winter in warmer waters, but the exact breeding locations are poorly known (Kasamatsu et al., 1995; Perrin and Brownell, 2002).

Normal swimming speeds have been reported as 6.1 km/h (3.3 knots) (Lockyer, 1981). Dive times range from 1.5 to 7 min (Stewart and Leatherwood, 1985), but dive depths are not well known. Minke whales generally feed on small schooling fish, euphausiids, and copepods. They specialize their diet both seasonally and geographically based on prey availability (Stewart and Leatherwood, 1985).

There is no direct measurement of auditory threshold for the hearing sensitivity of Bryde's whales (Ketten, 2000; Thewisson, 2002).

Minke whales produce a variety of sounds, primarily moans, clicks, downsweeps, ratchets, thump trains, and grunts in the 80 Hz to 20 kHz range (Winn and Perkins, 1976; Thompson et al., 1979; Edds-Walton, 2000; Mellinger and Clark, 2000; Frankel, 2002). 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 200 Hz band (Winn and Perkins, 1976). Complex vocalizations recorded from Australian minke whales involved pulses ranging between 50 and 9,400 Hz, followed by pulsed tones at 1,800 Hz and tonal calls shifting between 80 and 140 Hz (Gedamke et al., 2001)

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-second 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 seconds. Similar sounds with a frequency range from 396 to 42 Hz have been recorded in the St. Lawrence Estuary (Edds-Walton, 2000 *in* Gedamke et al., 2001).

Short, mid-frequency clicks with energy between 3 and 12 kHz for 1 to 20 ms were recorded in the presence of one animal south of Newfoundland (Beamish and Mitchell, 1973 *in* Gedamke et al., 2001); however, these sound may have been produced by an unseen species (Gedamke et al., 2001).

Gedamke et al. (2001) described vocalizations of the dwarf minke whale in the winter months just north of the Great Barrier Reef in Australia, where they are generally found from May to September. Gedamke et al. (2001) reports the dwarf minke whale making a complex and stereotyped sound sequence which is referred to as the "star wars" vocalization. The measurements of transmission loss produced an empirical equation of 18 log (R). The broadband (100 Hz to 10 kHz) RLs of three units of the sequence reached 145 dB. SLs of between 150 and 165 dB were calculated.

The function of the sounds produced by minke whales is unknown, but they are assumed to be used for communication such as maintaining space among individuals (Richardson et al., 1995).

The **humpback whale (*Megaptera novaeangliae*)** is listed as endangered under the ESA, depleted under the MMPA, protected under CITES, and classified as vulnerable by the IUCN. Population estimates for the North Pacific stocks are 1,300 in the eastern North Pacific and 4,000 in the central North Pacific (Carretta et al., 2002; Carretta et al., 2005). Estimates for the Southern Hemisphere population south of 30 deg S are on the order of 13,000 to 15,000 (Butterworth et al., 1993). The best estimate for the North Atlantic population is 10,600 (Smith et al., 1999).

Humpback whales are distributed throughout the world's oceans. Primarily a coastal species in which most populations travel over deep pelagic waters during migrations, humpback whales typically feed at higher latitudes and breed at lower latitudes. Almost all feeding occurs during the late spring through early fall in mid-to-high-latitude areas in shallow coastal waters or near the edge of a continental shelf. Calving takes place in shallow waters in isolated tropical areas from late fall through late winter. Breeding is assumed to take place in or near these calving areas during the same period. 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).

Calambokidis and Barlow (2004) reported on the abundance of humpback whales in the eastern North Pacific. Humpback whales that feed off of California, Oregon, and Washington migrate seasonally to wintering grounds off Baja California and mainland Mexico. Photographic identification data showed a separation of populations of humpback whales that feed from California to southern Washington and those that feed off British Columbia and Alaska. Using the capture-recapture method of estimation, the abundance of humpback whales in the California, Oregon, and Washington study area is estimated to range from 569 to 914 individuals. The estimated humpback whale abundance, using the line-transect method of estimation, in the California, Oregon, and Washington study area is 1,000 individuals (Calambokidis and Barlow, 2004).

Barco et al. (2002) reported on humpback whale population identity in the waters off of 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 St. Lawrence, Greenland, Iceland, and Norway. This fidelity is maternally directed and in some areas, is reflected in the genetic structure of the population. 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. Humpback whales have been documented in waters from New Jersey to North Carolina with the majority of sightings from January to April, although some sightings are made in the summer. Results from this study have shown a minimum of 44 individuals in the U.S. mid-Atlantic from 1990 to 2000, although it is possible that some individuals were documented more than once or not at all. Existing data support the hypothesis that humpback whales use the U.S. mid-Atlantic waters primarily during the winter, mixing while migrating from their summer feeding grounds, with some additional occupation of the waters at other times of the year (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; around the main Hawaiian Islands; off the tip of Baja California; and off the Revillagigedo Islands.

Mean swim speeds during migration are near 4.5 km/h (2.4 knots) (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) (Hamilton et al., 1997). Dives on feeding grounds ranged from two to five min (Dolphin, 1987; Croll, et al., 1999). Dive depths average near 40 m (131 ft). Humpbacks eat a wide variety of prey including schooling fish and krill, which are likely found above 300 m (1,000 ft) (Hamilton et al., 1997).

There is no direct measurement of auditory threshold for the hearing sensitivity of humpback whales (Ketten, 2000; (Thewissen 2002). Because of 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 know 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 115-124 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 2002). 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 extend from 50 Hz to more than 10,000 Hz with most energy below 3000 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 have shown to elicit reactions from animals up to 9 km (4.9 nm) 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., 1994; 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 nm) (Au et al., 2000). Singing males are typically solitary and maintain spacing of 5 to 6 km (2.7 to 3.2 nm) apart (Tyack, 1981; Frankel et al., 1994). 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 in 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. The 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 or whales, nor later than November, possibly because the whales 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 the male humpback whales prior to the migration to the winter grounds (Gabriele and Frankel, 2002).

Humpback whale songs have also been recorded off of Cape Cod, Massachusetts. Clark and Clapham (2004) have studied singing on an almost daily basis by humpback whales between May and June in the Georges Bank off of Cape Cod, Massachusetts. Song occurrence decreased in the late spring. There was, however, no pronounced diurnal pattern in the occurrence of singing. Portions of the songs were detectable in the band of 80 to 400 Hz. It is possible that these songs represent an advertisement of males as well as an assessment by females of males. Males may establish a bond in the summer at the feeding grounds which may have a possible pay-off on the breeding grounds in the winter. The songs may also be an intra-sexual display between the males. There is a hypothesis that singing is driven by elevated testosterone levels and, therefore, song would be rare in the mid-summer. Since the detection of songs declined in June, this study is consistent with the hypothesis (Clark and Clapham, 2004).

Balaenidae (Right whales)

Balaenids are also known as “right whales”. The family Balaenidae includes three whales of the genus *Eubalaena*: **North Atlantic right whale (*Eubalaena glacialis*)**, **North Pacific right whale (*E. japonica*)** and **southern right whale (*E. australis*)**.

All right whale species (*Eubalaena spp*.) are listed as endangered under ESA, depleted under the MMPA, and protected under CITES. The North Atlantic and North Pacific right whales are classified as endangered by the IUCN. The southern right whale is classified by the IUCN as lower risk/conservation dependent. Three geographically isolated populations are recognized as separate species. The **North Atlantic right whale** stock **(*Eubalaena glacialis*)** is nearly extinct or extremely endangered with an approximate abundance estimate of about 300. The **North Pacific right whale (*E. japonica*)** has no available abundance estimate. The **southern right whale (*E. australis)*** is located in the Southern Ocean and has the largest abundance, currently estimated at 7,000 (Kenney, 2002). The southern right whale is recovering more successfully than the northern right whale.

Historically, right whales have occurred from temperate to subpolar latitudes. However, due to exploitation, the right whale distribution is limited. Right whales occur around coastal or shelf waters, but are also found over abyssal depths. For most of the year, their distribution is correlated to the distribution of their prey. Whales have been observed calving during the winter in the northern and southern hemispheres in the coastal waters of the lower latitudes and then migrate to the higher latitudes in the spring and summer. Critical habitat is designated in five locations: 1) coastal Florida and Georgia; 2) the Great South Channel, east of Cape Cod; 3) Cape Cod and Massachusetts Bays; 4) the Bay of Fundy; and 5) and Browns and Baccaro Banks, south of Nova Scotia (National Marine Fisheries Service, 2004a).

From late fall to early spring, right whales breed and give birth in temperate shallow areas, migrating 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 extend in distribution primarily between Florida and Nova Scotia (Croll et al., 1999). They calve between the northeast coast of Florida and southeastern Georgia and forage in the Bay of Fundy (IFAW, 2001; Vanderlaan et al., 2003). The North Pacific population is primarily sighted in the Sea of Okhotsk and the eastern Bering Sea. Breeding grounds for this species are unknown. Southern right whales are predominately found off Argentina, South Africa, and Australia (Kenney, 2002). 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 evidence indicating that North Atlantic right whales are losing their genetic variability. The results, in conjunction with behavioral data, which shows that North Atlantic right whales may have reduced fertility, fecundity, and juvenile survivorship, support the hypothesis that inbreeding depression is influencing the recovery of the species (Schaeff et al., 1997).

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 (2.2 mi/hr) while those that remained in the Bay of Fundy had a swim speed average of 1.1 km/hr (0.7 mi/hr). The three whales that did not leave the Bay of Fundy still traveled more than 2,000 km (1,243 mi) each before returning to their original tagging area. Most of the areas traveled by the northern right whales were along bank edges, in basins, or along the continental shelf. Eighty percent of the locations visited by the right whales had water depths greater than 183 m (597 ft). All of these whales were in or near shipping lanes and moved along areas identified as right whale habitat (Mate et al., 1997).

The most obvious social interaction of the North Atlantic right whale is surface active groups (SAGs). They are generally composed of an adult female and two or more males and engage in social behavior near the surface of the water. There is evidence that females make distinct calls while participating in the SAGs. A playback experiment from 1999 to 2001 in the Bay of Fundy showed that of the 36 trials carried out, 27 of 31 SAG playbacks resulted in male whales approaching the recordings (Parks, 2003).

Feeding areas are not well known for the Southern right whale species.
Right whales feed primarily on copepods and occasionally on euphausiids (krill) along coastal areas (Kenney, 2002). Right whales are not regarded as deep divers since they find their prey near the surface (Leatherwood and Reeves, 1983). Average dive times for North Atlantic right whales range between two and seven minutes (CETAP, 1982). The average dive depth was 7.3 m (24 ft) (Winn et al., 1994), although they can dive as deep as 306 m (1,000 ft) (Mate et al., 1992). North Atlantic right whales were recorded diving over 150 m (492 ft) while foraging (Matthews et al., 2001). Maximum dive duration for southern right whales is 20 min (Croll et al. 1999). Information on the dive patterns of North Pacific right whales is unknown.

There is no direct measurement of auditory threshold for the hearing sensitivity of right whales (Ketten, 2000; Thewissen, 2002). However, based on the thickness or width measurements of the basilar membrane from slide samples, their frequency range is estimated to be 10 Hz to 22 kHz, based on established marine mammal models (Parks et al., 2001).

North Atlantic right whales produce LF moans with frequencies ranging from 70 to 600 Hz (Clark, 1982; Matthews et al., 2001; 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). Source levels for North Pacific right whales were not available from these studies.

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).

Parks and Tyack (2005) describe North Atlantic right whale vocalizations from SAGs. Recordings were made of SAGs 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.

Geographic variation is evident in comparing North Atlantic right whale vocalizations to both North Pacific and southern right whale vocalizations. North Pacific right whales produce a call type increasing in frequency from 90 to 150 Hz (McDonald and Moore, 2002). During feeding observations near the eastern Bering Sea, intense bouts of patterned moans were recorded lasting for 5 to 10 min.

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 seconds and are thought to function in long-distance contact (Clark, 1983). Tonal down sweeps are also produced by this species. Sounds are used as contact calls and for communication over distances of up to 10 km (5.3 nm) (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, 2002).

The **pygmy right whale (*Caperea marginata)*** is protected under CITES and classified as lower risk/least concern under IUCN. There are no available data on abundance estimates for this species. It is found only in the Southern Hemisphere between 30 and 60 deg S (Kemper 2002). It has been recorded in coastal and oceanic temperate and sub-Antarctic regions including 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. Mating and calving seasons are unknown (Ross et al., 1975; Lockyer, 1984; Baker, 1985).

Records show this species swims at a speed of 5.4 to 9.4 km/h (2.9 to 5.1 knots) and dives up to 4 min (Kemper, 2002). There is no information available on the dive depths of pygmy right whales. The available literature suggests that copepods and euphausiids make up its diet.

There is no direct measurement of auditory threshold for 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 down sweep in frequency to 60 Hz. No geographical or seasonal differences in sounds have been documented. Estimated SLs were between 153 and 167 dB (Frankel, 2002).

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).

The **gray whale (*Eschrichtius robustus*)** 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 lower risk/conservation dependent under IUCN. Based on the population estimate for the most recent survey taken in 1997-1998, the eastern Pacific stock is approximately 26,600 (Jones and Swartz, 2002).

Gray whales are confined to the shallow waters of the North Pacific ranging from the continental shelf off the Bering and Chukchi seas south to southern Japan in the west, and the tip of Baja California in the east. Every year most of the population makes a large north-south migration from high latitude feeding grounds to low latitude breeding grounds.

The western North Pacific population migrates along Korea, Honshu, Kyushu and the east coast of Japan. The Seto Sea and South China Sea may be potential calving grounds (Jones and Swartz, 2002). Most gray whales in the eastern Pacific breed or calve during the winter in areas of shallow water along southern California (Jones and Swartz, 2002).

Swim speeds during migration average 4.5 to 9 km/h (2.4 to 4.9 knots) and when pursued may reach about 13 km/h (7 knots) (Jones and Swartz, 2002). 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, and the maximum dive depth recorded is 170 m (557 ft) (Jones and Swartz, 2002).

Gray whales are mainly bottom feeders, foraging during the summer and fall in the high latitudes. They feed off the ocean floor over the continental shelves in depths of 4 to 120 m (13 to 394 ft). Prey items primarily consist of benthic invertebrates and crustaceans (Jones and Swartz, 2002). Average dive times of foraging whales are 4–5 min (Rice and Wolman, 1971).

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 nm) from shore. However, this response was extinguished when the source was moved out of their migration path, but with the SL increased to duplicate the animals' RL within their migration corridor (Clark et al., 1999).

Gray whales produce a variety of sounds from 15 Hz to 20 kHz (Dahlheim et al., 1984; Moore and Ljungblad, 1984). 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-

825 Hz (Richardson et al. 1995). Tonal moans are produced during migration in frequencies ranging between 100 and 200 Hz (Jones and Swartz, 2002). 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, 2002). 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 calving/breeding ground. The SLs for these sounds range between 167 and 188 dB (Frankel, 2002).

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. Short-term responses of gray whales to the playback of noise from oil and gas development were studied in 1983 to 1984 in Central California (Malme et al., 1984 *in* Moore and Clarke, 2002), in 1985 near the Bering Sea (Malme et al., 1985 *in* Moore and Clarke, 2002), and in San Ignacio Lagoon, Baja California, Mexico from 1981 to 1984 (Dahlheim, 1987 *in* Moore and Clarke, 2002). The underwater noise sources played during these experiments included helicopter overflights, drillship operations, drilling and production platforms, a semi-submersible drilling rig, and tripping operations. Malme et al. (1984 and 1988) also conducted experiments using air gun arrays and single air guns (*in* Moore and Clarke, 2002). The gray whale responses from the noise playback experiments and from the air gun shots include changes in swimming speed and direction away from the sound sources (Malme et al., 1984 *in* Moore and Clarke, 2002), changes from feeding with a resumption of feeding after exposure (Malme et al, 1988 *in* Moore and Clarke, 2002), changes in call rates and structure (Dahlheim, 1987 *in* Moore and Clarke, 2002), and changes in surface behavior (Moore and Clarke, 2002).

Table 3.2-3. Information Summary for Mysticetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/ Sound Production
Blue Whale (*Balaenoptera musculus*)	ESA endangered; CITES protected; IUCN endangered	- All oceans; along edge of continental shelf in temperate and tropical zones - Higher latitudes in summer, lower latitudes in winter	Global estimates: 11,200 to 13,000 Eastern North Pacific: 1,500 Western North Atlantic: 300	Dive duration: 4-15 min Average dive depth: 140 m Average dive depth during foraging: 67.6 m Average speed: 4.5 km/hr Max speed: 7.2 km/hr Diving intervals of 5-20 shallow dices at 12-20 s followed by deep dives of 3-30 min	Hearing - No direct data available Sound Production frequency range:10-200 Hz signal type: -LF calls from 10-110 Hz -FM calls: < 90 Hz -Songs: 15-20 Hz source levels: 180-190 dB
Fin Whale (*Balaenoptera physalus*)	ESA endangered; CITES protected; IUCN endangered	- All oceans - Higher latitudes in summer, lower latitudes in winter -Temperate and cold waters	Global estimates: 100,000 - 150,000 Eastern North Pacific: 2,500 Western North Atlantic: 2,800	Dive duration: 4.2 ±1.67 min Average dive depth: 60 m Maximum dive depth: 360 m Forage depth: <100 m for 5-8 mi Average swim speed: 1-16 km/hr Diving intervals of 5-20 shallow dices at 12-20 s followed by deep dives of 3-30 min	Hearing - No direct data available Sound Production frequency range: 10-200 Hz signal type: -FM call: 20-70 Hz -Pulses: 18-35 Hz source levels: high as 180-190 dB

Table 3.2-3. Information Summary for Mysticetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/ Sound Production
Sei Whale (*Balaenoptera borealis*)	ESA endangered; CITES protected; IUCN endangered	All oceans; concentrated in temperate zones; - Higher latitudes in summer, lower latitudes in winter -In North Atlantic, located off Nova Scotia and Labrador in the summer and as far south as Florida in the winter - In the North Pacific, range from California to the Gulf of Alaska in the east and from Japan to the Bering Sea in the west	- 14,000 in N. Pacific - 37,000 in Southern Hemisphere - 10,000 in N. Atlantic	Dive duration: 0.75-15 min Average duration: 1.5 min Dive depths: foraging dives 20 to 30 m Duration deep dives: 15 minutes 4.6 km/hr	Hearing - No direct data available Sound Production frequency range: 1.5 – 3.0 kHz signal type: FM pulse source levels: no direct data available
Bryde's Whale (*Balaenoptera edeni*)	IUCN- Data deficient species; CITES protected	- Tropical and subtropical; - Primarily between 40° N and 40° S latitudes in water temperatures of 16.3ºC	- Data unavailable for most regions - Western N. Pacific: 24,000 -Eastern tropical Pacific: 13,000 -Gulf of Mexico: 56 in 2003	Dive duration: up to 20 min Dive depths unavailable Speed: 20 km/hr	Hearing - No direct data available Sound Production frequency range: 20-900 Hz signal type Moans: 124-250. Pulse: 100-900 Hz, and below 69 Hz source levels: 152-174 dB Calves Pulses: 700-900 Hz Source levels 152-174 dB

Table 3.2-3. Information Summary for Mysticetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/ Sound Production
Minke Whale (*Balaenoptera acutorostrata*)	IUCN - lower risk/near threatened species; CITES protected	- All oceans - Higher latitudes in summer, lower latitudes in winter - Found most often in the North Atlantic	NE Atlantic: 60,500-186,000 N. Pacific: 17,000-28,000 Southern Hemisphere: 200,000 Canadian east coast: 4,000 Coasts of California, Oregon, and Washington: 1,015	Dive duration: 1.5-7 min Dive depths unavailable Speed: 6.1 km/hr	Hearing - No direct data available Sound Production frequency range: 80-20,000 Hz Down sweeps from 250 to 50 Hz Signal type Thump trains: 100-200 Hz Pulses: 50-9,400 Hz followed by puses at 1,800 Hz Tonal: 80-140 Hz Rachets: 80-850 Hz Pings/clicks: 3.3-20 kHz Source levels: 150-165 dB re: 1 µPa at 1 m

Table 3.2-3. Information Summary for Mysticetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/ Sound Production
Humpback Whale (*Megaptera novaeangliae*)	ESA endangered; CITES protected; IUCN vulnerable	- All oceans - Higher latitudes in summer, lower latitudes in winter	N. Atlantic: 10,600 Eastern N. Pacific: 1,300 Central N. Pacific: 4,000 Southern Hemisphere: 13,000-15,000	- Dives duration: 3-4 min in Alaska; 3.5 min in Gulf of California Average depth: 40 m Maximum dive depth: 240 m Foraging depth: <300 m for 2-5 min Speed: 4.5 km/h	Hearing - Predicted audiograms: 700 Hz – 10 kHz - Maximum sensitivity at 2-6 kHz Sound Production -frequency range: 20-10,000 Hz -signal type calls: 20-2,000 Hz Dominant frequency: 500 Hz songs: 20-10,000 Hz Social sounds: 50 Hz to 10 kHz with most energy below 3000 Hz Mean source level of a male song: 165 dB
North Atlantic Right Whale (*Eubalaena glacialis*)	ESA endangered; CITES protected; IUCN Endangered	-Primarily in temperate and subpolar waters of North Atlantic ocean -Range from Florida to Nova Scotia	NW Atlantic: Approx. 300	Dive duration: 2-7 min Average dive depth: 7.3 m Maximum dive depth: 306 m Max dive duration: 20 min Not deep divers since they feed on the surface Speed: 1.1-3.5 km/h	Hearing - No direct data available Sound Production frequency range: 70-600 Hz signal type LF calls: 70 Hz source levels: 140-190 dB re: 1 µPa at 1 m

Table 3.2-3. Information Summary for Mysticetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/ Sound Production
North Pacific Right Whale (*Eubalaena japonica*)	ESA endangered; CITES protected; IUCN Endangered	-Primarily in temperate and subpolar waters of North Pacific ocean -Distributed between the Sea of Othotsk and the eastern Bering Sea	N. Pacific: nearly extinct, no estimate	No direct data available Not deep divers since they feed on the surface	Hearing - No direct data available Sound Production frequency range: 90-150 Hz signal type: songs source levels: No direct data available
Southern Right Whale (*Eubalaena australis*)	ESA endangered; CITES protected; IUCN - lower risk/conservation dependent	-Southern Ocean - Found in Argentina, South Africa, and Australia	Global estimate: 7,000	Dive duration: 20 min Average dive depth: no direct data available Not deep divers since they feed on the surface Speed: <11.9 km/h	Hearing - No direct data available Sound Production frequency range: 50-500 Hz with HF near 1,500 Hz signal type: calls source levels: 172-187 dB re: 1 µPa at 1 m

Table 3.2-3. Information Summary for Mysticetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/ Sound Production
Pygmy Right Whale (*Caperea marginata*)	CITES protected; IUCN - lower risk/least concern species	-Temperate waters of S. Hemisphere 30°-60°S -Coastal and oceanic temperate and sub-Antarctic regions including southern Africa, South America, Australia, and New Zealand	No direct data available	Dive duration: 4 min Average dive depth: No direct data available Speed: 5.4-9.4 km/h	Hearing - No direct data available Sound Production frequency range: 60-300 Hz signal type pulses: 90-135Hz with a down sweep to 60 Hz source levels: 153-167 dB re: 1 µPa at 1 m
Gray Whale (*Eschrichtius robustus*)	ESA - Western Pacific population listed as endangered; Eastern Pacific population delisted; CITES protected; IUCN – lower risk/conservation dependent	-Usually in coastal N. Pacific, however during summer feeding seasons may be found far off coast. - From continental shelf off the Bering and Chukchi seas south to southern Japan in the west and the tip of Baja California in the east.	Western Pacific: nearly extinct Eastern Pacific: 26,600	Dive depths: forage on continental shelf at depths of 4-120 m Dive duration: 3-5 min and 7-10 min Maximum dive depth: 170 m Not deep divers Speed: 4.5-9 km/h and up to 13 km/h	Hearing Hearing sensitivity: 800-1500 Hz Sound Production frequency range: 15 Hz-20 kHz signal type knocks/pulses: <100-2 kHz with the most energy at 327-825 Hz moans: 100-200 Hz clicks/grunts: 100-10,000 Hz source levels: 167-188 dB re: 1 µPa at 1 m

Table 3.2-3. Information Summary for Mysticetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/ Sound Production
Source: Richardson et al., 1995; Croll et al., 1999; Rugh, et al, 1999. Evans, 1987; Au et al., 2000; Houser et al. 2001; Olson et al. 2003; Frankel, 2002; Jones and Swarz, 2002; Dahlheim and Ljungblad, 1990.					

3.2.4.2 Odontocetes Species

The odontocetes being evaluated include six families containing over 54 species (see text box below). Odontocetes can be distinguished from mysticetes by the presence of functional teeth and a single blowhole and range in size from the sperm whale at 16 m (52 ft) and 45 tons (40,823 kg) to the harbor porpoise at 1.45 m (4.8 ft) and 50 kg (Bjorge and Tolley, 2002; Whitehead, 2002).

Odontocetes have a broad acoustic range with recent hearing thresholds measuring between 400 Hz and 100 kHz (Richardson et al., 1995; Finneran et al., 2002). Many odontocetes produce a variety of click and tonal sounds for communication and echolocation purposes (Au, 1993). It is generally believed that odontocetes communicate mainly above 1,000 Hz and echolocate above 20 to 30 kHz (Wursig and Richardson, 2002). Little is known about the details of most sound production and auditory thresholds for many species (Frankel, 2002). Table 3.2-4 of the provides species-specific information on the protected status (according to ESA, CITES and IUCN), distribution, abundance, diving behavior, hearing and sound production of odontocetes.

Physeteridae

The family Physeteridae includes a single known genus and species, the sperm whale (*Physeter macrocephalus),* which is the largest species of all the odontocetes (Whitehead, 2002).

The **sperm whale** is currently endangered under the ESA, depleted under the MMPA, classified by IUCN as vulnerable, and classified as protected under CITES. Estimates vary from several hundred thousand worldwide to almost 2 million (Rice, 1989; Reeves and Whitehead, 1997). Survey estimates in the eastern tropical Pacific were 39,200 based on acoustic detection (Carretta et al., 2002). Estimates were 1,400 for the Eastern Pacific, 4,700 for the Northern Atlantic, and 1,350 for the Gulf of Mexico (Carretta et al., 2002; Waring et al., 2004).

Sperm whales are primarily found in deeper ocean waters and distributed in polar, temperate and tropical zones of the world (Reeves and Whitehead, 1997) and have the largest range of all cetaceans except killer whales (Rice, 1989). They are commonly found near the Equator and in the North Pacific (Whitehead, 2002). The migration patterns of sperm whales are not well-studied.

The sperm whale has a prolonged breeding season extending from late winter through early summer. In the Southern Hemisphere, calving season is between November and March (Simmonds and Hutchinson, 1996), although specific breeding and foraging grounds are not well known for this species.

Family: Physeteridae	
Physeter macrocephalus	Sperm whale
Family: Kogiidae	
Kogia breviceps	Pygmy sperm whale
Kogia simus	Dwarf sperm whale
Family: Ziphiidae (Beaked Whales)	
Hyperoodon ampullatus	Northern bottlenose whale
Hyperoodon planifrons	Southern bottlenose whale
Berardius bairdii	Baird's beaked whale
Berardius arnuxii	Arnoux's beaked whale
Ziphius cavirostris	Cuvier's beaked whale
Indopacetus pacificus	Longman's beaked whale
Mesoplodon species	13 species
Tasmacetus shepherdi	Shepherd's beaked whale
Family: Monodontidae	
Delphinapterus leucas	Beluga or white whale
Family: Delphinidae (Dolphins)	
Orcinus orca	Killer whale (orca)
Pseudorca crassidens	False killer whale
Feresa attenuata	Pygmy killer whale
Peponocephala electra	Melon-headed whale
Globicephala macrorhynchus	Short-finned pilot whale
Globicephala melas	Long-finned pilot whale
Grampus griseus	Risso's dolphin
Delphinus delphis	Common dolphin (short beaked)
Delphinus capensis	Common dolphin (long-beaked)
Lagenodelphis hosei	Fraser's dolphin
Steno bredenansis	Rough-toothed dolphin
Stenella attenuata	Pantropical spotted dolphin
Stenella clymene	Clymene dolphin
Stenella coeruleoalba	Striped dolphin
Stenella frontalis	Atlantic spotted dolphin
Stenella longirostris	Spinner dolphin
Tursiops truncatus	Bottlenose dolphin
Lagenorhynchus acutus	Atlantic white-sided dolphin
Lagenorhynchus albirostris	White-beaked dolphin
Lagenorhynchus australis	Peale's dolphin
Lagenorhynchus cruciger	Hourglass dolphin
Lagenorhynchus obliquidens	Pacific white-sided dolphin
Lagenorhynchus obscurus	Dusky dolphin
Lissodelphis borealis	Northern right whale dolphin
Lissodelphis peronii	Southern right whale dolphin
Cephalorhynchus commersonii	Commerson's dolphin
Cephalorhynchus eutropia	Black or Chilean dolphin
Cephalorhynchus heavisidii	Heaviside's dolphin
Cephalorhynchus hectori	Hector's dolphin
Family: Phocoenidae (Porpoises)	
Phocoena phocoena	Harbor porpoise
Phocoenoides dalli	Dall's porpoise

Swim speeds of sperm whales range from 1.25 to about 4 km/h (0.7 to 2.2 knots) (Jaquet et al., 2000; Whitehead, 2002). Dive durations range between 18.2 to 65.3 min (Watkins et al., 2002). Sperm whales may be the longest and deepest diving mammals, having been recorded diving for over 2 hours to depths of 3,000 m (9,842 ft) (Clarke, 1976; Watkins et al., 1985). 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 et al., 1989; Wahlberg, 2002). Sperm whales mostly feed on squid, but also include demersal and mesopelagic fish in their diet, although, their feeding habits are region-specific (e.g., Iceland) (Reeves and Whitehead, 1997; Whitehead, 2002).

Recent audiograms measured from a sperm whale calf resulted in an auditory range of 2.5 to 60 kHz, 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; Thode 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 (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, 2002). SELs of clicks have been measured between 202 and 236 dB (Madsen and Møhl, 2000; Mohl et al., 2000; Thode et al., 2002; Mohl et al., 2003).

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. 2000). Mohl et al. (2003) further described the directionality of the clicks and that 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).

Thode et al. (2002) reported on depth-dependent acoustic features of diving sperm whales in the Gulf of Mexico. The correlation between the sperm whale's depth and inter-click interval is a characteristic behavioral pattern of other echolocating animals when they are getting close to a target. The returns were always detected when the animal was descending toward the ocean bottom, but were never detected once the animal initiated what was presumed to be foraging behavior. Even during the initial descent phase, the detection of bottom returns was sporadic. After long periods during which only direct and surface-reflection paths were recorded, the bottom returns often faded within seconds, with a 10-dB increase in signal energy that is typically accompanied by energy variation in the direct signal arrival of less than 3 dB. These observations suggest that sperm whale signals have directional properties (Thode et al., 2002).

Zimmer et al. (2005b) discuss the three-dimensional beam pattern of regular sperm whale clicks. Regular clicks have several components by which the whale produces a narrow, high-frequency sonar beam to search for prey, a less-directional backward pulse which provides orientation cues, and a low-frequency component of low directionality which 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 a 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. (2005b) propose that the initial backward pulse is produced by the phonic lip and activates air volumes connected to the phonic lips, which generates the low-frequency component. The two dominant frequencies in the low-frequency component indicate either one resonator with aspect-dependent radiation patterns or that two resonators exist with similar volumes at the surface but different rates at which the volumes are reduced by increasing static pressure. 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, 2002)**.** Abundance estimates of the global population size is unknown. However, there are estimates for specific geographic regions. Wade and Gerrodette (1993) derived an abundance estimate of 11,200 (CV=0.294) for the dwarf sperm whale in the eastern tropical Pacific (ETP). The best estimate for the California/Oregon/Washington pygmy and dwarf sperm whale stock is 247 (CV=1.06) with the minimum abundance estimate of 120 (Carretta et al., 2005).

Pygmy and dwarf sperm whales are distributed worldwide, primarily in temperate to tropical deep waters from 40°S to 60°N. They are especially common along continental shelf breaks (Evans, 1987; Jefferson et al., 1993). Dwarf sperm whales have generally been sighted in warmer waters than pygmy sperm whales (Caldwell and Caldwell, 1989). Breeding areas for both species include waters off of Florida (Evans, 1987). There is little evidence of whether pygmy and dwarf sperm whales have a seasonal migration pattern (McAlpine, 2002).

Swim speeds vary and were found to reach up to 11 km/h (5.9 knots) (Scott et al., 2001). In the Gulf of California, *Kogia* species have been recorded with an average dive time of 8.6 min and a maximum dive time of 43 min for dwarf sperm whales in the Gulf of Mexico (Breese and Tershy, 1993; Willis and Baird, 1998). *Kogia* spp. consume a variety of cephalopod species and occasionally feed on fish and crustaceans (McAlpine, 2002).

There are sparse data on the hearing sensitivity for pygmy sperm whales. An auditory brainstem response 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).

Recent recordings from captive pygmy sperm whales indicate that they produce sounds between 60 and 200 kHz with peak frequencies at 120-130 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 a LF sweep between 1,300 and 1,500 Hz from a captive pygmy sperm whale in Hawaii. Richardson et al. (1995) reported pygmy sperm whale frequency ranges for clicks to be between 60 and 200 kHz with the dominant frequency at 120 kHz. No geographical or seasonal differences in sounds have been documented. Estimated source levels were not available.

Ziphiidae (beaked whales)

The family Ziphiidae is divided into two subfamilies (Ziphiinae and Hyperoodontinae) containing twenty species of whales in five genera (Mead, 2002a). Ziphiidae are not listed under the ESA, MMPA or IUCN, but are protected under CITES.

Subfamily Ziphiinae

In the subfamily Ziphiinae, *Berardius* spp. includes Baird's beaked whale (*Berardius bairdii)* and Arnoux's beaked whale (*B. arnuxii*). In the genus *Tasmacetus* spp., there is one species,, Shepherd's beaked whale, (*T. shepherdi*). One species of *Ziphius* spp. exists, Cuvier's beaked whale (*Z. cavirostris*).

Both the **Baird's (*Berardius bairdii)*** and **Arnoux's beaked whales (*B. arnuxii*)** are currently classified as lower risk status by IUCN. Abundance estimates of the global population size for either species is unknown. In the northwest Pacific, Baird's beaked whales are estimated near 7,000 (Kasuya, 2002). During the summer and fall of 1991, 38 Baird's beaked whales were recorded off California (Barlow, 1995). The minimum abundance estimate in the eastern North Pacific (California, Oregon, and Washington waters) is 228 Baird's beaked whales (Carretta et al., 2005).

Arnoux's beaked whales are distributed around Antarctic waters and have been sighted near northern New Zealand, South Africa, and southeastern Australia (Ponganis and Kooyman, 1995). Baird's beaked whales occur in the North Pacific ranging from the continental shelf off the Bering and Okhotsk seas south to southern Japan in the west and northern Baja California in the east (Kasuya, 1986; Kasuya, 2002). 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 have only been documented to have an inshore-offshore movement off California beginning in July and ending in September through October (Dohl et al., 1983). 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. They primarily feed on benthic fish and cephalopods (Kasuya, 2002). Arnoux's beaked whales have only been found to feed on squid. No foraging dive data are available for *Berardius* spp.

Ohizumi et al. (2002) reports that Baird's beaked whales migrate to the coastal waters of the western North Pacific and the southern Sea of Okhotsk in the summer. Few analyses have been conducted on their stomach contents. In this study, most of the whales had little in their stomachs. The prey items mostly found were rat-tail fish, and hakes, but also mesopelagic and deep-sea squids, unidentified crabs. However, the crabs were also found in the stomachs of prey fish which suggests that the crabs were secondarily introduced. The abundance of demersal fish found in the whales' stomachs suggest that Baird's beaked whales dive to the bottom to forage. Whales were caught at water depths of approximately 1,000 m (3281 ft). However, trawl data and sighting surveys also state that Baird's beaked whales have been observed in waters from 1,000 to 3,000 m (3281 to 9843 ft) deep (Ohizumi et al., 2002).

Swim speeds for ziphiids have averaged 5 km/h (2.7 knots) (Kastelein and Gerrits, 1991). Baird's beaked whales were recorded diving between 15 and 20 min, with a maximum dive duration of 67 min (Barlow, 1999; Kasuya, 2002). 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 depth data are available for either species.

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.

The **Shepherd's beaked whale** (***Tasmacetus shepherdi***) is currently classified as a data deficient species by IUCN. Abundance estimates of this species are not available.

Shepherd's beaked whales are distributed around temperate Antarctic waters. Records show they exist in the waters off Brazil, the Galapagos Islands, New Zealand, Argentina, Australia, and the south Sandwich Islands (Evans, 1987; Mead, 2002b). No data are available to confirm seasonal migration patterns for Shepherd's beaked whales, nor breeding and calving grounds.

General swim speeds for ziphiids have averaged 5 km/h (2.7 knots) (Kastelein and Gerrits, 1991). No data are available on dive times or dive depths of Shepherd's beaked whales. Their diet consists of small squid, euphausiids, crustaceans, and fish; (Mead and Payne, 1975; Evans, 1987).

There is no direct measurement of auditory threshold for the hearing sensitivity of Shepherd's beaked whales (Ketten, 2000; Thewissen, 2002). No literature is available on the sound production of this species.

Cuvier's beaked whale (*Ziphius cavirostris*) is currently classified as a data deficient species by the IUCN. Abundance estimates of the global population size for this species is unknown. A survey estimate for the eastern North Pacific (California, Oregon, and Washington waters) was 1,900 individuals (Carretta et al., 2005). The best data available are from the eastern tropical Pacific with estimates of 90,725 Cuvier's beaked whales (Ferguson and Barlow, 2003).

Cuvier's beaked whales are found in deep, offshore waters of all oceans, from 60 deg N to 60 deg S (Jefferson et al., 1993), but are more common in subtropical and temperate waters than in the tropical and subpolar waters of their range (Evans, 1987). They are common in offshore deep waters near the Mediterranean, British Isles, Caribbean seas, the Sea of Japan, western North America, and off of Hawaii (Omura et al., 1955; Caldwell et al., 1971; Houston, 1991; Blanco and Raga, 2000; Waring et al., 2001; Baird et al., 2004). No data on breeding and calving grounds is available.

Swim speeds of Cuvier's beaked whale have been recorded between 5 and 6 km/h (2.7 and 3.3 knots) (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). Dive depths for this species are inconclusive. Cuvier's beaked whales consume squid and deep-sea fish (Clarke, 1996).

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 have been recorded producing HF clicks between 13 and 17 kHz (Frantzis et al., 2002). These sounds were recorded during diving activity and may be associated with echolocation purposes. There is no available data regarding seasonal or geographical variation in the sound production of Cuvier's beaked whales. Beaked whales are capable of producing SLs of 200 to 220 dB (peak-to-peak) (Johnson et al., 2004).

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 (656.2 ft) of the surface. The Cuvier's beaked whale started clicking at an average depth of 475 m (1,558.4 ft), ranging from 450 to 525 m (1,476 to 1,722 ft), and stopped clicking when they started their ascent at an average depth of 850 m (2,789 ft), with a range of 770 to 1,150 m (2,526 to 3,773 ft). The intervals between regular clicks were approximately 0.4 second. Trains of clicks often end in a rapid increase in the click rate, which is also called a buzz. According to these studies, both the Cuvier's beaked whale and the Blainville's beaked whale have a somewhat flat spectrum that was accurately sampled by Johnson et al. (2004) 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).

Zimmer et al. (2005a) also studied Cuvier's beaked whales and their echolocation clicks. The highest measured SL was 214 dB (peak-to-peak). It is recognized in this study that it is possible that Cuvier's beaked whales cannot produce any higher source levels, but it is more likely that the full capabilities of the Cuvier's beaked whales are underestimated by this study. Therefore, the maximum SL shown in this study may be the result of the whale's reducing the volume when ensonifying at each other (Zimmer et al., 2005a).

Subfamily Hyperoodontinae

The subfamily Hyperoodontinae, *Hyperoodon* spp. includes animals from 3 genuses: *Hyperoodon*, *Indopacetus*, and *Mesoplodon*. The *Hyperoodon* genus is composed of the northern bottlenose whale (*Hyperoodon ampullatus)* and the southern bottlenose whale (*H. planifrons*). Longman's beaked whale (*Indopacetus pacificus*) is the only species in the *Indopacetus* genus. The genus *Mesoplodon* includes 13 species: Bahamonde's beaked whale (*Mesoplodon bahamondi*)[1], Sowerby's beaked whale (*M. bidens*), Andrew's beaked whale (*M. bowdoini*), Hubb's beaked whale (*M. carlhubbsi*), Blainville's beaked whale (*M. densirostris*), Gervais' beaked whale (*M. europaeus*), ginkgo-toothed beaked whale (*M. ginkgodens*), Gray's beaked whale (*M. grayi*), Hector's beaked whale (*M. hectori*), strap-toothed whale (*M. layardii*), True's beaked whale (*M. mirus*), pygmy beaked whale (*M. peruvianus*), and Stejneger's beaked whale (*M. stejnegeri*). Most of the beaked whale species in the family Ziphiidae, including in the subfamily Hyperoodontinae. are poorly known and insufficiently studied.

Northern bottlenose whales (*Hyperoodon ampullatus)* and **southern bottlenose whales (*H. planifrons*)** are currently classified as lower risk conservation dependent status by IUCN. Abundance estimates of the global population size is unknown. The Gully, southeast of Sable Island, Nova Scotia, has approximately 230 northern bottlenose whales (Whitehead et al., 1997). Estimates taken during January show close to 600,000 southern bottlenose whales present south of the Antarctic Convergence (Kasamatsu and Joyce, 1995).

The northern bottlenose whale is found only in the cold temperate-to-subarctic latitudes of the North Atlantic (35 to 80°N). They mostly congregate mostly seaward of the continental shelf in water deeper than 1,000 m (3,300 ft) (Leatherwood and Reeves, 1983; Jefferson et al., 1993). Northern bottlenose whales are commonly found foraging in the Gully, off the coast of Nova Scotia, Canada (Gowans, 2002). There is sparse evidence that this species migrates north in the spring and south in the fall (Leatherwood and Reeves, 1983). Calving and breeding grounds are unknown.

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

[1] Reyes et al. (1995) recently described Bahamonde's beaked whale through phylogenetic analysis of mitochondrial. DNA. This species, which was named in 1996, was recognized as the most recent new cetacean species. However, Van Helden et al., (2002) have shown *Mesoplodon traversii* to be a senior synonym of this recently described species.

Swim speeds for ziphiids have averaged 5 km/h (2.7 knots) (Kastelein and Gerrits, 1991). Hooker and Baird (1999) documented northern bottlenose whales with regular dives from 120 m (394 ft) to over 800 m (2625 ft), with a maximum recorded dive depth of 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, 2002), and the deeper dives of northern bottlenose whales have been associated with foraging behavior (Hooker and Baird, 1999).

There is no direct measurement of auditory threshold for the hearing sensitivity of bottlenose whales (Ketten, 2000; Thewissen, 2002).

Northern bottlenose whales produce echolocation-type clicks between 8 to 12 kHz, whistles between 3 to 16 kHz, and clicks between 500 Hz and 26 kHz (Winn et al., 1970). 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 k Hz 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, and no seasonal or geographical variation is known for the sound production of southern bottlenose whales. Estimated source levels are not documented.

Longman's beaked whale (*Indopacetus pacificus*) is currently classified as data deficient by IUCN. Abundance estimates of this species are not available.

It is believed that Longman's beaked whale is limited to the Indo-Pacific region (Leatherwood and Reeves, 1983; Jefferson et al., 1993). Recent groups of whales sighted in the equatorial Indian and Pacific oceans have tentatively been assigned to this species (Ballance and Pitman, 1998; Pitman et al., 1998). No data is available to confirm seasonal migration patterns for Longman's beaked whales. No data of breeding and calving grounds is available.

General swim speeds for ziphiids have averaged 5 km/h (2.7 knots) (Kastelein and Gerrits, 1991). No data is available on dive times or dive depths of Longman's beaked whales. There is no literature available on the diet of this species.

There is no direct measurement of auditory threshold for the hearing sensitivity of Longman's beaked whales (Ketten, 2000; Thewissen, 2002). No literature is available on the sound production of this species.

Species in the genus ***Mesoplodon*** are currently classified with a data deficient status by IUCN. The worldwide population size for all species of *Mesoplodon* spp. are unknown. Estimates of 25,300 in the eastern tropical Pacific 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 3200 whales

(Waring et al, 2004)., and a minimum estimate of 1250 whales was reported in the eastern North Pacific (Carretta et al, 2005).

Mesoplodon whales are distributed in offshore, pelagic waters between 72°N and 60°S (Leatherwood and Reeves, 1983; Jefferson et al., 1993; Wade and Gerrodette, 1993; Carlstrom et al., 1997). Sowerby's beaked whale, Blainville's beaked whale, Gervais beaked whale, and True's beaked whale regularly occur in the North Atlantic (MacLeod, 2000). Ginkgo-toothed beaked whales have been sighted in the northwestern Pacific, Blainville's beaked whale has been recorded in the western North Pacific, and Stejneger's beaked whale is commonly found near the Aleutian Islands (Evans, 1987; Kasuya and Nishiwaki, 1971). The breeding season for Sowerby's beaked whales occurs in late winter or spring (Jefferson et al., 1993). This is the only *Mesoplodon* species for which any information associated with breeding is known.

General swim speeds for ziphiids have averaged 5 km/h (2.7 knots) (Kastelein and Gerrits, 1991). Dives of Blainville's beaked whales averaged 7.47 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.

Mesoplodon whales are deep diving species which consume small cephalopods and bentho-pelagic fish (Sullivan and Houck, 1979; Leatherwood et al., 1988; Mead, 1989; Jefferson et al., 1993; MacLeod et al., 2003). Blainville's beaked whales diving to depths near 900 m (2625 ft) for 20 min or longer are most likely foraging (Leatherwood et al., 1988; Baird et al., 2004).

There is no direct measurement of auditory threshold for the hearing sensitivity of *Mesoplodon* species (Ketten, 2000; Thewissen, 2002). There is sparse data available on the sound production of *Mesoplodon* species.

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, both *in*: Richardson et al., 1995). A stranded Blainville's beaked whale in Florida produced chirps and whistles below 1 kHz up to 6 kHz (Caldwell and Caldwell, 1971a). There are no available data regarding seasonal or geographical variation in the sound production of *Mesoplodon* species.

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 (656.2 ft) of the surface. The Blainville's beaked whale started clicking at an average depth of 400 m (1312.3 ft), ranging from 200 to 570 m (656.2 to 1870.1 ft), and stopped clicking when they started their ascent at an average depth of 720 m (2362.2 ft), with a range of 500 to 790 m (1640.4 to 2591.9 ft). The intervals between regular clicks were approximately 0.4 second. Trains of clicks often end in a rapid increase in the click rate, which is also called a buzz. Both the Cuvier's beaked whale and the Blainville's beaked whale have a somewhat flat spectrum that was accurately sampled by Johnson et al. between 30 and 48 kHz. There may be a slight decrease in the spectrum above 40 kHz, but the 96 kHz sampling rate wa 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 *(Delphinapterus leucas)*. Belugas are also known as “white whales” (O'Corry-Crowe, 2002).

The **beluga** *(Delphinapterus leucas)* is classified as a vulnerable species by the IUCN, and the Cook Inlet stock is a proposed candidate species under the ESA. The worldwide abundance size is estimated near 100,000. Estimates ranging between 12,000 and 14,000 have been documented off Western Greenland.

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 in North America extend from Alaska across the Canadian western arctic to the Hudson Bay (Sergeant and Brodie, 1969). Occasional sightings and strandings occur as far south as the Bay of Fundy (Atlantic). In the Pacific, migratory belugas summer in the Okhotsk, Chukchi, Bering, and Beaufort seas, the Anadyr Gulf, and off Alaska. Other beluga populations reside in Cook Inlet year round (Hansen and Hubbard, 1998; Rugh et al., 1998). Mating is believed to occur primarily in late winter to early spring when most belugas are still on their wintering grounds or on spring migration (O’Corry-Crowe, 2002). Calving season can range from late spring to early summer.

The beluga is not a fast swimmer, with maximum swim speeds estimated between 16 and 22 km/h (8.6 and 11.9 knots) and a steady swim rate in the range of 2.5 to 3.3 km/h (1.3 to 1.8 knots) (Brodie, 1989; O’Corry-Crowe, 2002). 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 minute. Deep dives last for 9 to 18 min, and dive depths range between 300 and 600 m (984 and 1968 ft). In deep waters beyond the continential shelf, belugas may dive in excess of 1000 m (3281 ft), remaining submerged for up to 25 min (O’Corry-Crowe, 2002).

Belugas feed mostly on shallow water fish, but may also consume squid and a variety of crustaceans and euphausiids (Gaskin, 1982). No foraging dive data is available.

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.

Belugas produce tonal calls or whistles in the 260 to 20,000 Hz 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 2002). There are a variety of 50 different call types including “groans”, “whistles”, “buzzes”, “trills” and “roars” (O'Corry-Crowe 2002). 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 et al., 1985, 1987; Au, 1993). There is supportive evidence of geographical variation from distinctive calls used for individual recognition among beluga whales (Bel'kovich and Sh'ekotov, 1990).

Delphinidae

The family Delphinidae includes five subfamilies containing over 30 species of dolphins (Perrin, 1989; LeDuc, 2002).

Subfamily Globicephalinae

The subfamily Globicephalinae contains the killer whale or orca (*Orcinus orca)*, the false killer whale (*Pseudorca crassidens)*, the pygmy killer whale *(Feresa attenuata)*, the melon-headed whale (*Peponocephala electra*), the long-finned pilot whale (*Globicephala melas)* and the short-finned pilot whale (*Globicephala macrorhynchus*).

The **killer whale (*Orcinus orca)*** is classified as lower risk (conservation dependent) by the IUCN. The worldwide abundance size is estimated near 100,000 (Reeves and Leatherwood, 1994). Estimates of 8,500 individuals have been documented in the eastern tropical Pacific (Wade and Gerrodette, 1993). Shipboard surveys in the Antarctic gave a rough estimate of nearly 70,000 killer whales. Two thousand (2000) killer whales have been estimated in the eastern North Pacific Ocean, and 445 whales have been identified in Norwegian waters (Ford, 2002; Carretta et al., 2005). A minimum of 133 killer whales was reported in the Gulf of Mexico (Waring et al, 2004).

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 (Leatherwood and Dahlheim, 1978; Ford, 2002). However, they appear to be more common within 800 km (430 nm) of major continents in cold temperate to subpolar waters (Mitchell, 1975).

Swimming speeds usually range between 6 to 10 km/h (3.2 to 5.4 knots), but they can achieve speeds up to 37 km/h (20 knots) in short bursts (Lang, 1966; LeDuc, 2002). In southern British Columbia and northwestern Washington State, killer whales spend 70 percent 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 recorded range from 1 to 10 min (Norris and Prescott, 1961; Lenfant, 1969; Baird et al., 1998).

Killer whales have perhaps the most diverse food habits of any marine mammal, feeding on a variety of fish species, cephalopods, pinnipeds, sea otters, whales, dolphins, seabirds, and marine turtles (Hoyt, 1981; Gaskin, 1982; Jefferson et al., 1991). In the Bering Sea there is some suggestion that killer whales prey on fish at water depths of 200 to 300 m (660-990 ft) or more (Yano and Dahlheim, 1995a and b).

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 1-20 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, 2002). 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, 2002; Frankel, 2002). 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 whales (*Pseudorca crassidens)* are classified as lower risk (least concern) by the IUCN. The global population for this species is unknown. Estimates of 39,800 have been documented in the eastern tropical Pacific (Wade and Gerrodette, 1993). In the northwestern Pacific, an estimate of near 17,000 has been documented (Miyashita, 1993).

False killer whales are found in tropical to warm temperate zones in deep, offshore waters from 60 deg S to 60 deg N (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, 2002a).There are no available data on specific breeding grounds. Calving season may be considered year-round with a peak in late winter (Baird, 2002a).

False killer whales have an approximate swim speed of 3 km/h (1.6 knots), although a maximum swim speed has been documented as 28.8 km/h (11.9 knots) (Brown et al. 1966; Rohr et al., 2002). No data is available on diving (Baird 2002a). Their diet consists primarily of fish and squid and on occasion, other small odontocetes (Evans and Raga, 2001; Baird, 2002a).

False killer whales hear underwater sounds in the range of <1 to 115 kHz (Johnson, 1967; Awbrey et al., 1988; Au, 1993). Their best underwater hearing occurs at 17 kHz, where the threshold level ranges between 39 to 49 dB RL (Sauerland and Dehnhardt, 1998).

Au et al. (1997) conducted a survey on the effects of the Acoustic Thermometry of Ocean Climate (ATOC) program on false killer whales and on Risso's dolphins, which will be discussed later. The ATOC program broadcast a low-frequency 75-Hz phase modulated, 195 dB SL signal through ocean basin-sized water masses to study ocean temperatures on a global scale. The hearing sensitivity was measured for false killer whales. The hearing thresholds for false killer whales were 140.7 dB RL, plus or minus 1.2 dB for the 75-Hz pure tone signal and 139.0 dB RL plus or minus 1.1 dB for the ATOC signal. The results of this study concluded that small cetaceans, such as false killer whales and Risso's dolphins, swimming directly over the ATOC source do not seem to hear the transmitted sound unless the animals dove to a depth of approximately 400 m (1312 ft). If these animals were at a horizontal range greater than 0.5 km (0.3 mi), the level of the ATOC signal would be below their hearing threshold at any depth. Also, this study indicates that for ranges greater than 0.5 km (0.3 mi), the maximum sound-pressure level above a depth of 560 m (1837.3 ft) is approximately 130 dB RL. As the range increases beyond 2 km (1.2 mi), the sound-pressure level will become progressively lower (Au et al., 1997).

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 between 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 is 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 whales *(Feresa attenuata)* are classified as a data deficient species by the IUCN. They are one of the least known cetacean species. The global population for this species is unknown. Estimates of 39,800 have been documented in the eastern tropical Pacific (Wade and Gerrodette, 1993). An estimated 408 pygmy killer whales was reported in the Gulf of Mexico (Waring et al., 2004).

The pygmy killer whale have been recorded in oceanic tropical and subtropical waters around the world from about 40°S to 40°N (Caldwell and Caldwell, 1971b; Donahue and Perryman, 2002). It is sighted relatively frequently in the eastern tropical Pacific, the Hawaiian Archipelago and off Japan (Leatherwood et al., 1988; Donahue and Perryman, 2002). 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 is not available. No dive data are available. Pygmy killer whales feed on cephalopods and small fish (Donahue and Perryman, 2002). They are also suspected of feeding on small marine mammals (Evans and Raga, 2001).

There is no direct measurement of auditory threshold for the hearing sensitivity of pygmy killer whales (Ketten, 2000; Thewissen, 2002). Little is known of the sound production of this species. One documentation describes pygmy killer whales producing LF “growl” sounds (Pryor et al., 1965).

Melon-headed whales (*Peponocephala electra*) are classified as a lower risk (least concern) species by the IUCN. The global population for this species is unknown. Estimates of 45,400 have been documented in the eastern tropical Pacific (Wade and Gerrodette, 1993). An estimate of 3,451 whales was reported for the Gulf of Mexico (Waring et al., 2004).

The melon-headed whale occurs in pelagic waters near tropical and subtropical climate regions, but records range between 20°S to 20°N (Jefferson and Barros, 1997). Breeding areas and seasonal movements of this species have not been confirmed.

General swim speeds for this species is not available. No data is available on dive depths and dive times of melon-headed whales. 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).

There is no direct measurement of auditory threshold for the hearing sensitivity of 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 8-12 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 for click bursts (Watkins et al., 1997).

Pilot whales include the **long-finned pilot whale (*Globicephala melas)*** and the **short-finned pilot whale (*G. macrorhynchus)*.** Long-finned pilot whales are classified as a lower risk species by the IUCN. The global population for this species is unknown. Estimates of 778,000 and 200,000 exist in the northeast Atlantic and south of the Antarctic Convergence in January, respectively (Olson and Reilly, 2002). An estimate of 14,524 long-finned pilot whales was reported for the western North Atlantic (Waring et al, 2004).

Short-finned pilot whales are classified as a lower risk (conservation dependent) species by the IUCN. The global population for this species is unknown. In the northwest Pacific, abundance estimates are found near 54,000 (Miyashita, 1993). Estimates of 160,000 have been documented in the eastern tropical Pacific (Wade and Gerrodette, 1993). Estimates of 2,388 and 14,524 short-finned pilot whales were reported for the Gulf of Mexico and western North Atlantic, respectively (Waring et al, 2004; Waring et al., 2002).

Pilot whale distribution is wide ranging with short-finned pilot whales having a tropical and subtropical distribution and long-finned pilot whales occurring outside of tropical waters (Olson and Reilly, 2002). There is little overlap in their ranges. Overlaps do occur at about 30^{o} to 40^{o} N in the North Atlantic and at around 35^{o} S in the Southern Atlantic (Evans and Raga, 2001).

Long-finned pilot whales occur off shelf edges in deep pelagic waters and in temperate and subpolar zones from 20° to 75°N and from 5° to 70°S, 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 which may be correlated to breeding season lasting from May to November (Nelson and Lien 1996; Sergeant 1962).

Short-finned pilot whales are found in warmer waters of temperate and tropical zones of the world from 50°N to 40°S (Leatherwood and Dahlheim, 1978; Kasuya and Marsh 1984). There appears to be little seasonal movement of this species. Some short-finned pilot whales staying year-round near the California Channel Islands while 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/h (1.1 to 6.5 knots) (Shane, 1995). Long-finned pilot whales have an average speed of 3.3 km/h (1.8 knots) (Nelson and Lien, 1996). Short-finned pilot whales have swim speeds ranging between 7 and 9 km/h (3.8 and 4.6 knots) (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). Long-finned pilot whales range in dive depths from 16 m (52 ft) during the day to 648 m (2126 ft) during the night (Baird et al. 2002). The dive times varied between 2 and 13 min. A short-finned pilot whale was recorded as diving to 610 m (2,000 ft) (Ridgway, 1986).

There is no direct measurement of auditory threshold for the hearing sensitivity of either long- or short-finned pilot whales (Ketten, 2000; Thewissen, 2002).

Pilot whales echolocate with a precision similar to bottlenose dolphins and also vocalize with other school members (Olson and Reilly, 2002). Long-finned pilot whales produce sounds as low as 500 Hz and as high as 18 kHz, with dominant frequencies between 1 to 11 kHz (Schevill, 1964; Busnel and Dziedzic, 1966; Taruski, 1979; Steiner, 1981; McLeod, 1986). These sounds include double clicks and whistles with a mean frequency common among this species at 4,480 Hz (Olson and Reilly, 2002; Frankel, 2002). Sound production of long-finned pilot whales are correlated with behavioral state and environmental context (Taruski, 1979; Weilgart and Whitehead, 1990; Frankel, 2002). 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, 2002). There is 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 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). Sounds produced by this species average near 7,870 Hz, higher than that of a long-finned pilot whale (Olson and Reilly, 2002). 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 and Reilly, 2002).

Subfamily Delphininae

The subfamily Delphininae includes Risso's dolphin (*Grampus griseus*), both short-beaked (*Delphinus delphis)* and long-beaked (*Delphinus capensis)* common dolphins, Fraser's dolphin (*Lagenodelphis hosei*) and bottlenose dolphin (*Tursiops truncatus*). The genus, *Stenella* contains five species: pantropical spotted dolphin (*Stenella attenuata),* Clymene dolphin (*Stenella clymene*), striped dolphin (*Stenella coeruleoalba*), Atlantic spotted dolphin (*Stenella frontalis*), and spinner dolphin (*Stenella longirostris*). The genus, *Lagenorhynchus,* contains six species: the Atlantic white-sided dolphin (*Lagenorhynchus acutus*), white-beaked dolphin (*Lagenorhynchus* *albirostris*), Peale's dolphin (*Lagenorhynchus australis*), hourglass dolphin (*Lagenorhynchus cruciger*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) and dusky dolphin (*Lagenorhynchus obscurus)*.[2]

Risso's dolphin (*Grampus griseus*) is classified as a data deficient species by the IUCN. The global population for this species is unknown. In the ETP, estimates of 175, 800 have been documented (Wade and Gerrodette, 1993). Ship surveys give an estimate of approximately 8,500 Risso's dolphins off California (Barlow, 1995). Estimates of 12,748 and 29,110 were reported for the eastern North Pacific and western North Atlantic, respectively (Carretta et al., 2005; Waring et al., 2002).

Risso's dolphin inhabits deep oceanic and continental slope waters from the tropics through the temperate regions from 55°S to 60°N (Leatherwood et al., 1980; Jefferson et al., 1993; Baird, 2002b). They occur predominantly at steep shelf-edge habitats, between 400 and 1000 m (1300 and 3281 ft) deep with water temperatures commonly between 15 and 20°C and rarely below 10°C (Baird, 2002b). 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 is available, and Risso's dolphins have been known to calve year round, peaking in the winter (Baird, 2002b).

Swim speeds from Risso's dolphins were recorded at 2 to 12 km/h (1.1 to 6.5 knots) off Santa Catalina Island (Shane, 1995). Risso's dolphins feed on squid species found more than 400 m (1,300 ft) deep (Gonzalez et al., 1994 *in* Croll et al., 1999). Behavioral research suggests that Risso's dolphins primarily feed at night (Baird, 2002b). There are currently no known studies on diving behavior.

Audiograms for Risso's dolphins indicate their hearing SLs equal to or less than approximately 125 dB in frequencies ranging from 1.6 to 110 kHz (Nachtigal et al, 1995 *in* Nedwell et al., 2004). Phillips et al. (2003) reports that Risso's dolphins are capable of hearing frequencies up to 80 kHz. Best underwater hearing occurs between 4 and 80 kHz with hearing threshold levels from 63.6 to 74.3 dB RL. Hearing thresholds from this study were tested between 1.6 and 110 kHz and were approximately 125 dB down to approximately 65 dB RL (Nachtigall et al., 1995 *in* Croll et al., 1999 and Nedwell et al., 2004). Other audiograms obtained on Risso's dolphin (Au et al., 1997) confirm previous measurements and demonstrate hearing thresholds of 140 dB RL for a one-second 75 Hz signal (Au et al., 1997; Croll et al., 1999).

Au et al. (1997) conducted a survey on the effects of the Acoustic Thermometry of Ocean Climate (ATOC) program on false killer whales and on Risso's dolphins, which will be discussed later. The ATOC program broadcasted a low-frequency 75-Hz phase modulated, 195 dB SL acoustic signal over ocean basins to study ocean temperatures on a global scale. The hearing sensitivity was measured for Risso's dolphins and their thresholds were found to be 142.2 dB RL, plus or minus 1.7 dB for the 75-Hz pure tone signal and 140.8 dB RL plus or minus 1.1 dB for the ATOC signal (Au et al., 1997).

[2] The classification was taken from Perrin (1989) and reflects a traditional view of species interrelationships. This classification is not based on molecular systematic analysis.

Risso's dolphins produce sounds as low as 0.1 kHz and as high as 65 kHz. Their dominant frequencies are between at 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* Croll et al., 1999). 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, 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.

The three **common dolphin species,** the **short-beaked (*Delphinus delphis)*** and **long-beaked (*Delphinus capensis)*,** and the **very long-beaked (*Delphinus tropicalis*),** are classified as lower risk/least concern species by the IUCN. The global population for all species is unknown. Common dolphins are the most abundant species at an estimate of 365,617 short-beaked common dolphins in the eastern Pacific (Carretta et al., 2005). Ship surveys give an estimate of 225,821 short-beaked common dolphins in California (Barlow, 1995). An estimate of 31,000 have been documented in the northwestern Atlantic (Waring et al., 2004). There is little data available on abundance estimates of long-beaked common dolphins. The only regional estimate is from the coast of California at 25,163 long-beaked common dolphins (Carretta et al., 2005).

Short-beaked and long-beaked common dolphins are distributed worldwide in temperate, tropical, and subtropical oceans, primarily along continental shelf and bank regions from about 60°N to 50°S (Perrin, 2002b; Jefferson et al., 1993). They seem to be most common between 40°N to 40°S 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, 2002b). Short-beaked common dolphins occur from southern Norway to West Africa in the eastern Atlantic Ocean (including the Mediterranean and Black Seas), from Newfoundland to Florida in the western Atlantic, from Canada to Chile along the coast and pelagically in the eastern Pacific, and in the central North Pacific (excluding Hawaii) from central Japan to Taiwan. Short-beaked common dolphins are also found around New Caledonia, New Zealand, and Tasmania in the western Pacific, and possibly in the South Atlantic and Indian Oceans. 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, South Africa. There is a possibility that they also occur off Oman in the Indian Ocean. Very long-beaked common dolphins are only known to occur in the northern Indian Ocean and in Southeast Asia.

Seasonal abundance estimates of short-beaked common dolphins in the North Pacific suggests that their migrations north to south, and/or inshore to offshore may vary with oceanographic conditions (Perrin, 2002b). In the eastern Pacific, they primarily occupy upwelling-modified habitats with less tropical characteristics compared to surrounding waters (Perrin, 2002b). Calving peaks during May and June both in the northeastern Atlantic and North Pacific. No breeding grounds are known for common dolphins (Croll et al., 1999).

Swim speeds for *Delphinus* spp. have been measured regularly at 5.8 km/h (3.1 knots) with maximum speeds of 16.2 km/h (8.7 knots) (Hui, 1987). During 7-second intervals, they have been recorded as swimming up to 37.1 km/hr (20 knots) (Croll et al., 1999). Dive depths range between 9 and 200 m (30 and 656 ft), with a majority of dives being 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 (Perrin, 2002b). The deepest foraging dive recorded was 200 m (656 ft) (Evans, 1994 *in* Perrin, 2002b). Common dolphins feed on a variety of prey including mesopelagic fish and squids in the deep scattering layer and on epipelagic schooling species such as small scombroids, clupeoids, and squid (Evans, 1994; Perrin, 2002b). However, their diet varies depending on the region.

Common dolphins produce sounds as low as 0.2 kHz and as high as 150 kHz, with dominant frequencies at 0.5 to 18 kHz and 30 to 60 kHz (Caldwell and Caldwell, 1968; Popper, 1980; Au, 1993; Moore and Ridgway, 1995 *in* Croll et al., 1999). Signal types consist of clicks, squeals, whistles, and creaks (Evans 1994 *in* Croll et al., 1999). Whistles of short-beaked common dolphins range between 7.4 and 13.6 kHz, while long-beaked common dolphins have a frequency range of 7.7 and 15.5 kHz for their whistle production (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*) is classified as a data deficient species by the IUCN. The global population for this species is unknown. Estimates of 289,300 have been documented in the eastern tropical Pacific (Wade and Gerrodette, 1993; Dolar, 2002). An estimate of 726 animals was reported in the Gulf of Mexico (Waring et al., 2004).

Fraser's dolphins occur primarily in tropical and subtropical waters from 50°N to 40°S, although most documentation shows distributions from 30°N to 30°S (Dolar, 2002; Croll et al., 1999). This species is commonly found near central Visayas, Philippines in near-shore waters, along the outer continental shelf, and in deep oceanic waters (Watkins et al., 1994; Leatherwood et al., 1993 *in* Croll et al., 1999), as well as Indonesia and the Lesser Antilles where they can be observed 100 m (328 ft) from shore (Dolar, 2002). They were observed 15 km (9.3 mi) offshore in the eastern tropical Pacific, as well as in the high seas at 45 to 110 km (28 to 68.3 mi) from the coast, where the water depths are between 1500 and 2000 m (4921 and 6562 ft). In the Sulu Sea, Fraser's dolphins were observed in water depths up to 5000 m (16404 ft) and in shallower waters adjacent to the continental shelf. They are more common in the Gulf of Mexico compared to anywhere else, and they are commonly seen in waters with depths around 1000 m (3280.8 ft) (Dolar, 2002). Fraser's dolphins are occasionally seen in the Atlantic Ocean (Watkins et al., 1994). 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, 2002).

Swim speeds of Fraser's dolphin have been recorded between 4 and 7 km/h (2.2 and 3.8 knots) with swim speeds up to 28 km/hr (15 knots) 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 eastern tropical Pacific. 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 (1968.5 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. They feed on mesopelagic fish, crustaceans, and cephalopods, particularly Myctophidae, Chauliodontidae, and Oplophoridae (Croll et al., 1999; Dolar, 2002).

There is no direct measurement of auditory threshold for 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.

The **bottlenose dolphin (*Tursiops truncatus*)** is classified as a data deficient species by the IUCN. The global population for this species is unknown. Estimates of 243,500 have been documented in the eastern tropical Pacific (Wade and Gerrodette, 1993). In the western North Pacific, 169,000 bottlenose dolphins were estimated (Miyashita, 1993). A total of 6,900 bottlenose dolphins was estimated in the Black Sea, and a minimum of 2,000-3,000 animals have been estimated for Shark Bay, Australia (Croll et al., 1999). Additionally, approximately 30,000 and 35,000 animals have been estimated for the western North Atlantic and Gulf of Mexico (including the shelf) (Waring et al., 2004).

The bottlenose dolphin is distributed worldwide in temperate to tropical waters, mostly between 50 °S to 45°N and up to 60°N around the United Kingdom and northern Europe (Croll et al., 1999). In North America, they inhabit waters with temperatures ranging from 10 to 32°C (Wells and Scott, 2002). They are primarily coastal, but they also occur in very diverse habitats ranging from rivers and protected bays (Scott and Chivers, 1990; Sudara and Mahakunlayanakul, 1998) to oceanic islands and the open ocean (Scott and Chivers, 1990), over the continental shelf, and along the shelf break (Wells and Scott, 2002). Bottlenose dolphins are common in the southern Okhotsk Sea, the Kuril Islands, and along central California in the North Pacific. In the Atlantic, they are found inshore during the summer months in New England north to Nova Scotia and have been sighted in Norway and the Lofoten Islands. The southern range extends as far south as

Tierra del Fuego, South Africa, Australia, and New Zealand (Wells and Scott, 2002). Seasonal movements vary between inshore and offshore locations and year-round home ranges (Croll et al., 1999; Wells and Scott, 2002). Calving season is generally year-round with peaks occurring from early spring to early fall (Scott and Chivers, 1990 *in* Croll et al., 1999). Data on breeding grounds is not available.

Sustained swim speeds for bottlenose dolphins range between 4 and 20 km/h (2.2 and 10.8 knots). Speeds commonly range from 6.4 to 11.5 km/h (3.4 to 6.2 knots) and may reach speeds as high as 29.9 km/h (16.1 knots) for 7.5 seconds (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 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).

The diet of the bottlenose dolphin is diverse in nature, ranging from coastal squid and fish to small mesopelagic fish and squid (Croll et al., 1999), with a preference for sciaenids, scombrids, and mugilids (Wells and Scott, 2002). Seasonal and geographical variation may influence the diet of bottlenose dolphins (Evans, 1994). There is also some evidence that dolphins feed in different areas depending on sex and size. Lactating females and calves have been reported foraging in the near-shore zone, while adolescents feed farther offshore. Females without young and male adults may feed still farther offshore (Wells and Scott, 2002). Bottlenose dolphins appear to be active during both the day and night. Their activities are influenced by the seasons, time of day, tidal state, and physiological factors such as reproductive seasonality (Wells and Scott, 2002).

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 from the front (Richardson et al., 1995).

Bottlenose dolphins produce sounds as low as 0.05 kHz and as high as 150 kHz with dominant frequencies at 0.3 to 14.5 kHz, 25 to 30 kHz, and 95 to 130 kHz (Johnson, 1967; Popper, 1980; McCowan and Reiss, 1995; Schultz et al., 1995; Croll et al., 1999; Oswald et al., 2003). The maximum SL 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 *in* Helweg et al., 2003; Jones and Sayigh, 2002). According to Au (1993), sonar clicks are broadband, ranging in frequency from a few kHz 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 percent of the peak frequency (Houser et al., 1999 both *in* Helweg et al., 2003).

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.

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 (Frankel, 2002; Sayigh, 2002). Maximum sound levels can reach 228 dB. Stereotypically, 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 a SL of 125 to 140 dB (3.3 ft) (Croll et al., 1999).

McCowan et al. (1999) discusses bottlenose dolphins and their structure and organization of communication mathematically. They apply Zipf's law, which examines the first-order entropic relation and evaluates the signal composition of a repertoire by examining the frequency of use of signals in a relationship to their ranks. It measures the potential capacity for information transfer at the repertoire level by examining the optimal amount of diversity and redundancy necessary for communication transfer across a noisy channel. The results from this experiment suggest that Zipf's statistic can be applied to animal vocal repertoires, specifically in this case, dolphin whistle repertoires, and their development. Zipf's statistic may be an important comparative measure of repertoire complexity both inter-species and as an indicator for vocal acquisition or learning of vocal repertoire structure within a species. The results also suggest that dolphin whistles contain some higher-order internal structure, enough to begin to predict statistically what whistle types might immediately follow the same or another whistle type. A greater knowledge of the higher-order entropic structures could allow the reconstruction of dolphins whistle sequence structure, independent of additional data inputs such as actions and non-vocal signaling (McCowan et al., 1999).

In contrast to the signature whistle theory, McCowan et al. (2001) stated that predominant whistle types produced by isolated dolphins were the same whistle types that were predominant for all adult subjects and for infant subjects by the end of their first year in both socially interactive and separation contexts. No evidence for individually distinctive signature whistle contours was found in the bottlenose dolphins studied. Ten of 12 individuals produced one shared whistle type as their most predominant whistle during contexts of isolation. The two other individuals produced two other predominant whistle types that could not be considered signature whistles because both whistle types were shared among many different individuals within and across independent captive social groups (McCowan et al., 2001).

Jones and Sayih (2002) reported geographic variations in behavior and in the rates of vocal production. Both 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).

The genus ***Stenella*** contains 5 species of dolphins: clymene, Atlantic spotted, striped, pantropical spotted, and spinner dolphins. Clymene and Atlantic spotted dolphins are classified as data deficient species status and the striped, pantropical, spotted and spinner dolphins are classified as lower risk status under the IUCN.

The worldwide population size for all species of *Stenella* spp.are unknown. Striped dolphins are known to be the most abundant species in the Mediterranean Sea (Archer, 2002). Pantropical, spinner and striped dolphins are estimated to be the most abundant cetaceans in the eastern tropical Pacific. Estimates of 2,059,100 pantropical spotted dolphins, 1,651,100 spinner dolphins, and 1,918,000 striped dolphins are reported for the eastern tropical Pacific (Croll et al., 1999). Estimates of 91,300 pantropical spotted dolphins, 12,000 spinner dolphins, 17,300 clymene dolphins, 31,000 Atlantic spotted dolphins, and 6,500 striped dolphins are reported for the Gulf of Mexico (Waring et al., 2004).

The five species of ***Stenella*** inhabit coastal and oceanic tropical and subtropical waters from 40°S to 40°N (Perrin and Gilpatrick, 1994; Perrin and Hohn, 1994). Pantropical, clymene, spotted and spinner dolphins are particularly found in tropical waters, while striped dolphins occur in more temperate waters with seasonal upwelling and seasonal changes (Perrin and Hohn, 1994). Spotted dolphins tend to be distributed coastally in depths of less than 400 m (1312 ft), while the other four species of *Stenella* stay offshore in depths greater than 700 m (2297 ft) (Croll et al., 1999). There has been some evidence of migration from seasonal and annual shifts in abundance of pantropical, spotted and spinner dolphins in the eastern tropical Pacific. Pantropical and spinner dolphins are considered seasonal breeders (Perrin and Hohn, 1994; Croll et al., 1999). There are no specific breeding areas.

Very little information is known about clymene dolphins because they are one of the most recently recognized species of dolphins. They are only found in the tropical to warm-temperate waters of the South and mid-Atlantic Ocean. Most sightings of clymene dolphins have been in deep, offshore waters. Very little is known about their ecology. They feed mostly on mesopelagic fish and squid (Jefferson, 2002a).

The Atlantic spotted dolphin is found only in the tropical and warm-temperate waters of the Atlantic Ocean. They range from approximately 50°N to 25°S, and are commonly found around the southeastern United States 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. Atlantic spotted dolphins eat a variety of prey, including epipelagic and mesopelagic fish and squids, and benthic invertebrates (Perrin, 2002a).

Striped dolphins are common in tropical and warm-temperate waters, usually below 43°N. 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. Striped dolphins forage at depths of 200 to 700 m (656 to 2297 ft), and feed on a variety of pelagic or benthopelagic fish and squid. Off the coast of Japan and South Africa, striped dolphins feed on fish in the family Myctophidae. In the Mediterranean, they eat more squid (Archer, 2002). In the Ligurian Sea, striped dolphins are commonly found along the Ligurian Sea Front, which has water depths of 2000 to 2500 m (6562 to 8202 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).

Pantropical spotted dolphins occur throughout the tropical and sub-tropical Indo-West Pacific. Their distribution is generally between 30 and 40°N and 20 to 40°S (Perrin, 2002d). They range from South Africa to the Red Sea and Persian Gulf, east to Australia, the Indo-Malayan Archipelago, and the Philippines, and north to southern Japan (Rudolph and Smeenk, 2002). 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 of their feeding is at night (Stewart, 2002). Their prey includes small epipelagic fish, squids, and crustaceans, flying fish (Perrin, 2002d).

Spinner dolphins are pantropical. They occur in all tropical and most subtropical waters, and range between 30 and 40°N and 20 to 30°S. Spinner dolphins are common in the high seas, but coastal populations do exist in Hawaii, the eastern Pacific, Indian Ocean, and Southeast Asia. They dive to 600 m (1969 ft) or deeper to feed mainly on mesopelagic fish and squids . The dwarf species in Southeast Asia is found in shallower waters in the Gulf of Thailand, Timor Sea, and Arafura Sea. These dolphins eat mostly benthic and reef fish and invertebrates (Perrin, 2002c).

Average swim speeds of 11 km/h (5.9 knots) were measured from striped dolphins in the Mediterranean (Archer and Perrin, 1999). Hawaiian spinner dolphins have swim speeds ranging from 2.6 to 6 km/h (1.4 to 3.2 knots) (Norris et al., 1994). Pantropical spotted dolphins have been recorded swimming up to 39.7 km/hr (21.4 knots) for 2 seconds, although, this may be an overestimate. Other individuals have been recorded as swimming at speeds of 4 to 19 km/hr (2.2 to 10.3 knots) with bursts up to 22 km/hr 12 knots) (Perrin, 2002d). 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 with depths as deep as 100 m (Scott et al., 1993). Dives of up to 3.4 min have been recorded (Perrin, 2002d). An Atlantic spotted dolphin was documented with a maximum dive duration of 3.5 min (Davis et al., 1996).

Based on auditory brainstem responses, striped dolphins hear SLs equal to or louder than 120 dB in the range of less than 10 to greater than 100 kHz (Popper, 1980). 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). They have relatively less hearing sensitivity below 32 kHz and above 120 kHz. There is no direct measurement of auditory threshold for the hearing sensitivity of the remaining *Stenella* dolphins (Ketten, 2000; Thewissen, 2002).

Dolphins of the genus *Stenella* produce sounds as low as 0.1 kHz and as high as 160 kHz with tri-modal dominant frequencies at 5 to 60 kHz, 40 to 50 kHz, and 130 to 140 kHz (Caldwell and Caldwell, 1971c; Popper, 1980; Steiner, 1981; Norris et al., 1994; Richardson et al., 1995; Au et al., 1998; Croll et al., 1999; Oswald et al., 2003). The amount and variety of signal types generally increases with increasing social activity, particularly in Hawaiian spinner dolphins (Frankel, 2002). 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).

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 is 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).

The 6 species in the genus ***Lagenorhynchus*** (Peale’s, dusky, Atlantic white-sided, white-beaked, hourglass, and Pacific white-sided dolphins) are currently classified with Peale’s and dusky dolphins as data deficient species status. Atlantic white-sided, white-beaked, hourglass, and Pacific white-sided dolphins are classified as lower risk status. The worldwide population sizes for all species of *Lagenorhynchus* spp. are unknown. Between 30,000 and 50,000 Pacific white-sided dolphins have been estimated around Japan (Nishiwaki and Oguro, 1972), and ship surveys report an estimate of 39,800 Pacific white-sided dolphins in eastern North Pacific waters (Carretta et al., 2005). Atlantic white-sided dolphins estimates were totaled to approximate 77,000 along the North American seaboard (Croll et al., 1999). A total of 3,486 white-beaked dolphins were reported in the shelf water along the coast of Labrador (Alling and Whitehead, 1987), and 6,000 white-beaked dolphins were estimated in the western North Atlantic (Waring et al., 2004). 144,300 hourglass dolphins have been estimated south of the Antarctic Convergence in January (Kasamatsu and Joyce, 1995).

Peale's dolphins inhabit the inshore waters of southern South America and the Falkland Islands, from 60° to 35°S. They live in coastal bays, inlets and the shelf waters. Occasional sightings have occurred around the Palmerston Atoll in the south Pacific (Goodall, 2002c; Reeves and Leatherwood, 1994 *in* Croll et al., 1999). In the Strait of Magellan and near Isla Chiloe, resident Peale's dolphins have been noted throughout the year, with more animals present during the summer. The dolphins move inshore during the summer in Tierra del Fuego. They are found in open coasts over continental shelves to the north and deep, protected bays and channels to the south and west. They often swim in kelp beds. Prey include octopus in the kelp beds and demersal and bottom fish. Peale's dolphins dive sequences are usually three short dives followed by one longer dive. Their dive durations last between 3 and 157 seconds, averaging 28 seconds (Croll et al., 1999).

Dusky dolphins occur off the coastal waters of New Zealand, South America, southwestern Africa and several islands in the South Atlantic and southern Indian Oceans from 60° to 9°S (Croll et al., 1999). They are distributed from northern Peru south to Cape Horn and from southern Patagonia north to approximately 36°S. They can also be found off of southwest Africa from False Bay to Lobito Bay, Angola, and off of New Zealand including Chatham and Campbell Islands. No well-defined seasonal migrations are apparent, but they are known to have a range of 780 km (484.7 mi) (Van Waerebeek and Wursig, 2002). However, 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 Patagonia, they are known to forage during the day on fish. Off of New Zealand, they feed at night on prey in the deep scattering layer. Prey include hake, anchovies, and squid (Van Waerebeek and Wursig, 2002). Off Argentina, the mean dive time for dusky dolphins was 21 seconds, with shorter dives during the day and longer dives at night (Wursig, 1982). Dusky dolphins in New Zealand swim at mean routine speeds between 4.5 and 12.2 km/hr (2.4 and 6.6 knots) (Cipriano, 1992).

Atlantic white-sided dolphins are found in the cold-temperate waters of the North Atlantic from 35°N to 80°N. They generally range over the continental shelf and slope, extending into deeper oceanic waters and occasionally into coastal areas. Cape Cod is the southern limit to the Atlantic white-sided dolphin, with an eastern limit of Georges Band and Brittany. In the north, they extend at least to Greenland, southern Iceland, and the south coast of Svalbard Island. Atlantic white-sided dolphins apparently undergo seasonal movements on both sides of the Atlantic. Calving occurs during the summer months (Croll et al., 1999; Kinze, 2002). They prey on herring, mackerel, gadid fish, smelts and hakes, sand lances, and squids. Atlantic white-sided dolphins are probably not deep divers. A tagged dolphin dove an average of 38.8 seconds with 76 percent of dives lasting less than 1 minute (Mate et al., 1994). This dolphin also swam at an average speed of 5.7 km/h (3.1 knots).

White beaked dolphins share a similar habitat to that of the Atlantic white-sided dolphin, but within a more northern range, which includes the western Mediterranean Sea (Evans, 1987; Jefferson et al., 1993; Reeves and Leatherwood, 1994; Cipriano, 2002; Kinze, 2002). White-beaked dolphins are distributed in the temperate and subarctic North Atlantic Ocean. They are often in shelf waters and sometimes in shallow coastal waters. They can be found as far north as the White Sea in the northeast Atlantic and are abundant along the Norwegian coasts and in the northern parts of the North Sea along the United Kingdom, Belgium, the Netherlands, Germany, and Denmark. White-beaked dolphins are less abundant in the northwest Atlantic compared to the northeast, and the largest concentrations are found off the Labrador coast and in southwest Greenland. Some individuals have been seen as far south as Cape Cod. Calving occurs during the summer months (Croll et al., 1999; Kinze, 2002). They feed mostly on mesopelagic fish such as cod, whiting, other gadids, and squids (Kinze, 2002).

Hourglass dolphins are pelagic animals that occur in the high latitudes of the Southern Hemisphere from 68 to 33 deg S latitude (Croll et al., 1999; Goodall, 2002b). It has been suggested that this species may undergo a southward migration to the Antarctic during the summer season (Kasamatsu and Joyce, 1995 *in* Goodall, 2002b). They are found on both sides of the Antarctic Convergence and northward in cool currents associated with the West Wind Drift. Water temperatures range from - 0.3 to 13.4 deg C (31.5 to 56.1 deg F). Most sightings are near islands and banks, often in the Drake Passage. Hourglass dolphins feed on small fish and squid, seabirds and in plankton slicks (Goodall, 2002b). Hourglass dolphins have swim speeds between 7 and 29 km/h (3.8 and 15.7 knots) (Croll et al., 1999; Goodall, 2002b).

Pacific white-sided dolphins are mostly pelagic and have a primarily temperate distribution across the North Pacific, 20 to 60 deg N latitude (Jefferson et al., 1993 *in* Croll et al., 1999; Croll et al., 1999). They have been recorded with a seasonal north-south migration pattern and calve during the late winter and spring off California and in the North Pacific (Croll et al., 1999) from Taiwan to the Kurile and Commander Islands in the west. They are more common on the coasts in the fall and winter and move offshore in the spring and summer, following their prey. It is assumed based on feeding habits that Pacific white-sided dolphins dive to at least 120 m (393.7 ft), with most of their foraging dives lasting 15 to 20 seconds (Croll et al., 1999). Captive Pacific white-sided dolphins have been recorded as swimming up to 27.7 km/hr (15.0 knots) during 2-second intervals (Croll et al., 1999). Ferrero et al. (2002) examined the indications of habitat use patterns in the central North Pacific for Pacific white-sided dolphin, along with Dall’s porpoise and northern right whale dolphins. They are the three most common cetacean species in the central North Pacific (from 37 to 46 deg N latitude and 170 deg E to 150 deg W longitude) . Similar to that reported in Croll et al. (1999), Ferrero et al. (2002) reported that the Pacific white-sided dolphin occurs across temperate Pacific waters to latitudes as low as or lower than 38 deg N, and northward to the Bering sea and coastal areas southeast of Alaska. The primary habitat feature of the studied area is the Polar Front Region which is at 45 deg N latitude at 170 deg E longitude, curving southward to 42 deg N latitude at 150 deg W longitude. North of the front, the surface waters have relatively low salinity and waters to the south of the Front generally have a higher salinity. The sea surface temperature, however, was the most pronounced environmental feature in the studied species’ habitat. Pacific white-sided dolphins showed the broadest preference for sea surface temperature in the study area (Ferrero et al., 2002).

No breeding grounds are known for *Lagenorhynchus* spp.

Pacific white-sided dolphins hear frequencies in the range of about 0.5 to 135 kHz when the sounds are equal to or softer than 120 dB RL. At a frequency of 1 kHz, they can listen to pure tones that are at least 106 dB RL. At an intensity less than 90 dB RL, they can hear a frequency range of 2 to 128 kHz (Tremel et al., 1998 *in* Croll et al., 1999). There is no direct measurement of auditory threshold for the hearing sensitivity of the remaining *Lagenorhynchus* dolphins (Ketten, 2000; Thewissen, 2002).

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, 1980; Richardson et al., 1995).

Peale's dolphin vocalizations were recorded in the Chilean channel. The recordings showed that Peale's dolphins make broadband clicks at 5 to 12 kHz and narrowband clocks at 1- to 2-kHz bandwidths (Goodall, 2002c). Peale's dolphin SLs were recorded at low levels of 80 dB 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).

The average estimated SL for an Atlantic white-sided dolphin is approximately 154 dB with a maximum at 164 dB (Croll et al., 1999).

Clicks produced by white-beaked dolphins resemble those by bottlenose dolphins. They make short, broadband clicks with peak frequencies of about 120 kHz. They are approximately 10 to 30 microsec in duration. Some clicks have a secondary peak of 250 kHz. The maximum sound level from one study was recorded at 219 dB and was measured at a range of 22 m (72.2 ft). The minimum recorded sound level was 189 dB at a distance of 1.5 m (4.9 ft) from the dolphin (Rassmussen et al., 2002).

Pacific white-sided dolphins produce broad-band clicks which have a SL at 180 dB (Richardson et al 1995; Rasmussen et al., 2002).

There are no available data regarding seasonal or geographical variation in the sound production of *Lagenorhynchus* dolphins.

Subfamily Steninae

The subfamily Steninae includes one species of interest: the rough-toothed dolphin (*Steno bredenansis*).

Rough-toothed dolphins (*Steno bredenansis*) are currently classified with a data deficient species status under IUCN. The worldwide population size for this species is unknown. Estimates of 145,900 have been documented in the eastern tropical Pacific (Wade and Gerrodette, 1993). Estimates of 2,223 have been documented in the Gulf of Mexico (Waring et al., 2004)

Rough-toothed dolphins occur between 45 deg S to 55 deg N in deep, oceanic tropical, subtropical, and warm-temperate waters around the world and appear to be relatively abundant in certain areas. (Croll et al., 1999; Jefferson, 2002c). In the Atlantic Ocean, they are found between the southeastern United States and southern Brazil, across to the Iberian Peninsula and West Africa. Some animals have been seen in the English Channel and North Sea. Their range also includes the Gulf of Mexico, Caribbean Sea, and the Mediterranean Sea (Jefferson, 2002c).

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. Their range includes the southern Gulf of California and the South China Sea. They have an extensive distribution north of 20 deg S with scattered sighting records in New Zealand, the Indian Ocean, and along the western United States. Rough-toothed dolphins feed on fish and cephalopods (Jefferson, 2002c). Breeding areas and seasonal movements of 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 and have a distinctive splash (Jefferson, 2002c). Swim speeds of this species vary from greater than 5.5 to 16 km/h (3.0 to 8.6 knots). Rough-toothed dolphins can dive down between 30 and 70 m (98 and 230 ft)(Croll et al., 1999). The dive duration ranges from 0.5 to 3.5 min (Ritter, 2002). The maximum dive recorded was 70 m (230 ft). Although, due to their morphology, it is believed that they are capable of diving much deeper. Dives up to 15 min have been recorded for groups of dolphins (Croll et al., 1999).

There is no direct measurement of auditory threshold for the hearing sensitivity of rough-toothed dolphins (Ketten, 2000; Thewissen, 2002).

Rough-toothed dolphins produce sounds ranging from 0.1 kHz up to 200 kHz (Popper, 1980; Miyazaki and Perrin, 1994; Richardson et al., 1995). Clicks have peak energy at 25 kHz, while whistles have a maximum energy between 2 to 14 kHz and at 4 to 7 kHz (Norris and Evans, 1967; Norris, 1969; Popper, 1980). There is no available data regarding seasonal or geographical variation in the sound production of this species.

Subfamily Lissodelphinae

The subfamily Lissodelphinae consists of two species, the northern right whale dolphin (*Lissodelphis borealis)* and the southern right whale dolphin (*Lissodelphis peronii).*

The finless **northern right whale dolphin (*Lissodelphis borealis)*** is currently classified as lower risk status and the **southern right whale dolphin (*Lissodelphis peronii)*** is listed as data deficient under IUCN. The worldwide population size for these species is unknown. Although, ship surveys have produced population estimates of 16,417 northern right whale dolphins in the eastern Pacific (Carretta et al., 2005).

Right whale dolphins inhabit cool-temperate and sub-Arctic waters in the North Pacific, circumpolar sub-Antarctic, and cool-temperate waters in the Southern Ocean. They are found in oceanic, deep waters, on highly productive continental shelves, or where deep waters approach the coast (Lipsky, 2002).

Northern right whale dolphins inhabit deep, offshore waters in the North Pacific. They range from 29 to 59 deg N latitude (Croll et al., 1999), but are commonly found from 34 to 55 deg N latitude and 145 deg W to 118 deg E longitude. They range from the Kuril Islands, Russia, south to Sanriku, Honshu, Japan, and eastward to the Gulf of Alaska and south to Southern California (Lipsky, 2002). They prefer cold, deep, offshore waters, most often between 8 and 19 deg C

(Croll et al., 1999). This species migrates southward and inshore during the winter and northward and offshore during the summer months (Kasuya, 1971 *in* Croll et al., 1999; Leatherwood and Walker, 1979; Lipsky, 2002). They feed mostly on squid and lanternfish, but also prey on Pacific hake, saury, and mesopelagic fish (Lipsky, 2002).

Ferrero et al. (2002) examined the indications of habitat use patterns in the central North Pacific for northern right whale dolphins, along with Dall's porpoise and Pacific white-sided dolphins. They are the three most common cetacean species in the central North Pacific (from 37 N to 46 deg N latitude and 170 deg E to 150 deg W longitude). Similar to that reported in Croll et al. (1999), Ferrero et al. (2002) reports that northern right whale dolphins range from 30 to 50 deg N latitude in the eastern Pacific Ocean and from 35 to 51 deg N latitude in the western Pacific Ocean. The primary habitat feature of the studied area is the Polar Front Region which is at 45 deg N latitude at 170 deg E longitude, curving southward to 42 deg N latitude at 150 deg W longitude. North of the front, the surface waters have relatively low salinity and to the south generally have higher salinity. The sea surface temperature, however, was the most pronounced environmental feature in the studied species' habitat. The northern right whale dolphins were found to occupy the warmer waters. However, this could also have been related to their reproductive activity (Ferrero et al., 2002).

Southern right whale dolphins inhabit the area between the Subtropical and Antarctic Convergence zones most commonly between 25 and 55 deg S latitude but range from 25 to 65 deg S latitude. Their range extends northwards along cold-water boundaries (Lipsky, 2002). They are commonly found in northern Chile (Lipsky, 2002). It has been suggested that southern right whale dolphins may migrate, although this species seems to inhabit waters off Namibia, Africa year round. Breeding grounds are unknown for both species. They feed on a variety of squids and fish (Lipsky, 2002).

Swim speeds for northern right whale dolphins can reach 34 to 40 km/hr (18.3 to 21.6 knots) (Croll et al., 1999; Lipsky, 2002). Southern right whale dolphins can swim up to 22 km/h (12 knots) (Cruickshank and Brown, 1981). The maximum dive times recorded are 6.25 min for northern right whale dolphins and 6.5 min for southern right whale dolphins (Croll et al., 1999). They appear to make dives to more than 200 m (656 ft) while foraging (Jefferson et al., 1994; Fitch and Brownell, 1968; Croll et al., 1999).

There is no direct measurement of auditory threshold for the hearing sensitivity of *Lissodelphis* dolphins (Ketten, 2000; Thewissen, 2002).

Northern right whale dolphins 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 *in* Croll et al., 1999; Leatherwood and Walker, 1979 *in* Croll et al., 1999). The maximum known peak to peak SL of northern right whale dolphins is 170 dB (Fish and Turl, 1976 *in* Croll et al., 1999).

There are no data available on southern right whale dolphin sound production or on seasonal or geographical variation in the sound production of right whale dolphins.

Subfamily Cephalorhynchinae

The subfamily **Cephalorhynchinae** includes four species of the *Cephalorhynchus* genus: **Commerson's dolphin (*Cephalorhynchus commersonii)***, **black or Chilean dolphin (*Cephalorhynchus eutropia)***, **Heaviside's dolphin (*Cephalorhynchus heavisidii)*** and **Hector's dolphin (*Cephalorhynchus hectori)***.

The four species are currently classified with Commerson's, black, and Heaviside's dolphins as data deficient species status and Hector's dolphins as endangered status under IUCN. The worldwide population size for all species of *Cephalorhynchus* spp. are unknown. Total population of Hector's dolphins is estimated at 3,408 (Croll et al., 1999). In the northeastern Strait of Magellan, abundance estimates were recorded at 718 for Commerson's dolphins (Croll et al, 1999).

Cephalorhynchus dolphins are found in temperate coastal waters in the Southern Hemisphere, (Goodall et al., 1988; Goodall, 1994a and 1994b; Sekiguchi et al., 1998; Dawson, 2002). They occur in waters less than 200 m (656 ft) deep and are commonly seen in the surf zone. (Dawson, 2002). *Cephalorhynchus* dolphins feed on demersal and pelagic fish, squid, and crustaceans (Slooten and Dawson 1994; Croll et al., 1999). Heaviside's dolphin particularly preys on octopus (Dawson, 2002).

Commerson's dolphins inhabit coastal waters of the southwestern Atlantic off South America and the Kerguelen Islands in the southern Indian Ocean (Croll et al., 1999; Goodall, 1994a). They are mainly found in the coastal waters of Argentina and in the Strait of Magellan, but are sometimes seen in the Falkland Islands. They range from Rio Negro at 40°S and Cape Horn at 55°S down to the Drake Passage at 61°S to the Falkland Islands. At Kerguelen, they are frequently seen on the eastern side in the Golfe du Morbihan (Dawson, 2002). There is evidence of seasonal movement for this species (Goodall, 1994a). Calving season ranges between October and March (Goodall et al., 1988 *in* Croll et al., 1999).

The black or Chilean dolphin is restricted to the shallow, coastal waters, estuaries, and rivers of Chile, the Straits of Magellan, the channels of Tierra del Fuego, and along the west coast of Chile. Chilean dolphins have been noted as a year-round resident throughout their range. Chilean dolphins have a large latitudinal range, from Valparaiso at 33°S to near Cape Horn at 55°S on both open and sheltered coasts (Dawson, 2002). Calving appears to occur between October and March (Goodall et al., 1988 *in* Croll et al., 1999).

Heaviside's dolphins are only found along the west coast of southern Africa and Namibia from 17 deg S on the Namibian coast to Cape Town at 34 deg S and typically occur in shallow water no deeper than 100 m (328 ft) (Croll et al., 1999; Dawson, 2002). Most sightings are around Cape Town and Walvis Bay. There is no evidence of large-scale seasonal movement for Heaviside's dolphins (Dawson, 2002). They appear to calve in the austral summer (Croll et al., 1999).

Hector's dolphins inhabit shallow waters and occur off of New Zealand (Slooten and Dawson, 1994; Croll et al., 1999). They are most common on the east and west coasts of South Island between 41 and 44 deg S, particularly around Banks Peninsula and between Karamea and Moakawhio Point. A small population exists on the west coast of North Island between 36 and 38 deg S. An isolated population also exists in Te Wae Bay on the Southland coast. They are rarely seen more than 8 km (5 mi) from shore or in waters greater than 75 m (246 ft) deep. They range over about 30 km (18.6 mi) of coastline (Dawson, 2002). Calving season for Hector's dolphins range from early November to mid-February. There is no evidence of seasonal movement for Hector's dolphins (Croll et al., 1999).

No breeding areas are known for *Cephalorhynchus* dolphins.

No swim speeds are described for *Cephalorhynchus* dolphins. Heaviside's dolphins make relatively shallow and short dives typically less than 20 m (66 ft). Most dives lasted less than two min, and the maximum recorded dive from this species was 104 m (340 ft) by a male and 92 m (301.8 ft) by a female (Sekiguchi et al., 1998). The average long dive of Hector's dolphins lasts 89 seconds (Slooten and Dawson, 1994, Croll et al., 1999).

There is no direct measurement of auditory threshold for the hearing sensitivity of *Cephalorhynchus* dolphins (Ketten, 2000; Thewissen, 2002; Croll et al., 1999).

Dolphins of this genus produce sounds as low as 320 Hz and higher than 150 kHz, with dominant frequencies at 0.8 to 1 kHz, 1 to 2 kHz, 4 to 4.5 kHz, and 116 to 134 kHz (Croll et al., 1999; Watkins et al., 1977; Watkins and Schevill, 1980; Kamminga and Wiersma, 1981; Sho-Chi et al., 1982; Evans and Awbrey, 1984; Dawson, 1988; Evans et al., 1988; Dziedzic and De Buffrenil, 1989; Dawson and Thorpe, 1990; Au, 1993). The maximum peak to peak SL ranges from 160 dB for Commerson's dolphin to 163.2 dB for Hector's dolphin (Croll et al., 1999). The high click rates produced by this genus of dolphins are termed "cries" or "squeals" (Watkins et al., 1977; Dziedzic and DeBuffrenil, 1989; Dawson, 1988 ; Dawson and Thorpe, 1990). Hector's dolphin is the only *Cephalorhynchus* species that has been recorded comprehensively in the wild. Almost all of their sounds are short (140 microsec) with a high, narrow-band frequency of 125 kHz. Trains consist of several thousand ultra-sonic clicks. The maximum click rate calculated was 1149 clicks/second. Both Heaviside's and Chilean dolphins make this sound, but they have not been recorded. Commerson's and Hector's dolphins produce HF narrow band clicks (3-dB bandwidth = 10 to 22 kHz) with most energy focused around 120 to 130 kHz and little to no energy below 100 kHz (Croll et al., 1999). Clicks appear to have a role in both communication and echolocation (Dawson, 2002). Dziedzic and DeBuffrenil (1989) recorded sounds from Commerson's dolphins. Their "cry" sounds had a frequency up to 10 kHz with the most powerful part of the spectrum between 200 Hz and 5 kHz with a dominant component at about 1 kHz. Low-frequency clicks at 6 kHz had a duration of approximately 6 μs and had two dominant components at 1 and 2.4 kHz. Frequencies recorded from Heaviside's dolphin had a restricted bandwidth to less than 5 kHz and often less than 2 kHz with the major emphasis around 800 Hz. A secondary emphasis was sometimes around 2 to 5 kHz (Watkins et al., 1977).

Phocoenidae

The family Phocoenidae includes three species that have ranges that could overlap potential LFA operating areas. These are the harbor porpoise *(Phocoena phocoena),* Dall's porpoise *(Phocoenoides dalli),* and spectacles porpoise (*Phocoena dioptrica*).

The **harbor porpoise** ***(Phocoena phocoena)*** is considered a candidate species for the Gulf of Maine stock under the ESA and classified as vulnerable under IUCN. The North Atlantic population is estimated at 456,717 (IWC, 1996). The overall estimate from a survey in the North Sea in 1994 was 341,000 (Evans and Raga, 2001). Estimates taken from ship surveys off California and Oregon/Washington estimate 52,743 and 39,586 harbor porpoises, respectively (Barlow, 1995; Carretta et al., 2005). An estimate of 89,700 was reported for the Gulf of Maine (Waring et al., 2004).

Harbor porpoise are found in cold temperate and sub-arctic coastal waters of the Northern Hemisphere, from 15 to 70^o N (Gaskin, 1992; Jefferson et al., 1993; Bjorge and Tolley, 2002). 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 0 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, over deep water (Croll et al., 1999; Gaskin, 1992). For example, they are not found in California waters deeper than 125 m (410 ft) (Barlow, 1988). They show seasonal movement in northwestern Europe, which may be related to oceanographic changes throughout certain times of the year (Heimlich-Boran et al., 1998; Gaskin, 1992; Read and Westgate, 1997). Although migration patterns have been inferred in harbor porpoise (Gaskin, 1992), data suggests that seasonal movements of individuals are discrete and not temporally coordinated migrations (Read and Westgate, 1997). In certain areas harbor porpoise seem to be resident (Berrow et al., 1998). Three major isolated populations exist: 1) the North Pacific, 2) North Atlantic, and 3) the Black Sea of Azov (Yurick and Gaskin, 1987). However, there is morphological and genetic data that suggest that different populations may exist within these three regions (Croll et al., 1999).

Swim speeds for harbor porpoises range between 16.6 and 22.2 km/h (9.0 to 12.0 knots) (Kanwisher and Sundnes, 1965; Gaskin et al., 1974). Dive times range between 0.7 and 1.71 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). Descent rates are not constant. The deeper the dives, the faster mean decent and initial descent rates are (Croll et al., 1999).

The diet of this species is primarily small, pelagic schooling fish, but may include cephalopods (Read and Gaskin, 1988; Gannon et al., 1998; Bjorge and Tolley, 2002). Harbor porpoises have been known to dive for two to six min during foraging activity.

Harbor porpoise can hear frequencies in the range of 100 Hz to 140 kHz (Andersen, 1970; Kastelein et al., 2002). Kastelein et al. (2002) determined the best range of hearing for a two-year old male to be from 16 to 140 kHz. This harbor porpoise also demonstrated the highest upper frequency hearing of all odontocetes presently known (Kastelein et al., 2002).

Harbor porpoise are known to produce sounds ranging from 40 Hz to at least 150 kHz (Frankel, 2002), with dominant frequencies at 2 kHz and at 110 to 150 kHz (Popper, 1980; Richardson et al., 1995). Variations of click trains have different functions based on the different frequency ranges associated with each activity. For example, long range detection has been associated with low frequency calls ranging from 1.4 to 2.5 kHz, while higher frequency, narrow band click trains ranging from 110 to 150 kHz may be used for object detection. Whistles are also part of the harbor porpoise repertoire, ranging from 40 to 600 Hz (Frankel, 2002). Estimated SLs can reach 177 dB (Richardson et al., 1995).

Dall's porpoise *(Phocoenoides dalli)* is considered lower risk (conservation dependent) under the IUCN. The total population of Dall's porpoise is estimated to be 1.4 to 2.8 million (Jones et al., 1987). Estimates of 75,900 are reported for the eastern Pacific (Carretta et al., 2005).

Dall's porpoise is found exclusively in the North Pacific Ocean and adjacent seas (Bering Sea, Okhotsk Sea, and Sea of Japan) between 28 and 63^{o} N including southern California and southern Japan (Jefferson, 2002b). This oceanic species is primarily found in deep offshore waters, but is also found in deeper nearshore waters along the North American west coast (Jefferson, 2002b). This species is a resident year-round in the eastern North Pacific with seasonal inshore-offshore and north-south movements (Croll et al., 1999), but in most areas are very poorly defined (Jefferson, 2002b).

Ferrero et al. (2002) examined the indications of habitat use patterns in the central North Pacific for Dall's porpoise, along with northern right whale dolphins and Pacific white-sided dolphins. They are the three most common cetacean species in the central North Pacific (from 37 to 46 deg N and 170 deg E to 150 deg W) . Ferrero et al. (2002) reports that Dall's porpoise are principally a cold temperate and sub-arctic species, ranging from the Bering Sea south to 41 deg N in pelagic waters, which is within the range described by Jefferson (2002b). The primary habitat feature of the studied area is the Polar Front Region which is at 45 deg N at 170 deg E, curving southward to 42 deg N at 150 deg W. North of the Front, the surface waters have relatively low salinity and waters to the south of the Front generally have a higher salinity. The sea surface temperature, however, was the most pronounced environmental feature in the studied species' habitat. Dall's porpoise were only present in low numbers in the southern latitudes of this study, but it is believed that this may have been the southern fringe of their habitat (Ferrero et al., 2002).

Dall's porpoises are thought to be one of the fastest small cetaceans (Croll et al., 1999; Jefferson, 2002b). Dall's porpoise average swim speeds are between 2.4 and 21.6 km/h (1.3 and 11.7 knots), 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/h (29.7 knots) for quick bursts (Leatherwood and Reeves, 1986). They are relatively deep divers, diving to 275 m (900 ft) and for as long as 8 min (Ridgway, 1986; Hanson et al., 1998).

Dall's porpoises feed on cephalopods, schooling fish and occasionally on crustaceans (Mizue and Yoshida, 1965; Crawford, 1981; Walker, 1996; Jefferson, 2002b).

There is no direct measurement of auditory threshold for 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 20-100 kHz is about 116-130 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.

Spectacled porpoise (*Phocoena dioptrica*) are circumpolar found in the Southern Hemisphere in cool temperate, sub-Antarctic waters from about 32 to 59^{o} S (Croll et al., 1999; Goodall, 2002a). 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 (Croll et al., 1999, Goodall, 2002a).

What little is known about the spectacled porpoise is from skeletal remains and rare. However, sightings at sea have been widely distributed. There are no world-wide population estimates. There is no data on diving, swim speeds, hearing, or vocalizations.

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Sperm whale (*Physter macrocephalus*)	ESA endangered CITES protected IUCN Vulnerable	- All oceans tropical and temperate waters; -Deep waters -Commonly found near Equator and in the North Pacific	Global estimates: 500,000 –up to almost 2 million North Pacific: 250,000 Eastern tropical Pacific: 39,200 Eastern Pacific: 1,400 North Atlantic: 4,700 Gulf of Mexico: 1,350	Dive duration: 18.2-65.3 min Average dive depth: 400 m Maximum dive depth: 3,000 m Foraging Dives: 300-1245 m for 30-40 min Travel speed: 1.25-4 km/h	Hearing Hearing range: 2.5 -60 kHz Dominant Frequencies Hear: 5-20 kHz Sound Production frequency range: <0.1- 30 kHz signal type: -click trains -codas source level: 202 an 236 dB re: 1µPa at 1 m for clicks
Pygmy and dwarf sperm whale (*Kogia* species)	IUCN-lower risk, least concern species	-Deep ocean temperate, subtropical, and tropical waters -40° to 60° N	Derived abundance of 11,200 for the Eastern Tropical Pacific and 247 in California, Oregon, and Washington, with a minimum of 120	Dive duration: 8.6 min Average dive depth: No direct data available Max dive duration: 43 min Travel speed: <11 km/h	Hearing Hearing range: 90 -150 kHz Sound Production frequency range: 60 - 200 kHz Peak frequencies: 120-130 kHz signal type: Echolocation pulses: peak 125-130 kHz LF sweep: 1300-1500 Hz source levels: No direct data available

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Baird's and Arnoux's beaked whales (*Berardius* species)	IUCN-lower risk	-All oceans temperate, subtropical deep waters -Most abundant around shelf breaks and seamounts Baird's: -Continental Shelf off the Bering and Othotsk Seas to southern Japan in the west and northern Baja California in the east Arnoux's: -Antarctic waters -Northern New Zealand, South Africa, and southeast Australia	Global estimates: No direct data available - Baird's population in NW Pacific: Baird's 7,000 California: 38 in 1991 North Pacific: minimum estimate 228	Dive duration: - Baird's – 15-20 min - Arnoux's – 10-65 min Dive depth: No direct data available Dive duration max: -Baird's – 67 min -Arnoux's – 70 min Travel speed: 5 km/h	Hearing No direct data available Sound Production frequency range: Baird's: 12 - 134 kHz Dominant frequency produced: 23-24.6 kHz, and 35-45 kHz Arnoux's: 1-8.7 kHz signal type: burst pulse clicks FM whistles click trains source levels: No direct data available
Shepherd's beaked whale (*Tasmacetus shepherdi*)	IUCN-data deficient species	-Cold temperate seas of S. Hemisphere -temperate Antarctic waters -Brazil, the Galapagos Islands, New Zealand, Argentina, Australia, and the south Sandwich Islands	No direct data available	No direct data available Travel speed: 5 km/h	Hearing No direct data available Sound Production No direct data available

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Cuvier's beaked whale (*Ziphius cavirostris*)	IUCN-data deficient species	- Offshore waters of all oceans -Most common in the subtropical and temperate regions -Common in offshore deep waters of Mediterranean, British Isles, Caribbean seas, the Sea of Japan, western North America, and off of Hawaii -60°N to 60°S	Global estimate: No direct data available E. tropical Pacific: 90,725 Eastern North Pacific: 1,900	Dive duration: 20-87 min Average dive duration: 30 min Dive depth: No direct data available Travel speed: 5-6 km/h	Hearing No direct data available Sound Production frequency range: 13-17 kHz signal type: HF clicks source levels: No direct data available

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
N. and S. bottlenose whales (*Hyperoodon* species)	IUCN-lower risk/conservation dependent species	Northern Bottlenose: -Cold temperate and subarctic latitude of the North Atlantic -Deep waters, >1000 m -35º to 85 ºN -Seaward of the Continental Shelf -Common in The Gully off Nova Scotia Southern Bottlenose: -South of 20°S with circumpolar distribution -Near South Africa in February and southward towards the Antarctic in October	Global estimate: No direct data available The Gully-SE Sable Island: N. bottlenose 230 S. Antarctic Convergence: S. bottlenose 600,000	Dive duration: N. bottlenose: up to 70 min S. bottlenose: 11-46 min Average: 25.3 min Dive depth: N. bottlenose: 120-800 m Maximum dive depth: N. bottlenose: 1453 m S. bottlenose: no direct data available Travel speeds: 5 km/h	Hearing No direct data available Sound Production frequency range: N. bottlenose: 500 Hz - 26 kHz Peak frequency (from Nova Scotia): 24 kHz signal type: echolocation clicks: 812 kHz clicks: 500-26 kHz whistles: 3-16 kHz click series while diving: peak frequencies at 6-8 kHz and 16-20 kHz click trains while socializing: peak frequencies at 2-4 kHz and 10-12 kHz source levels: No direct data available S. bottlenose: no direct data available
Longman's beaked whale (*Indopacetus pacificus*)	IUCN-data deficient	- Indo-Pacific region - Possibly around Equatorial Indian and Pacific oceans	No direct data available	No direct data available Travel speeds: 5 km/hr	Hearing No direct data available Sound Production No direct data available

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Beaked whale (*Mesoplodon* species)	IUCN-data deficient species	- All oceans; tropical to temperate offshore waters - 72°N to 60°S -North Atlantic: Sowerby's, Blainville's, Gervais, and True's beaked whales -Northwestern Pacific: Ginkgo-toothed beaked whales - North Pacific: Blainville's beaked whale Aleutian Islands: Stejneger's beaked whale	Global estimate: No direct data available E. tropical Pacific: 25,300 California: 250 Minimum population estimates for western North Atlantic: 3200 Minimum population estimate for eastern North Pacific: 1250	Blainville's Dive duration: 7.47 min Maximum dive duration: 45 min Dive depth: No direct data available for most species Blainville: Max to near 900 m for >20 min Travel speeds: 5 km/h	Hearing No direct data available Sound Production frequency range: Blainville's: chirps and whistles at <1 kHz - 6 kHz Hubb's: Whistles 2.6-10.7 kHz Pulses: 300 Hz -80kHz Dominant frequencies: 300 Hz-2 kHz Stejneger's: 500 Hz - >26 kHz source levels: 200-220 dB re: 1µPa at 1 m
Beluga *Delphinapterus leucas)*	ESA -Cook Inlet stock proposed Candidate Species IUCN - vulnerable species	-Circumpolar ranging into subarctic coastal waters -Both shallow and deep water -East and west coasts of Greenland -Extend from Alaska across the Canadian western arctic to the Hudson Bay -Occasional sightings as far south as the Bay of Fundy in the Atlantic -In the Pacific, migratory Belugas summer in the Okshotsk, Chukchi,	Global estimate: ~100,000; Western Greenland 12,000-14,000	Dive depth: 647 m for 15 min Maximum dive depth: >1000m for up to 25 min Shallow surface dives: <1min Deep dives: 300-600 m for 9-18 min Max travel speed: 22 km/h Ave travel speeds: 2.5 – 3.3 km/h	Hearing Hearing range: 40 Hz -150 kHz Threshold of 42 dB re: 1µPa at 1 m at < 11-100 kHz Sound Production frequency range: 100 Hz – 120 kHz signal type: Tonal calls: 100 Hz-16 kHz Echolocation clicks: 120 kHz clicks: bimodal 40-60 kHz and 100-120 kHz

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
		Bering, and Beaufort seas, the Anadyr Gulf, and off Alaska -Residents in Cook Inlet			whistles: 260 Hz – 20 kHz source levels: 206-225 dB re: 1µPa at 1 m
Killer whale (*Orcinus orca*)	IUCN-lower risk/conservation dependent	-All oceans; temperate to subpolar waters -80°N to 77°S -Most common within 800 km of major continents	Global estimate: 100,000; E. tropical Pacific: 8,500 NE Pacific: 2000 Antarctic: 70,000 Norwegian waters: 440 Gulf of Mexico: 133	Dive duration: 1 – 10 min Dive depth: 100 m Maximum dive depth: 265 m Foraging dive: <180 m Travel speed max: 37 km/h Travel speed average: 6-10 km/h	Hearing hearing range: <500 Hz - 120 kHz Dominant frequencies: 15-42 kHz with a threshold of 34-36 dB re: 1µPa at 1 m Sound Production frequency range: 80 Hz – 85 kHz Dominant frequencies: 1-20 kHz signal type: dialects: 500 Hz – 10 kHz source levels: 105-124 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
False killer whale (*Pseudorca crassidens*)	IUCN-Lower risk/least concern	-W. Atlantic; tropical to warm temperate deep waters -60°S to 60°N	Global estimate: No direct data available E. tropical Pacific: 39,800 NW Pacific: 17,000	No direct data available Travel speed max: 28.8 km/h Travel speed average: 3 km/h	Hearing hearing range: <1 -115 kHz Dominant frequencies: 17 kHz at 39-49 dB re: 1µPa at 1 m; 140 dB re: 1µPa at 1 m at 75 Hz; 108 dB re: 1µPa at 1 m at 1 kHz; and 70 dB re: 1µPa at 1 m at 5 kHz Sound Production frequency range: 4 – 130 kHz Dominant frequencies: 25-30 kHz and 95-130 kHz signal type whistles: 4.7-6.1 kHz clicks: 20-60 kHz and 100-130 kHz source level clicks: 228 dB re: 1µPa at 1 m
Pygmy killer whale (*Feresa attenuata*)	IUCN-data deficient species	-All oceans; oceanic tropical to subtropical waters -40°S to 40°N -Frequently sighting in the E. tropical Pacific, the Hawaiian Archipelago, and off of Japan	Global estimate: No direct data available E. tropical Pacific: 39,800 Gulf of Mexico: 408	Dive duration: 25 sec Travel speeds: Unknown	Hearing No direct data available Sound Production -LF growls -little data available

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Melon-headed whale (*Peponocephala electra*)	IUCN-lower risk/least concern species	-Tropical to subtropical pelagic waters -20°S to 20°N	Global estimate: No direct data available E. tropical Pacific: 45,400 Gulf of Mexico: 3,451	No direct data available Possibly forages at depths of 1500 m Travel speeds: unknown	Hearing No direct data available Sound Production frequency range: 8 – 40 kHz signal type click bursts: 20-40 kHz whistles: 8-12 kHz source levels: 155-165 dB re: 1µPa at 1 m
Long-finned pilot whale (*Globicephala melas*)	IUCN: lower risk/least concern	-All oceans; outside tropical waters, temperate and subpolar waters -20°N to 75°N -5°S to 70°S, excluding North Pacific -Occur along shelf edges in deep pelagic waters -High abundance in Mediterranean Sea	Global estimate: No direct data available N/E Atlantic: 778,000 Antarctic Convergence: 200,000 W. North Atlantic: 14,524	Dive duration: 2 – 13 min Dive depth: 16m day ; 648 m night Travel speeds: 2-12 km/h Travel speed average: 3.3 /h	Hearing No direct data available Sound Production frequency range: 500 Hz – 18 kHz Dominant frequencies: 1-11 kHz signal type double clicks whistles: 4.48 kHz source levels: no direct data available
Short-finned pilot whale (*Globicephala macrorhynchus*)	IUCN-lower risk/conservation dependent	-Tropical, subtropical, and temperate waters -50°N to 40°S -Residents around the California Channel Islands	Global estimate: No direct data available E. tropical Pacific: 160,000 N/W Pacific: 54,000 Gulf of Mexico: 2,388 W. North Atlantic: 14,524	Dive duration: no direct data available Dive depth: 610 m Travel speeds: 2-12 km/h Travel speeds average: 7-9 km/h	Hearing No direct data available Sound Production frequency range: 280 – 100 kHz Dominant frequencies: 2-14 kHz and 30-60 kHz signal type calls: 7.87 kHz source level clicks: 180 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Risso's dolphin (*Grampus griseus*)	IUCN-data deficient species	-Temperate to tropical oceanic waters -55°S to 60°N -Continental slope waters -Shelf-edge habitats between 400 and 1000 m deep -Water temperature 15-20 ºC and rarely below 10 ºC -Common in the north-central Gulf of Mexico and in northwestern Atlantic -Seasonal migrations for Japan and North Atlantic populations	Global estimate: No direct data available E. tropical Pacific: 175,800 N/W Atlantic: 3,500 in summer; 350+ in winter California: 8,500 E. North Pacific: 12,748 W. North Atlantic: 29,110	Diving behavior: no direct data available Possibly forage at 400 m deep Travel speeds: 2-12 km/h	Hearing hearing range: 1.5 -100 kHz at 120 dB re: 1µPa at 1 m Dominant frequency: 4-80 kHz at 63.6-74.3 dB re: 1µPa at 1 m Sound Production frequency range: 100 Hz – 65 kHz Dominant frequencies: 2-5 kHz and 65 kHz Max peak-peak source level: 120 dB re: 1µPa at 1 m at -5 kHz signal type whistles: 4- 22 kHz clicks: 6-22 kHz burst pulses: 2-20 kHz grunts: 400-800 Hz barks: 2-20 kHz buzzes: 2.1-22 kHz chirps: 2-4 kHz source level: 216 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Short-beaked common dolphin (*Delphinus delphis*)	IUCN-lower risk/least concern species	-All oceans; temperate, subtropical, and tropical waters -60°N to 50°S -Along continental shelf and bank regions -Most common 40 ºN-40 ºS in coastal waters of the Pacific Ocean, beyond 200 m isobath and north of 50 ºN in the Atlantic Ocean -Occur southern Norway to West Africa in eastern Atlantic Ocean -From Newfoundland to Florida in the western Atlantic, from Canada to Chile along the coast and pelagically in the eastern Pacific, and in central North Pacific from central Japan to Taiwan -Found around New Caledonia, New Zealand and Tasmania in the western Pacific -Possibly in the South Atlantic and Indian Oceans	Global estimate: No direct data available E. Pacific: 365,617 California: 225,821 N/W Atlantic: 31,000	Maximum dive duration: 5 min Dive depth: 9-200 m Avg dive depth: 9-50 m Maximum dive depth: 260 m Max foraging dive: 200 m Travel speeds: 5.8-16.2 km/h Travel speed max: 37.1 km/h	Hearing hearing range: <5 kHz - 150 kHz at a source level less than or equal to 120 dB re: 1µPa at 1 m Dominant threshold: 65 kHz at 53 dB re: 1µPa at 1 m Sound Production frequency range: 200 Hz – 150 kHz Dominant frequencies: 0.5-18 kHz and 30-60 kHz signal type whistles: 7.4 – 13.6 kHz clicks: 15-100 kHz source level: 180 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Long-beaked common dolphin (*Delphinus capensis*)	IUCN-lower risk/least concern species	-All oceans; temperate, subtropical, and tropical waters -60°N-50°S -Along continental shelf and bank regions -Most common 40 ºN-40 ºS in coastal waters of the Pacific Ocean, beyond 200 m isobath and north of 50 ºN in the -Prefer shallower, warmer waters than short-beaked common dolphins -Occur around West Africa, 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, South Africa. -Possibly around Oman in the Indian Ocean	Global estimate: No direct data available California: 25,163	Maximum dive duration: 5 min Dive depth: 9-200 m Avg dive depth: 9-50 m Maximum dive depth: 260 m Max foraging dive: 200 m Travel speeds: 5.8-16.2 km/h Travel speed max: 37.1 km/h	Hearing hearing range: <5 kHz - 150 kHz at a source level less than or equal to 120 dB re: 1µPa at 1 m Dominant threshold: 65 kHz at 53 dB re: 1µPa at 1 m Sound Production frequency range: 200 Hz – 150 kHz Dominant frequencies: 0.5-18 kHz and 30-60 kHz signal type whistles: 7.7-15.5kHz echolocation clicks: 15-100 kHz source level: 180 dB re: 1µPa at 1 m In the North Atlantic: Mean source level of 143 dB re: 1µPa at 1 m with a max frequency of 154 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Very long-beaked common dolphin (*Delphinus* tropicalis**)**	IUCN-lower risk/least concern species	-Temperate, subtropical, and tropical waters -60°N-50°S -Found only in the northern Indian Ocean and Southeast Asia	No estimate	Maximum dive duration: 5 min Dive depth: 9-200 m Avg dive depth: 9-50 m Maximum dive depth: 260 m Max foraging dive: 200 m Travel speeds: 5.8-16.2 km/h Travel speed max: 37.1 km/h	Hearing hearing range: <5 kHz - 150 kHz Source Level of less than or equal to 120 dB re: 1µPa at 1 m Dominant threshold: 65 kHz at 53 dB re: 1µPa at 1 m Sound Production frequency range: 200 Hz – 150 kHz Dominant frequencies: 0.5-18 kHz and 30-60 kHz signal type

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Fraser's dolphin (*Lagenodelphis hosel*)	IUCN-data deficient species	-All oceans; tropical and subtropical oceanic waters -50°N to 40°S, primarily between 30°N and 30°S -Found near central Visayas, Philippines in nearshore waters, along the outer continental shelf, and in deep oceanic waters -Also in Indonesia and the Lesser Antilles 100 m from shore -15 km and 45-110 km from shore in the E. Tropical Pacific at depths 1500-2000 m -In Sulu Sea, reach depths of 5000 m -Most common in Gulf of Mexico -Occasionally in the Atlantic Ocean	Global estimate: No direct data available E. tropical Pacific: 289,300 Gulf of Mexico: 726	Dive duration: No direct data available Dive depth: 600-700 m Eastern Tropical Pacific depths: <250 m and <500m Sulu Sea depths: <600m South Africa and the Caribbean: feed near surface Travel speeds: 4-7 km/h Travel speed max: 28 km/h	Hearing No direct data available Sound Production frequency range: 4.3 – <40 kHz signal type Clicks: below 40 kH whistles: 4.3 – 24 kHz source levels: no direct data available

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Bottlenose dolphin (*Tursiops truncatus*)	IUCN-data deficient species	-All oceans; temperate, tropical, and subtropical waters -45°N to 50°S and up to 60°N around the United Kingdom and northern Europe -Water temps of 10°-32°C -Primarily coastal but have diverse habitats of rivers and bays, oceanic islands and open ocean, over the continental shelf, and along the shelf break -Common in southern Okhosk Sea, the Kuril Islands, and along central California in the North Pacific -In Atlantic, found inshore during summer months in New England north to Nova Scotia and have been sighted off Norway and Lofoten Islands -Southern range extends as far south as Teirra del Fuego, South Africa, Australia, and New Zealand	Global estimate: No direct data available E. tropical Pacific: 243,500 N/W Pacific: 169,000 Black Sea: 6,900 Shark Bay, Australia: minimum of 3,000 Western N Atlantic and Gulf of Mexico: 30,000-35,000	Dive duration: 38 sec-1.2 min Dive depth: 98 m Maximum dive depth: 535 m Maximum dive duration: 10 min Travel speeds: 4-20 km/h Travel speed average: 6.4-11.5 km/h Travel speed max: 29.9 km/h	Hearing hearing range: 150 Hz - 135 kHz Best hearing frequency: 15 kHz with threshold of 42-52 dB re: 1µPa at 1 m Sound Production frequency range: 50 Hz – 150 kHz Dominant frequency: 0.3-14.5 kHz, 25-30 kHz, and 95-130 kHz signal type Whistles: 4-20 kHz, source level of 125-140 dB re: 1µPa at 1 m burst-pulse clicks: 40-130 kHz In Hawaii: 100-130 kHz source level: 228 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Dolphins (*Stenella* species)	IUCN-data deficient species -clymene and Atlantic spotted dolphins IUCN-lower risk/ conservation dependent species - striped, pantropical spotted, and spinner dolphins	-All oceans; tropical, subtropical, and temperate waters 40°S-40°N -Atlantic Spotted: 50°N-25°S in tropical and warm-temperate waters of the Atlantic Ocean; Commonly found around southeastern United States, in the Caribbean, and off of West Africa; around continental shelf and shelf-break -Striped: tropical and warm-temperate waters below 43°N and associated with convergence zones -Striped dolphins most abundant in the Mediterranean Sea but also in the eastern North Atlantic and south of the United Kingdom. -Pantropical Spotted: tropical and subtropical Indo-West Pacific; 30°N to 40°N and 20°S to 40°S	Global estimate: No direct data available E. tropical Pacific: Pantropical- 2,059,100 Spinner- 1,651,1000 Striped- 1,918,000 Gulf of Mexico: Pantropical- 91,300 Spinner- 12,000 Clymene- 17,300 Atlantic spotted- 31,000 Striped- 6,500	Pantropical dolphins: Dive duration: 1.95 min Dive depth: 100 m Maximum dive depth: 122 m during day; 213 m during night Travel speed max: 39.7 km/h Atlantic spotted dolphins: Maximum dive duration: 3.5 min Striped: Dive depth: 200-700 m foraging Travel speed: 11 km/h Spinner: Dive depth: 600 m foraging Hawaiian spinner dolphins: Travel speed: 2.6-6 km	Hearing hearing range: Striped dolphin: 500 Hz -160 kHz Source level: 120 dB re: 1µPa at 1 m at frequencies less than 10 kHz to greater than 100 kHz Less sensitivity below 32 kHz and above 120 kHz No direct measurement of auditory threshold for the remaining *Stenella* dolphins Sound Production frequency range: 100 Hz – 160 kHz Dominant frequency range: 5-60 kHz, 40-50 kHz, and 130-140 kHz signal type whistles burst-pulse calls clicks: 40-50 kHz and 110-130 kHz source level: 210 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
		-Range from South Africa to the Red Sea and the Persian Gulf, east to Australia, the Indo-Malayan Archipelago, and the Philippines, and north to southern Japan -Spinner: pantropical; 30°N to 40°N and 20°S to 30°S; common in the high seas, but coastal populations exist in the eastern Pacific, Indian Ocean, and Southeast Asia -Pantropical, spinner, and striped dolphins most abundant cetaceans in the E. tropical Pacific -Clymene: tropical to warm-temperate waters of the south and mid-Atlantic Ocean			Atlantic spotted dolphin: Clicks: 60 kHz-120 kHz with low frequency peak 40-50 kHz an high frequency peak 110 kHz-130 kHz Sounds: Whistle-squawks, buzzes, burst-pulses, synch pulses, barks, screams, squawks, tail slaps echolocation clicks: 40-50 kHz and a high frequency peak between 110 and 130 dB re: 1µPa at 1 m Whistles: <20 kHz BroadB re: 1µPa at 1 mand clicks: 60-120 kHz Harmonics: >50 kHz Source level: 223 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Dolphins (*Lagenorhynchus* species)	IUCN - data deficient species: Peale's and dusky dolphins IUCN - lower risk/least concern species: Atlantic white-sided, white-beaked, hourglass and Pacific white-sided dolphins	-Temperate and subpolar areas -Peale's: 60°S to 35°S in southern South America and the Falkland Islands in coastal bays, inlets, and shelf water; occasionally around the Palmerston Atoll -Dusky: N. Peru to Cape Horn and S. Patagonia to 36°S; occur off coastal waters of New Zealand, South America, southwestern Africa, and several islands in the South Atlantic and southern Indian Oceans; from 60° to 9°S -Atlantic white-sided: cold temperate N. Atlantic; 35°N to 80°N; extend over continental slope and deeper waters; Cape Cod is the southern limit; eastern limit is Georges Band and Brittany; extend north to Greendland, southern Iceland, and the south coast of Svalbard Island	Global estimate: No direct data available Pacific White-Sided Dolphins: 30,000-50,000 in Japan 39,800 in eastern North Pacific Hourglass Dolphins: 144,300 hourglass dolphins in the Antarctic Convergence Atlantic White-Sided Dolphins: 77,000 along the North American seaboard White-Beaked Dolphins: 3,486 in the shelf waters along the coast of Labrador 6,000 in the western North Atlantic	Atlantic white-sided dolphin: Dive duration: <1min Dive duration max: 4 min Travel speeds: 2-12 km/h Dusky: Dive duration: 21 seconds Shorter dives during the day, longer dives at night Travel speeds: 4.5-12.2 km/h in New Zealand; 7.7 km/hr in Argentina Peale's: Dive duration: 3-157 seconds Average dive duration: 28 seconds Dive depths: No direct data available Pacific white-sided: Dive depth: 120 Dive duration: 15-20 sec Travel speeds: Up to 27.7 km/h Hourglass: Travel speeds: 7-29 km/h	Hearing hearing range: Pacific white-sided: -500 Hz -135 kHz with source level 120 dB re: 1µPa at 1 m -1 kHz pure tone with source level of 106 dB re: 1µPa at 1 m -2-128 kHz with source level of 90 dB re: 1µPa at 1 m There is no direct measurement of auditory threshold for the rest of the *Lanenorhynchus* dolphins Sound Production frequency range: 60 Hz – 325 kHz Dominant frequencies: 0.3-5 kHz, 4-15 kHz, 6.9-19.2 kHz, and 60-80 kHz signal type clicks source levels: 80 - 211 dB re: 1µPa at 1 m Peale's: broadB re: 1µPa at 1 mand clicks 1-5 kHz at 80 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
		-White-beaked: temperate and subarctic N. Atlantic; in the Western Mediterranean Sea; often in shelf and coastal waters; as far north as White Sea in the northeast Atlantic and abundant along the Norwegian coasts and in the northern parts of the North Sea along the United Kingdom, Belgium, the Netherlands, Germany, and Denmark -Hourglass: High latitudes of the southern hemisphere; 68°-33°S; on both sides of the Atnarctic Convergence and northward in cool currents with the West Wind Drift; Water temperatures from -0.3° - 13.4°C -Pacific white-sided: Temperate; mostly pelagic; 20°N to 61°N on the east and across the North Pacific			White-beaked: Click: Peak frequency: 120 kHz Secondary peak freq: 250 kHz Max source level: 219 dB re: 1µPa at 1 m Min source level: 189 dB re: 1µPa at 1 m Atlantic White-Sided: Maximum source level 164 dB re: 1µPa at 1 m Average source level 154 dB re: 1µPa at 1 m Pacific White-Sided: BroadB re: 1µPa at 1 mand clicks with a source level of 180 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Rough-toothed dolphin (*Steno bredanensis*)	IUCN-data deficient species	-All oceans; deep oceanic tropical, subtropical, and warm-temperate waters -45°-55°N -In the Atlantic, found between the southeastern United States and southern Brazil, across to the Iberian Peninsula and West Africa -Range also includes Gulf of Mexico, Caribbean Sea, and Mediterranean Sea -In the Pacific, range from central Japan to northern Australia, and from Baja, California, Mexico south to Peru	Global estimate: No direct data available E. tropical Pacific: 145,900 Gulf of Mexico: 2,233	Dive duration: 0.5 – 3.5 min Dive depth: 30-70 m Max depth: 70 m Max duration: 15 min Travel speeds: 5.5-16 km/h	Hearing hearing range: Unknown Sound Production frequency range: 100 Hz – 200 kHz signal type clicks: peak of 25 kHz whistles: peaks at 2-14 kHz and 4-7 kHz source levels: No direct data available

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Northern right whale dolphin (*Lissodelphis borealis*)	IUCN-lower risk/least concern species	-Deep, offshore waters in the North Pacific -Cold temperate and Subantarctic -29° to 59°N, most common between 34° to 55°N and 145°w to 18°E -Range from Kuril Islands, Russial, south to Sanriku, Honshu, Japan, and eastward to the Gulf of Alaska and south to Southern California -Prefer cold, deep, offshore waters 8° to 19°C	Global estimate: No direct data available Eastern Pacific: 16,417	Dive duration: <6 min Dive depth: <200 m Max dive duration: 6.25 min Travel speed: 34-40 km/h	Hearing No direct data available Sound Production frequency range: 1– <40 kHz Dominant frequencies: 1.8-3 kHz signal type clicks source level: 170 dB re: 1µPa at 1 m
Southern right whale dolphin (*Lissodelphis peronii*)	IUCN- data deficient species	-Subtropical and Antarctic Convergence Zones -25°S to 65°S -Common in northern Chile	Global estimate: No direct data available	Dive duration: <6 min Dive depth: <200 m Max dive duration: 6.5 min Travel speed: 22 km/h	Hearing No direct data available Sound Production No direct data available

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Dolphins (*Cephalorhynchus* species)	IUCN data deficient species- Commerson's, black, and Heaviside's dolphins IUCN endangered - Hector's dolphin	-Coastal temperate waters of the Southern Hemisphere -Occur in <200 m water; common in surf zone -Commerson's: 40°S to 61°S in the Atlantic; off South America and the Kerguelen Islands in the southern Indian Ocean; mainly in the coastal waters ofArgentina and the Strait of Magellan -Black: 33°S to 55°S; shallow, coastal waters and estuaries and rivers of Chile, the Straits of Magellan, the channels of Tierra del Fuego, and along the west coast of Chile -Hector's: 41°S to 44°S and 36° to 38°S; shallow waters off New Zealand	Global estimate: No available data Hector's dolphins: 3,408 Commerson's dolphins: 718 in Straits of Magellan	Heaviside's dolphins: Dive duration: > 2 min Dive depth: > 20 m Maximum dive depth: 104 m by male; 92 m by female Hector's dolphins: Dive duration: 89 seconds Travel speeds: No available data	Hearing No direct data available Sound Production frequency range: 320 Hz – 150 kHz Dominant frequency range: 0.8-1 kHz, 1-2 Khz, 4-4.5 kHz, 116-134 kHz signal type clicks: 120-130 kHz source levels: 160 - 163 dB re: 1µPa at 1 m Commerson's: Cry: <10 kHz Dominant frequencies: 200 Hz, 1 kHz, and 5 kHz LF clicks: 6 kHz Dominant frequencies: 1-2.4 kHz Max source level: 160 dB re: 1µPa at 1 m Heaviside's: Frequency range: <2kHz and 5 kHz Dominant frequency: 800 Hz
		-Heaviside's: found along the west coast of southern Africa and Nambia from 17°S on Namibian coast to Cape Town at 34°S and near shallow waters no deeper than 100 m			Hector's: Frequency range: 125 kHz Max source level: 163.2 dB re: 1µPa at 1 m Commerson's and Hector's produce HF narrow band clicks with most energy focused around 120-130 kHz and little to no energy below 100 kHz

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Harbor porpoise (*Phocoena phocoena*)	ESA: Gulf of Maine stock candidate species IUCN- vulnerable	-Cold temperate to subarctic coastal waters of Northern Hemisphere -15°N to 70°N -Most in waters 5°-16°C and some in 0°-4°C -Mostly coastal	Global estimate: No direct data available N. Atlantic: 456,717 California: 52,743 North Sea: 341,000 in 1994 Gulf of Maine: 89,700	Dive duration: 0.7-1.71 min Maximum dive duration: 9 min Dive depth: 20 - 130 m Maximum dive depth: 226 m Travel speeds: 16.6 to 22.2 km/h	Hearing hearing range: 100 Hz - 140 kHz Source level: 120 dB re: 1µPa at 1 m Dominant frequencies: 16-140 kHz in juveniles Sound Production frequency range: 40 Hz – 150 kHz Dominant frequencies: 2 kHz and 110-150 kHz signal type clicks: 110 - 150 kHz LF calls: 1.4 – 2.5 kHz whistles: 40 – 600 Hz source level: 177 dB re: 1µPa at 1 m
Dall's porpoise (*Phocoenoides dalli*)	IUCN-lower risk/conservation dependant	-N. Pacific, Bering Sea, Okhotsk Sea, and Sea of Japan -28°N to 63°N -Including southern California and southern Japan -Deep offshore waters and deep nearshore waters	Global estimate: 1.4 to 2.8 million Eastern Pacific: 75,900	Dive duration: 8 min Dive depth: 275 m Travel speeds: 2.4-21.6 km/h Max travel speed: 55 km/h	Hearing Estimated reaction threshold 20-100 kHz at 116-130 dB re: 1µPa at 1 m Sound Production frequency range: 40 Hz – 160 kHz signal type LF clicks: 40 Hz - 12 kHz Narrow band clicks: 120-130 kHz source level: 175 dB re: 1µPa at 1 m

Table 3.2-4. Information Summary for Odontocetes

Species	Protected Status	Distribution	Abundance	Diving Behavior And Travel Speeds	Underwater Hearing/Sound Production
Spectacled porpoise (*Phocoena dioptrica*)	IUCN: Data Deficient	-Circumpolar in the southern hemisphere -Cool temperate, sub- and low-Antarctic waters -32°S to 59°S -Brazil to Argentina in offshore waters and around offshore islands including Tierra del Fuego, the Falklands, and South Georgia in the southwestern South Atlantic; Aukland and Macquarie in the southwestern Pacific; and Heard and Kergulen in the southern Indian Ocean	Unknown	Unknown	Unknown

3.2.5 Pinnipeds

Pinnipeds (sea lions, seals, and walruses) are globally distributed amphibious mammals with varying degrees of aquatic specialization (Gentry, 1998). There are up to 37 living species in the suborder, which includes eared seals (family Otariidae), true or earless seals (family Phocidae), and walruses (family Odobenidae) (Berta, 2002). Walruses are not found near SURTASS LFA sonar operation areas and will not be discussed in this document.

Compared to phocids, 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. The ears of otariids have ear flaps and are similar to carnivore ears, while phocid ears have no external features and are more water-adapted. Otariids have also retained their fur coats (Berta, 2002), while 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. Due to the otariid's need to hunt, they 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 3200 kg (99 to 7,055 lb) and from approximately one meter (3 ft) to 5 m (16 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., 2002). Pinnipeds were hunted for their furs, blubber, hides, and organs. Some stocks have begun to recover. However, species such as the northern fur seal and the Steller sea lions are still declining (Gentry, 2002). 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 feed on a variety of prey items, mainly fish and cephalopods, but also eat krill and crustaceans. Some pinnipeds are also known to eat other pinnipeds. For example, Steller sea lions are known to eat harbor, bearded, ringed, northern fur, and spotted seals. Pinnipeds usually feed underwater, 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 while adult harbor seals eat benthic animals. The amount of benthic prey in the diet of the bearded seal also increases with age (Berta, 2002; Bowen et al., 2002). 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 millions 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 (Bowen et al., 2002). Phocids are circumpolar but are most abundant in the North Atlantic and Antarctic Ocean, found in both temperate and polar waters (Bowen et al., 2002). The northern fur seal, Cape fur seal, and Antarctic 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., 2002).

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., 2002). 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 both tropical and polar waters. Some species have even adapted to live in fresh and estuarine waters (Berta, 2002).

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 (Berta, 2002). Pinnipeds are generally long-lived with estimates of longevity up to 40 years or more (Berta, 2002). Age of sexual maturity ranges from 2 to 6 years (Boyd, 2002). 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. Smaller species dive on average for 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, 2002).

Hearing capabilities and sound production is 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, 2002; Frankel, 2002; Van Parijs and Kovacs, 2002). 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. Underwater, pinnipeds can vocalize using whistles, trills, clicks, bleats, chirps, and buzzes as well as lyrical calls (Schusterman, 1978; Berta, 2002; Frankel, 2002). 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. Studies that have examined the hearing capabilities of some pinniped species, particularly ringed seals, harp seals, harbor seals, California sea lions, and northern fur seals (Mohl, 1968; Terhune and Ronald, 1972; 1975a; 1975b; Kastak and Schusterman, 1996, 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 man-made 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 underwater with a threshold of 89.9 dB RL at 100 Hz. Kastak and Schusterman (1996; 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, 1968; Terhune and Ronald, 1972, 1975; Terhune 1991). In a recent study, Kastak and Schusterman (1996) 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.

California sea lions are one of the few otariid species whose underwater sounds have been well studied. Other otariid species with documented vocalizations are the South American sea lions and northern fur seals (Fern’ndez-Juricic et al., 1999; Insley, 2000). Otariid hearing abilities are thought to be intermediate between Hawaiian monk seal 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: both in Richardson et al., 1995).

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

The family Otariidae is divided into two groups containing nine species of fur seals (*Arctocephalinae)* and seven species of sea lions (*Otariinae)*. Table 3.2.5 summarizes information on the status, distribution, abundance, diving behavior, sound production and hearing of Otariidae species being evaluated for potential impacts.

Fur Seals (*Arctocephalinae)*

The genus *Arctocephaus*, or southern fur seals, consists of eight species: Southern American fur seal (*A. australis*), New Zealand fur seal *(A. forsteri)*, Antarctic fur seal *(A. gazelle)*, Galapagos fur seal *(A. galapagoenisi)*, Juan Fernandez fur seal *(A. philippii)*, South African and Australian fur seals (*A. pusillus)*(consisting of two subspecies—South African fur seal (*A. p. pusillus)* and

Australian fur seal (*A. p. doriferus)),* Guadalupe fur seal (*A. townsendi),* and sub-Antarctic fur seals (*Arctocephalus tropicalis*) (Berta, 2002). The genus *Callorhinus* has a single species, the northern fur seal *(C. ursinus).* Antarctic fur seal (*Arctocephalus gazelle)* can be excluded from further analysis because it is a polar species.

South American fur seal (Arctocephalus australis), also known as the southern fur seal, are not listed under the IUCN. Their abundance is not well known. In 1976, there were approximately 40,000 seals in southern Chile. In 1982, there were 228 seals counted along the northern Chilean coast (22 to 23N). The Falkland Islands had a population estimated to be between 14,000 and 16,000 individuals in 1973. There were approximately 2,700 along the Argentinean coast in 1954. Two newer breeding colonies have been established on Staten Island and numbers have increased on a small island near Ushuaia. In 1979, almost 20,000 fur seals inhabited the Peruvian coast, primarily at Point San Fernando, San Fernando Islet, and Point San Juan. The majority of the population is in Uruguayan waters, with an estimated 280,000 fur seals (Reeves et al., 1992). More recently, Gentry (2002) estimated a total of 285,000 fur seals, with numbers continuing to increase.

South American fur seals occur at the Falkland Islands, including Volunteer Rocks, Elephant Jason Island, and New Island, and along the coasts of South America. They range as far north as southern Brazil in the Atlantic and near Paracas, Peru in the Pacific (Reeves et al., 1992). In the Atlantic, they can be found along the coast of Argentina to Uruguay. They prefer to haul out and breed on rocky beaches (Reeves et al., 2002). Females usually remain close to the rookery year-round. Males are sometimes seen seasonally up to 200 km (124 mi) offshore (Reeves et al., 1992).

In the Uruguayan islands, pupping occurs from November through December, with the majority of pups born in late November and early December. Along the Peruvian coast, pupping and breeding occurs from mid-October through mid-December, with the majority of pups born in November (Reeves et al., 1992).

Postpartum females alternate days foraging and nursing their pups. They will spend an average of 4.6 days at sea feeding and 1.3 days ashore nursing. The females dive and feed mostly at night, reaching depths of 40 m (131 ft) for close to 3 min. They have been recorded diving for up to 7 min and to maximum depths of 170 m (558 ft) (Reeves et al., 1992). South American fur seals eat sardines, southern anchovy, and jack mackerel (Bowen, 2002).

New Zealand fur seals (*Arctocephalus forsteri*) are a temperate species having two main breeding populations. One population is on the South Island of New Zealand and the second is along southeastern Australia. 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 sub-Antarctic Chatham, Campbell, Antipodes, Bounty, Aukland, and Macquarie Islands, and at Kangaroo Island off southern Australia. During the non-breeding season, they can be found as far west as Perth and as far northeast as Queensland, Australia and New Caledonia (Reeves et al., 2002). Newer colonies have been established at Kaikoura, Banks Peninsula, and Otago along the Nelson coast of New Zealand (Reeves et al., 1992). Their eastern boundaries lay at Bounty, Antipodes, and Chatham Islands and Snares, Aukland, and Campbell Islands to the south (Arnould, 2002).

In Australia, their abundance was estimated to total 35,000 in 1991. In the late 1980's, the population on Macquarie Island for non-breeding seals in April and May was estimated to be 2,000 individuals (Reeves et al., 2002). Gentry (2002) estimates the total population to be 135,000 individuals.

New Zealand fur seals eat mostly cephalopods and bony fish, but sometimes replace fish with rock lobster (Gentry, 2002). Males may also eat seabirds and penguins. Seals forage at night, diving between 10 and 15 m (35 and 50 ft). Their dives are usually deepest closer to dawn and dusk, with their longest dive bouts at night. Their dives are shallowest and shortest during the summer and deeper and longer during the autumn and winter (Reeves et al., 2002). Lactating females have been recorded as diving as deep as 274 m (898 ft). The average depths of their dive bouts are 5 to 10 m (16.4 to 32.8 ft). The longest measured dive was for 11 min (Stewart, 2002).

In-air vocalizations of the New Zealand fur seal haVE been described as a full-threat call. These individually distinctive vocalizations are emitted by males during the breeding season (Stirling, 1971). The hearing capabilities of this species are unknown.

Galapagos fur seals (*Arctocephalus galapagoensis*) are the smallest of the otariids and are the only fur seals that breed in a tropical climate (Reeves et al., 2002). They are also the only southern fur seal to extend their range into the northern hemisphere (Arnould, 2002). Their population size is unknown, although believed to be around 40,000 individuals and are therefore the rarest of the southern fur seals (Arnould, 2002; Gentry, 2002). Galapagos fur seals are listed as vulnerable under the IUCN. The Ecuadorian government prohibits the hunting of Galapagos fur seals, and this law has become well-enforced since the islands became a national park (Reeves et al., 2002).

Galapagos fur seals are non-migratory. Their range is centered around 1 deg S latitude and approximately 1,100 km (684 mi) west of Ecuador (Reeves et al., 1992). They only breed in the Galapagos Islands at 15 islands in the archipelago. The largest colonies are found at Isabela Island, which boasts one-third of their population, and at Fernandina Island. When they haul out, they typically seek shelter behind large boulders and in caves to avoid the heat. Males also stake their territories in the splash zone on the beach. Most of their breeding sites are on west-facing beaches because they are closer to the cool upwelling waters which circulate around the islands and create a higher productivity for prey species (Reeves et al., 2002).

The Galapagos fur seals feed mostly on lanternfish and squid. The seals forage most during new moons. This is believed to be because their prey migrate vertically and they come closer to the surface during the new moon (Reeves et al., 2002). 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 seconds. Yearlings dive to 47 m (150 ft) for 2.5 mi, and eighteen-month old juveniles dive up to 61 m (200 ft) for 3 min (Reeves et al., 2002; Stewart, 2002). The longest and deepest dive recorded by a Galapagos fur seal was for 6.5 min at a depth of 169 m (555 ft) (Reeves et al., 2002).

There is no information available on the hearing abilities or sound production of this species.

Juan Fernandez fur seals (*Arctocephalus philippi)* are classified as a vulnerable species under the IUCN. They were believed to be extinct until 1965 when a scientist discovered about 200 fur seals in the islands. The population was estimated to be around 12,000 in the late 1990's (Reeves et al., 2002) and was estimated to be around 18,000 in 2002 (Gentry, 2002).

Juan Fernandez fur seals are restricted to the Juan Fernandez island group, including Mas a Tierra or Robinson Crusoe, Santa Clara, and Mas Afuera or Alejandro Selkirk, and the San Feliz island group, including San Ambrosio and San Felix, off the coast of north central Chile. Breeding occurs on Mas a Tierra, Mas Afuera, and Santa Clara Islands. They haul out but do not breed on San Ambrosio Island (Reeves et al., 1992). In autumn and winter, vagrant fur seals have been recorded as far south as Punta San Juan, Chile, and as far north as Peru. They prefer to haul out in caves and on beaches with rocky, volcanic substrates, particularly on bluffs (Reeves et al., 2002).

Breeding occurs from mid-November to January (Reeves et al., 1992, 2002). Most pups are born in late November and December (Reeves et al., 1992). After mating, females have long foraging trips, lasting an average of 12 days with the longest lasting up to 25 days (Reeves et al. 2002).

Lactating females eat lanternfish and squid. They will forage at depths between 10 and 90 m (35 and 300 ft), reaching as far as 500 km (300 mi) offshore. They mainly feed and dive at night when their prey are migrating in the water column (Reeves et al., 2002). Their dives typically last 1.7 to 2 min (Stewart, 2002). Nothing is known about the diving habits of males, non-lactating females, or juveniles (Reeves et al., 2002).

South African/Australian fur seals (*Arctocephalus pusillus)* consists of two subspecies—**South African fur seal (*A. p. pusillus)*** and **Australian fur seal (*A. p. doriferus)***. The subspecies status is based on their slight cranial differences and on their location. The South African fur seal is believed to be the parent stock of the Australian fur seal (Reeves et al., 1992). The Australian fur seals, also known as Tasmanian fur seals, are closely related to the South African fur seal. However, their temperate distribution has made them a separate subspecies.

South African fur seals (A. *p. pusillus*) occur along the coast of South Africa and Namibia (Reeves et al., 1992). Their population numbers are unknown, but they are estimated to number several hundred thousand or more. Gentry (2002) estimated that the abundance of South African fur seals was around 1,700,000 individuals.

They have breeding colonies and haul-out sites from Cape Cross, Namibia around the Cape of Good Hope to Black Rocks, Cape Province and reaching west to Angola and south to Marion Island (Reeves et al., 2002). They may reach as far south as 11S, following the coastal Benguela Current (Reeves et al., 1992).

South African fur seals often breed and pup on small rocky islands. However, there are also several colonies on the mainland. Bulls arrive to the rookeries before the females, usually in mid-

October to early November (Reeves et al., 1992). Pupping typically occurs from late October through late December (Reeves et al., 1992; 2002). The females leave the rookeries for approximately seven days in the winter and four days in the summer for a postpartum feeding trip (Reeves et al., 2002).

Fur seals feed on fish and cephalopods, particularly mackerel, pilchard, Cape hakes, and anchovies. They feed within approximately 5 km (3.1 mi) of land and are believed to be non-migratory. Lactating females dive an average depth of 40 to 50 m (131.2 to 164 ft) for 1.5 to 2.5 min. The maximum recorded depth and durations for two females were 204 m (669 ft) and 7.5 min. However, dives deeper than 150 m (492 ft) were not common. Daytime dives are typically shallower than nighttime dives (Reeves et al., 1992) and they typically travel alone at sea but forage in groups (Reeves et al., 2002).

Australian fur seals (*Arctocephalus pusillus doriferus*) are the largest species of fur seals. Most of their breeding and haul out sites are protected by Australian federal, state, and territorial laws. In 1991, their abundance was estimated at 47,000 to 60,000 off southeast Australia and 15,000 to 20,000 off Tasmania (Reeves et al., 2002). Gentry (2002) estimated that there was a total of 60,000 Australia fur seals and stated that their populations are stable.

Australian fur seals are believed to be non-migratory. They breed in the Bass Strait on four islands off Victoria in southeast Australia and at five islands off Tasmania. The largest colonies are found at Lady Julia Percy Island, Seal Rocks, and Reid and Judgement Rocks off Tasmania. Vagrants have been seen as far north as Port Stephens in New South Wales (Reeves et al., 1992; Reeves et al., 2002). Maatsuyker Island is also an important haulout for fur seals (Arnould, 2002).

Bass Strait waters are nutrient-poor (Arnould, 2002). Fur seals must forage over the continental shelf and at the sea bottom, searching under rocks for squid and octopus (Gentry, 2002; Reeves et al., 2002).

Females dive to the seabed of the continental shelf, a depth of 65 to 85 m (213 to 279 ft). The average dive depth for males is 14 m (46 ft) for an average duration of 2.5 min, with deepest dives recorded at 102 m (338 ft) for 6.8 min (Reeves et al., 2002). Australian fur seals spend approximately one-third of their time at sea (Stewart, 2002).

There is no information available on the hearing abilities or sound production of this species.

Guadalupe fur seals *(Arctocephalus townsendi)* are currently classified as threatened under ESA, CITES protected and considered a vulnerable species under IUCN. The worldwide population size for this species is unknown. Estimates of 7,400 have been documented on Guadalupe Island, Mexico (Gallo-Reynoso, 1994).

Guadalupe fur seals are found in temperate waters off the eastern coast of Guadalupe Island, Mexico and along the coast of southern California. They prefer either a rocky habitat or volcanic caves. Currently the species only breeds on the eastern coast of Guadalupe Island. The stock of Guadalupe fur seals returns to Guadalupe Island to breed during the summer and again in the fall-winter to molt. Female Guadalupe fur seals give birth in June. It appears that the individuals are faithful to the same breeding site from year to year (Reeves et al., 1992).

Swim speeds of this species range from 1.8 to 2.0 m/s (3.4 to 3.9 knots) (Croll et al., 1999). Guadalupe fur seals are shallow divers, foraging within the upper 30 m (100 ft) of the water column. The average dive duration is near 2.6 min at depths near 61 m (200 ft) (Gallo-Reynoso, 1994; Reeves et al. 2002). Their diet consists of squid and lanternfish (Reeves et al., 2002).

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 is that males produce airborne territorial calls during the breeding season (Pierson, 1987).

Sub-Antarctic fur seals (*Arctocephalus tropicalis*) occur in the sub-Antarctic islands north of the Antarctic Convergence. The population of fur seals is believed to be between 280,000 and 350,000 individuals, with numbers continuing to increase. In 1995, the population at Macquarie Island was estimated to be around 110. In the early 1990s, there were approximately 50,000 sub-Antarctic fur seals at Amsterdam Island. In 1978, the population at Gough Island was estimated to be around 200,000 and was increasing (Reeves et al., 2002). Gentry (2002) estimated that there were more than 310,000 sub-Antarctic fur seals.

Sub-Antarctic fur seals haul out and breed 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. Occasionally, adult males have been seen near Brazil, Cape of Good Hope, and Australia. Males begin arriving at the islands in November and begin leaving in January. At Gough Island, most rookeries are on the western side of the island, on the windward coasts where the ocean spray and the wind have a cooling effect and help to reduce heat stress (Reeves et al., 1992). They prefer to breed in rocky coastal habitats while non-breeding animals haul out on tussock slopes above the beaches (Reeves et al., 2002).

Pupping occurs from late November to December (Reeves et al., 2002). Lactating females alternate their foraging days at sea and days on land. Their trips in the winter typically are longer and may last up to 28 days (Reeves et al., 2002). Their diet includes fish, cephalopods, and occasionally rockhopper penguins (Reeves et al., 1992). They commonly dive to depths of around 15 to 20 m (50 to 65 ft) in the summer and to 30 m (100 ft) in the winter. Each dive typically lasts 1 to 1.5 min. The deepest recorded dive was to 208 m (682 ft) and the longest dive lasted 6.5 min. Nocturnal diving is common at some sites (Reeves et al., 2002; Stewart, 2002).

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. The primary call of the female is a loud, tonal honk to call their pups (Reeves et al., 2002).

Northern fur seals (*Callorhinus ursinus*) are currently classified as a vulnerable species under IUCN and depleted under the MMPA. The worldwide population size for this species is estimated near 1.2 million (Gentry, 2002). Fur seals were harvested for their pelts beginning in 1771-1772 when they were discovered (Reeves et al., 1992).

Northern fur seals are subpolar animals widely distributed across the North Pacific in November and December, and are generally associated with the continental shelf break in the North Pacific. Males arrive at breeding grounds in the Bering Sea during May and June, while females arrive in July and early August (Gentry, 1998). Breeding locations are predictable due to site fidelity. Thirty-one breeding sites exist on Bering Island in the Commander Islands of Russia, which have been occupied since at least 1742. Other sites include the Pribilof Islands, Robben Island in the Sea of Okhotsk, the Kuril Islands, Bogoslof Island, and San Miguel Island for California (Gentry, 2002; Reeves et al., 2002). 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. They are typically solitary when observed at sea (Reeves et al., 2002). Some pups have also been seen along the Washington, British Columbia, and Japan coasts (Gentry, 2002).

Routine swim speeds of this species are reported between 1.5 to 1.9 m/s (2.9 to 3.7 knots) (Williams, 2002). 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 (Reeves et al., 1992). They forage primarily on small surface-schooling fish (e.g. Pollack, mackerel, capelin, herring, and eulachon) and squid in the upper 100 m (345 ft) of the water column. Northern fur seals do not feed on top of the continental shelf; instead, they forage along the shelf break. Diving behavior changes based on the behavior of prey (Gentry, 2002).

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 4 and 28 kHz.

Northern fur seals are known to produce clicks and high frequency sounds underwater (Frankel, 2002). Estimated source levels and frequency ranges are unknown. There are no available data regarding seasonal or geographical variation in the sound production of this species. There is evidence of long-term, on-land vocal recognition between mother and pup (Insley, 2000).

Sea Lions (*Otariinae)*

The genus *Otariinae*, or sea lions, consist of five living genera and seven species including Northern sea lions *(Eumetopias jubatus*) (also known as the Steller sea lion), California sea lions (*Zalophus californianus*), Australian sea lions (*Neophoca cinerea*), New Zealand sea lions (*Phocartos hookeri*) (also known as Hooker's sea lions), Galapagos sea lions (*Zalophus californianus wollebaeki*), Japanese sea lions (*Zalophus californianus japonicus*), and southern sea lion (*Otaria flavescens).*

Northern sea lions *(Eumetopias jubatus*) are also known as Steller sea lions. The stock west of 144W longitude was recently reclassified as endangered, and the threatened listing is being maintained for the remaining stock (FR Vol. 62 No. 86). They are classified as an endangered species under IUCN. The worldwide population size for this species was estimated near 100,000 in 1994 (Loughlin, 2002).

Northern sea lions are found in temperate or sub-polar waters and are widely distributed throughout the North Pacific and southern Bering Sea from Japan to California. 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 in Alaska and the southernmost rookery is found at Ano Nuevo Island in California (Loughlin, 2002). Smaller rookeries exist on Southeast Farallon Island, Cape St. George in California, along the Oxford and Rogue reefs in Oregon, and along the British Columbia coast at Cape St. James and North Danger Rocks (Reeves et al., 1992). They may haul out on sea ice in the Bering Sea and the Sea of Okhotsk, which is unusual for otariids (Reeves et al., 2002).

When females forage with pups during the summer, the trip may last an average of 18 to 25 hours; and they may travel up to17 km (10.6 mi). They dive an average of 4.75 hours per day. During the winter, females may travel for 200 hours with a trip length of approximately 130 km (81 mi) and dive for approximately 5.3 hours per day. The estimated home range in the summer for adult females is approximately 320 sq km (199 sq mi). In the winter the estimated home range is 47,600 sq km (29,577 sq mi) for adult females and 9,200 sq km (5717 sq mi) for yearlings (Loughlin, 2002).

Swim speeds of this species are not known. The maximum recorded dive depth is 328 m (1,076 ft). Average dive depths are 21 m (69 ft) and generally last for less than 1 min. Deeper dives are usually less than 250 m (820 ft). They forage primarily on small surface-schooling fish. Northern sea lions eat a variety of species, including pollock, cod, mackerel, herring, flatfish, sculpins, octopus, and squid. Females with pups usually feed at night during the breeding season but feeding occurs at all times when breeding season ends (Laughlin, 2002).

Northern sea lion underwater sounds have been described as clicks and growls (Poulter, 1968; Frankel, 2002). 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 (Laughlin, 2002). There is no available data regarding seasonal or geographical variation in the sound production of this species.

Kastelein et al. (2005) studied the differences between male and female northern seal lion hearing and vocalizations. They described male in-air vocalizations as belches, growls, snorts, scolds, and hisses, and are believed to be mainly related to the breeding season. The female and pup in-air vocalizations are described as bellows and bleats. The underwater vocalizations are belches, barks, and clicks. Their study was conducted because northern sea lion hearing may not resemble that of other tested *Otariids* and because there are large size differences between male and females which mean there could be differences in the size structure of hearing organs and therefore differences in hearing sensitivities. The background noise levels used in this study were given in equivalent sound-pressure spectrum levels, or time-averaged levels of fluctuating noise. The underwater audiogram of the male showed his maximum hearing sensitivity at 77 dB RL at 1 kHz. The range of his best hearing, at 10 dB from the maximum sensitivity, was between 1 and 16 kHz. His average pre-stimulus responses occurred at low frequency signals. The female's maximum hearing sensitivity, at 73 dB RL, occurred at 25 kHz. This study showed a difference of hearing threshold between the male and female due to frequency. 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 northern 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 northern sea lions in this study. This study also showed that low frequency sounds are audible (Kastelein et al., 2005).

California sea lions (*Zalophus californianus*) are common along the Pacific coast of the United States and Mexico. They are common as far north as Vancouver Island but may reach as far north as Prince William Sound, Alaska and are found as far south as Chiapas, Mexico (Heath, 2002). California sea lions breed mostly on the Channel Islands and the Pacific islands along Baja, California, Mexico in the Gulf of California (Reeves et al., 2002). Pups are rarely born as far north as the Farralon Islands off central California (Heath, 2002). Females and juveniles do not migrate extensively. However, males migrate north after the breeding season (Reeves et al., 2002). The largest California sea lion colony is on San Miguel Island (Reeves et al., 1992).
California sea lions haul out and travel in large numbers, preferably on sandy beaches. They breed in areas of high productivity due to foraging requirements during lactation (Heath, 2002). They feed mostly in cool upwelling waters along the continental shelf and seamounts and occasionally on the ocean bottom. They feed mostly on anchovy, squid, sardines, mackerel, rockfish, whiting, and blacksmith (Reeves et al., 2002).

In the summer, females may dive up to 75 m (245 ft), remaining submerged for 4 min at a time. For the rest of the year, the females typically dive deeper and longer. The maximum depth recorded was 536 m (1,760 ft). The maximum duration of a dive recorded was for 12 min. California sea lions spend several days at a time at sea, diving for most of that time (Reeves et al., 2002).

The most recent population estimates in the United States is a minimum of 139,000 individuals, with 49,000 pups born in 2001. The population in Mexico was estimated to be between 13,000 and 22,000. The total population is estimated to be 211,000 to 241,000 (Heath, 2002).

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).

Southall et al. (2005) examined the reliability of underwater hearing thresholds in pinnipeds. They found that underwater, low frequency behavioral hearing thresholds from the study years 2000 and 2001 for California sea lions were not statistically different compared to studies conducted four to seven years earlier. There were no measurable reductions in hearing sensitivity for the frequencies tested despite that the research conducted in 1996 and 2000 involved several hundred controlled noise exposures at similar frequencies resulting in auditory masking and a lesser number of exposures known to induce temporary hearing losses of 6 dB or greater (18 occurrences in California sea lions). The results from these tests suggest that hearing abilities in some mammals, including those regularly exposed to moderate levels of noise, may remain relatively unchanged over multiple years prior to senescence (aging) (Southall et al., 2005).

Underwater sounds produced by California sea lions include barks, clicks, buzzing, and winnies. Barks are less than 8 kHz with the dominant frequencies below 3.5 kHz. The winny call is typically between 1 to 3 kHz, and the clicks have dominant frequencies between 500 Hz to 4 kHz. Buzzing sounds are generally from less than 1 kHz to 4 kHz, with the dominant frequencies occurring below 1 kHz (Schusterman, 1967).

Australian sea lions (*Neophoca cinerea*) are a temperate species found between 28 and 38S (Ling, 2002). Their range is limited to Australia. The largest colony is found in eastern South Australia with 28 other colonies in Western Australia and 38 colonies in South Australia (Reeves et al., 2002). Australian sea lions have an estimated total population ranging between 9,300 and 12,000 (Gentry, 2002). The Seal Bay area has been designated as a conservation park for the sea lions (Ling, 2002).

Australian sea lions have a breeding range from Houtman Abrolhos in western Australia east to the Pages Islands near Kangaroo Island. The largest breeding colonies are found on Purdie Island, Dangerous Reef, Seal Bay on Kangaroo Island, and the Island of the Pages. Mainland breeding colonies exist at Point Labatt in southern Australia and near Twilight Cove (Thundula) in Western Australia. Australian sea lions prefer to haul out on sandy beaches and on rocky reefs but have been known to wander inland several kilometers. They are typically found in smaller breeding colonies of several hundred or less. They are primarily asocial except during breeding season (Reeves et al., 2002).

Females and juveniles do not typically migrate. During the non-breeding season, males migrate widely along the western coast. Vagrants are found as far north as Shark Bay and as far east as Portland, Victoria (Reeves et al., 2002).

Female Australian sea lions forage locally. Their diet is poorly known, but it is assumed that they eat mostly fish, small sharks, octopus, squid, and occasionally penguins. They feed mostly on the sea floor within 30 km (20 mi) of the shore at a depth of 150 m (492 ft) (Reeves et al., 2002).

There is no information available on the hearing abilities or sound production of this species.

New Zealand sea lions, also known as **Hooker's sea lions (*Phocartos hookeri*),** range along the Auckland Islands. They are listed under the IUCN as vulnerable with an estimated abundance of 12,500 to 13,000 individuals (Gentry, 2002; Gales, 2002).

New Zealand sea lions are found in a range of temperate habitats including sandy beaches, reef flats, grass and herb fields, dense bush and forests, and bedrock. They may also wander several kilometers inland (Gales, 2002). Their range centers around the Auckland Islands, approximately 400 km (249 mi) south of Stewart Island (Reeves et al., 1992). Approximately 95 percent of pups are born at Enderby, Dundas, and the Figure Eight Islands. Smaller colonies exist on Campbell Island and the Snares Islands. They typically spend more time at sea in the fall and the winter

(Reeves et al., 2002). Males haul out in the fall and winter at Port Pegasus on Stewart Island. Males also occur year-round at Otago Peninsula at Papanui Beach on the mainland of South Island, New Zealand. Males can migrate 600 km (375 mi) south of the Aucklands to Macquarie Island. Vagrants have also been identified in Maori middens on North Island, Cape Kidnappers, and Coromandel Peninsula.

The diet of New Zealand sea lions includes flounder, octopus, opalfish, munida, hoki, rattail, salps, squid, and crustaceans. Males may also eat seabirds, penguins, and seal pups (Gales, 2002; Reeves et al., 2002). Lactating females typically forage in benthic habitats. They may dive up to 120 m (400 ft) for 4 min at a time, diving continuously to the sea floor (Reeves et al., 2002). New Zealand sea lions are the deepest and longest divers of the otariids. On average, they make 7.5 dives an hour, spending 45 percent of that time submerged. Their average dive is 123 m (404 ft) in depth. The maximum recorded depth for a dive was approximately 500 m (1,640 ft). The average time that sea lions spend submerged at depths less than 6 m (19.7 ft) is 3.9 min. The maximum time recorded on a dive was 11.3 min (Gales, 2002). Swim speed is typically about 1 m/s (1.9 knots) (Williams, 2002).

Hooker sea lions all bark and produce clicks underwater (Poulter, 1968). There is no information available on the hearing abilities of this species.

Galapagos sea lions (*Zalophus californianus wollebaeki*) are an equatorial subspecies related to California sea lions. They are classified as a vulnerable species under IUCN. Their range is restricted to the Galapagos Islands with a small colony on La Plata Island off Ecuador. Occasionally, vagrants can be seen along the Ecuador and Columbia coasts, particularly around Isla del Coco, Costa Rica, and Isla del Gorgona (Heath, 2002). They typically haul out and travel in large numbers (Reeves et al., 2002).

The Galapagos sea lions' diet is associated with the isolated areas of high productivity found around the nutrient-rich upwelling areas of the Galapagos Archipelago. Sardines are a staple in their diet (Heath, 2002). They also eat anchovy, squid, mackerel, and rockfish. Galapagos sea lions forage along the continental shelf and seamounts and occasionally on the ocean bottom (Reeves et al., 2002). They forage within a few kilometers of the coast, feeding only at daytime. Their dives average 37 m (121 ft) but have been known to reach as deep as 186 m (610 ft) (Heath, 2002). Average dive duration is less than 2 min, and maximum recorded dive duration is 6.0 min (Kooyman and Trillmich, 1986). Swim speed is typically about 2 m/s (3.9 knots) (Williams, 2002).

There is no information available on the hearing abilities or sound production of this species.

Japanese sea lions (*Zalophus californianus japonicus*) are also a subspecies related to California sea lions. This temperate subspecies is believed to be extinct; there have been no reliable sightings since the 1950's. The subspecies is classified as extinct under IUCN. They are believed to have ranged along the southern coast of Kamchatka into the southern Sea of Japan (Reeves et al., 2002). Their range centered along the coasts of Honshu, off Shikoku and Kyoshu in Seto Inland Sea and in the islands of the Sea of Japan and the Izu region (Heath, 2002).

Rookeries existed at Takeshima, Ullung-do, the northwest and central-eastern coasts of Honshu, and four islands in the Izu region. Vagrants were seen in the southwestern Sea of Okhotsk, the Kuril Islands, southern Kamchatka, and the east coast of South Korea. There is no foraging information on Japanese sea lions (Heath, 2002).

South American sea lions (*Ottaria byronia*) are also known as the southern sea lion. In the early 1980's, the world population was estimated to be around 300,000. There are approximately 34,000 in Peru, 9,000 in Chile, more than 170,000 in Argentina, and at least 30,000 in Uruguay (Reeves et al., 1992). Cappozzo (2002) estimates 110,000 live on the southwestern Atlantic coast, concentrated mainly around Patagonia and the southern islands but there is no reliable information to estimate the population size on the Pacific coast.

South American sea lions are distributed along the coast of South America from southern Brazil to northern Peru, including the Falkland Islands, Tierra del Fuego, and Staten Island. They are not known to inhabit the Juan Fernandez Islands off Chile. They range as far north as the east coast of Rio de Janeiro or Sao Paulo along the west coast of Zorritos, Peru. The northernmost breeding sites are at Recife das Torres, Uruguay in the east and Lobos de Tierra Island, Peru in the west. They are also found on some islands south of Cape Horn, including the Diego Ramirez Islands of Chile and the San Martin de Tours of Argentina. They are occasionally seen as far west as Tahiti in the South Pacific (Reeves et al., 1992).

Male South American sea lions in particular are known to wander great distances. Groups have been observed more than 200 km (124 mi) north of the Falklands in late December when breeding season has already begun. They also enter estuaries and freshwater systems (Reeves et al., 1992).

There are no breeding colonies on the mainland of Brazil and Uruguay. Uruguayan breeding colonies exist on the Coronilla, Castillos, and Torres island groups and on Lobos Island. Breeding habitat varies with the location. In Chile, South American sea lions breed and pup in rocky areas and sometimes in caves that are inaccessible by land. In Argentina, they come ashore on open sandy or pebbly beaches. At Punta Norte, males and females both arrive during the first half of December for breeding (Reeves et al., 1992). Pupping begins in September and ends in March, depending on location (Reeves et al., 2002).

Postpartum females typically forage for three days at a time (Reeves et al., 1992). They often dive at night (Reeves et al., 2002). South American sea lions feed on Argentine hake, anchovy, red octopus squid, lobster krill, and sometimes jellyfish (Reeves et al., 1992; Reeves et al., 2002). They also occasionally eat fur seals, ducks, and penguins. They forage mainly in shallow waters, less than 300 m (984.2 ft), near coasts or productive fishing banks (Reeves et al. 1992). They eat fish that live on the seafloor because they are typically slow-swimming. Lactating females usually dive to depths of 250 m (820 ft) (Reeves et al., 2002).

Males often bark when establishing and maintaining territories and herding females. They make airborne high-pitched, directional calls during encounters with other males.

Table 3.2-5. Information Summary for Otariidae: Fur Seal and Sea Lions

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
South American fur seal (*Arctocephalus australis*)		-South American coast in both Atlantic and Pacific oceans -Falkland Islands -As far north as southern Brazil in Atlantic and near Paracas, Peru in Pacific -In the Atlantic, found along the coast of Argentina to Uruguay	Total population estimates: 285,000 Chile: 40,000 in 1976 Northern Chile: 228 in 1982 Falkland Islands: 14,000 to 16,000 in 1973 Argentinean coast: 2,700 in 1954 Peruvian coast: 20,000 in 1979 Uruguay: 280,000 in 1992	Female forage dive duration: 3 min Female forage dive depth: 40 m Female forage max dive depth: 170 m Max dive duration: 7 min	Hearing No direct data available Sound Production Males produce airborne vocalizations during breeding season and threat calls
New Zealand fur seal (*Arctocephalus forsteri*)		-Breeding populations on South Island, NZ, and southeastern Australia -Western limit is Perth -Northeast limit is Queensland, Australia, and New Caledonia -Eastern limit is Bounty, Antipodes, and Chatham Islands -Southern limit is Snakes, Aukland, and Campbell Islands	Estimate: 135,000 Australia: 35,000 in 1991 Macquarie Island: 2,000 non-breeding individuals in April and May in the late 1980's	-Forage at night Dive depth: 10-15 m Max duration: 11 min Max depth: 274 m for lactating female Average swim speed: Unknown	Hearing No direct data available Sound Production Males produce airborne vocalizations during breeding season

Table 3.2-5. Information Summary for Otariidae: Fur Seal and Sea Lions

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Galapagos fur seal (*Arctocephalus galapagoensis*)	IUCN-Vulnerable species	-Galapagos Islands, particularly Isabela Island and Fernandina Island	Estimate: 40,000	Age-Dependent 6 mo old: 6 m, 50 sec 12 mo old: 47 m, 2.5 min 18 mo old: 61 m, 3 min Max depth: 169 m for 6.5 min Average swim speed: Unknown	Hearing No direct data available Sound Production No direct data available
Juan Fernandez fur seal (*Arctocephalus philippi)*	IUCN-Vulnerable species	-Juan Fernandez island group, including Mas a Tierra or Robinson Crusoe, Santa Clara, and Mas Afuera or Alejandro Selkirk - San Feliz island group, including San Ambrosio and San Felix - As far south as Punta San Juan, Chile - As far north as Peru	Estimate: 12,000 in late 1990's Estimate: 18,000 in 2002	Diving behavior based on information on lactating females: Dive depths: 10-90 m Dive duration: 1.7-2 min Dive at night Reach as far as 500 km offshore	Hearing No direct data available Sound Production No direct data available
South African fur seal (*Arctocephalus pusillus pusillus*)		- Along the coast of South Africa and Namibia - Breeding colonies from Cape Cross, Namibia around the Cape of Good Hope to Black Rocks, Cape Province, reaching west to Angola and south to Maron Island - May reach as far south as 11ºS	Estimate: 1,700,000 in 2002	Diving behavior based on information on lactating females: Dive depths: 40-50 m Max depth: 204 m Dive duration: 1.5-2.5 min Max duration: 7.5 min Dive 5 km offshore Nighttime dives typically deeper than daytime dives	Hearing No direct data available Sound Production No direct data available

Table 3.2-5. Information Summary for Otariidae: Fur Seal and Sea Lions

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Australia fur seal (*Arctocephalus pusillus doriferus*)		-Found in Victoria, Australia, Lady Julia Percy Island, Seal Rocks, Reid and Judgement Rocks off Tasmania -Seen as far north as Port Stephens in New South Wales	Global estimate: 60,000 Southeast Australia: 46,000 to 60,000 in 1991 Tasmania: 15,000 to 20,000 in 1991	Dive to seabed of continental shelf Depth: 65-85 m females Depth: 14 m males Dive duration: 2.5 min male Max depth: 102 m for 6.8 min Average swim speed: Unknown	Hearing No direct data available Sound Production No direct data available
Guadalupe fur seal (*Arctocephalus townsendi*)	ESA - threatened IUCN - vulnerable species CITES protected	-E. coast of Guadalupe Island, Mexico; southern California	Guadalupe Island: 7,400	Dive duration: 2.6 min Dive depth: 30 m Average swim speed: 1.8-2.0 m/s	Hearing No direct data available Sound Production Males produce airborne vocalizations during breeding season
Sub-Antarctic fur seal (*Arctocephalus tropicalis)*		-Found in the Subantarctic islands north of the Antarctic Convergence - Haul out and breed in the South Atlantic and Indian oceans, mostly on the islands of Amsterdam, Saint Paul, Crozet, Gough, Marion, Prince Edward, and Macquarie -Males occasionally seen around Brazil, Cape of Good Hope, and Australia	Global estimate: 310,000 in 2002 Macquarie Island: 110 in 1995 Amsterdam Island: 50,000 in early 1990's Gough Island: 200,000 in 1978	Diving behavior based on information on lactating females: Dive depth: 15-20 m in the summer; to 30 m in the winter Dive duration: 1-1.5 min Max depth: 208 m Max duration: 6.5 min Nocturnal diving common	Hearing No direct data available Sound Production Males produce three types of airborne vocalizations: -Barks for territorial status -Guttural growls or puffs to state territorial boundaries -High-intensity calls to warn or challenge other males Females make a loud, tonal honk to call their pups

Table 3.2-5. Information Summary for Otariidae: Fur Seal and Sea Lions

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Northern fur seal *(Callorhinus ursinus)*	IUCN - vulnerable species MMPA - depleted	-North Pacific; Bering Sea	Global estimates: 1.2 million	Dive duration: 2.6 min Dive depth: 100 m Max depths: 207 - 230 m Average swim speed: 1.5-1.9 m/s	Hearing Frequency range: 500 Hz- 40 kHz Dominant range: 4 kHz and 28 kHz Sound Production Underwater clicks and high frequency vocalizations
Northern sea lion *(Eumetopias jubatus)*	ESA – endangered - Stock west of 144°W; threatened-remaining population	-Temperate to sub-polar waters in North Pacific -Southern Bering Sea from Japan to California	Global estimates: 100,000 in 1994	Dive duration: <1 min Dive depth: 21 m Max depth: 328 m Average swim speed: Unknown	Hearing No direct data available Sound Production Underwater clicks and growls Airborne: Males produce a low frequency roar when courting or signaling threats Pups make a bleating cry and their voices deepen with age
California sea lion (*Zalophus californianus*)		-Prince William Sound, Alaska south to Chiapas, Mexico -Common as far north as Vancouver Island -Reach as far north as Prince William Sound -Reach as far south as Chiapas, Mexico	Global estimate: 211,000-241,000 U.S.: 167.000-188,000 Mexico: 13,000-22,000	Dive depth in the summer: 75 m Dive duration: 4 min Max depth: 536 m Max duration: 12 min Average swim speed: Unknown Diving depth and durations increases after summer months	Hearing Frequency range: 75 Hz-64kHz Sound Production Barks: <8kHz with dominant frequencies below 3.5 kHz Whinny: 1-3 kHz Clicks: 500 Hz-4 kHz Buzz: <1-4 kHz with dominant frequencies below 1 kHz

Table 3.2-5. Information Summary for Otariidae: Fur Seal and Sea Lions

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Australian sea lion (*Neophoca cinerea*)	IUCN-Near-threatened	-Temperate waters of Australia, 28-38° S -Vagrants found as far north as Shark Bay and as far east as Portland, Victoria	Global estimate: 9,300-11,700	Depth: 150 m Feed mostly on the seafloor within 30 km of shore Average swim speed: Unknown	Hearing No direct data available Sound Production No direct data available
New Zealand sea lion (*Phocartos hookeri*)	IUCN-Threatened	-Auckland Islands - Males migrate south to Macquarie Island -Vagrants in Maori middens on North Island, Cape Kidnappers, and Coromandel Peninsula	Global estimate: 12,500-13,000	Depth: 123 m Duration: 3.9 min for dives less than 6 m depth Max Depth: 500 m Max Duration: 11.3 min Average swim speed: 1 m/s	Hearing No direct data available Sound Production Airborne barks and underwater clicks
Galapagos sea lion (*Zalophus californianus wollebaeki*)		-Galapagos Islands -Occasionally seen along Ecuador and Columbia coasts -La Plata Island off Ecuador	Global estimate: unknown	Depth: 37 m Dive duration: <2 min Max depth: 186 m Max dive duration: 6 min Forage only in the daytime Average swim speed: 2 m/s	Hearing No direct data available Sound Production No direct data available
Japanese sea lion (*Zaophus californianus japonicus*)	IUCN-Extinct	-Southern coast of Kamchatka into the southern Sea of Japan	Possibly extinct	Unknown	Hearing No direct data available Sound Production No direct data available

Table 3.2-5. Information Summary for Otariidae: Fur Seal and Sea Lions

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
South American sea lion (*Ottaria byronia*)		- Along the coast of South America from southern Brazil to northern Peru, including Falkland Islands, Tierra del Fuego, and Staten Island - Range as far north as the east coast of Rio de Janeiro or Sao Paulo along the west coast of Zorritos, Peru - Northernmost breeding site at Recife das Torres, Uruguay in the east and Lobos de Tierra Island, Peru in the west - Also found on some islands south of Cape Horn, including Diego Ramirez Island of Chile and the San Martin de Tours of Argentina -Occasionally seen as far west as Tahiti in South Pacific	Estimate: 110,000 in 2002 in southwestern Atlantic coast Early 1980's: 300,000 Peru: 34,000 Chile: 9,000 Argentina: 170,000 Uruguay: 30,000	Diving behavior based on information on lactating females: Dive depths: 250 m Forage in shallow waters, less than 300 m, near coasts and fishing banks Dive at night	Hearing No direct data available Sound Production In air, males often bark when establishing and maintaining territories and herding females Make airborne high-pitched directional calls during encounters with other males
Source: See individual species descriptions for literature references.					

3.2.5.2 Phocidae

The family Phocidae is divided into two subfamilies (Monachinae and Phocinae) containing 18 species of true seals. Phocids are generally restricted to polar and subpolar climate. Phocids are also known for their adaptability to live in estuarine or freshwater habitats, such as the Caspian and Baikal seals inhabiting lakes (Berta, 2002). In total, nine of the species are eliminated from consideration because they are found outside of SURTASS LFA sonar operational areas. There is little information on the responses of phocids to low frequency sound. One report by Richardson et al. (1995) indicates 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, 1968; Terhune and Ronald, 1972, 1975a; 1975b; Terhune, 1989, 1991; Terhune and Turnbull, 1995). Of the species that have been studied, 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). Phocids probably hear sounds underwater at frequencies up to about 60 kHz. Above 60 kHz, their hearing is poor. Table 3.2-6 summarizes information on the status, distribution, abundance, diving behavior, sound production and hearing of Phocidae species being evaluated for potential impacts.

Mediterranean monk seals (*Monachus monachus)* 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 at less than 500 (Croll et al., 1999). The largest colony at the Cape Blanc Peninsula on the coast of the Western Sahara, Africa was estimated at 100 in 1997 (Reeves et al., 2002).

Historically, Mediterranean monk seals had a large range from 20N, along northwestern Africa, into the Mediterranean Sea, and into the southern Black Sea. The range of these seals has significantly decreased. They have disappeared from the Canary Islands, the French, Italian, and Spanish Mediterranean mainlands, Cyprus, Egypt, Malta, and Israel. Cape Blanc is the southern limit of their range with groups on the tip of the Cape and along the Las Cuevecillas coast. Some seals have been seen further south around Dakar, Senegal, and Gambia. The Desertas Islands once had a large population of seals, but the numbers have declined to only a dozen individuals. Monk seals are present north of Cape Blanc between Cape Barbas and Guerguerat. They are distributed throughout the archipelago of the Mediterranean, particularly in the Aegean and northern Ionian seas. Small groups of seals occur in the Greek archipelago and some small groups occur along the Turkish and Bulgarian coasts of the Black Sea and Sea of Marmara. A few individuals live off the coast of Yugoslavia, Algeria (particularly the Oran coast), Morocco, the La Galite archipelago off northern Tunisia, the Cyrenaican coast of Libya, and around remote parts of Albania and Lebanon (Riedman, 1990; Reeves et al., 1992). Vagrant seals have also been seen off northwestern Corsica, the northeastern and southwestern islands of Sardinia, the southeastern coast and islands of Sicily, and the southeastern coast of Puglia (Reeves et al., 2002). There is no evidence of seasonal movement for Mediterranean monk seals. Mediterranean monk seals breed from the spring through the fall with a peak in births occurring between September and October (Sergeant et al., 1978; Kenyon 1981). Much like other phocids, Mediterranean monk seals are a solitary species. They usually haul out and give birth in caves or grottos.

No direct data are available on swim speed. Mediterranean monk seals tend to forage in coastal waters for fish, octopus, squid, and crustaceans. They do not forage at depths greater than approximately 70 m (230 ft) and most dives do not last longer than 10 min. Most of the monk seal observations have been within 5 to 6 km (3.1 to 3.7 mi) of the shore. However, they have also been observed as far as 37 km (23 mi) from shore. The home range for individuals in the Aegean Sea has been estimated to be within 20 to 40 km (12.4 to 24.9 mi) of the coastline. Mediterranean monk seals have been observed along 600 km (373 mi) of the shoreline of the Aegean Sea (Reeves et al., 1992).

There is no direct measurement of auditory threshold for the hearing sensitivity of Mediterranean monk seals (Thewissen, 2002), and there are no available data on the sound production of this species.

Hawaiian monk seals ***(Monachus schauinslandi)*** are listed as endangered under the ESA, classified as endangered under IUCN, and protected under CITES. The worldwide population size for this species was estimated at nearly 1,400 in 2000 (Reeves et al., 2002).

Hawaiian monk seals are found almost exclusively on the northwest Hawaiian Islands where they occasionally move among islands and atolls. Their rookeries are primarily located on the Leeward Islands of French Frigate Shoals, Pearl and Hermes Reef, Kure Atoll, and Laysan and Lisianski Islands (Croll et al., 1999; Reeves et al., 2002). Smaller colonies also live on Nihoa and Necker Islands. After two males were translocated to Johnston Atoll in 1997, a few seals have been seen there each year. Hawaiian monk seals have also been seen in the main islands of Hawaii and since the 1980s, pups have been born on the islands of Maui, Kauai, Oahu, and Molokai. Hawaiian monk seals do not seem to be tolerant of human presence. When the U.S. military inhabited Sand Island and the Midway Islands and Kure Atoll, the monk seals disappeared until after the military left. Monk seals prefer to be solitary animals (Reeves et al., 2002).

No swim speed data are available. Foraging dive durations last up to 4 min. Some dives have been recorded to last longer than 30 min; however, it is unclear if these are foraging dives. Hawaiian monk seals forage on benthic or reef fish, cephalopods, and crustaceans (particularly lobster). Seals may dive to depths from 60 m (200 ft) to greater than 250 m (820 ft). They have been recorded as diving up to 490 m (1,608 ft) (Reeves et al., 1992).

The Hawaiian monk seal can hear underwater sounds in the range of 2 to 40 kHz. 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. In air sounds include a soft liquid bubble (100 to 400 Hz), a guttural expiration (<800 Hz), a roar (<800 Hz), and a belch cough (Miller and Job, 1992).

Northern elephant seals (***Mirounga angustirostris)*** were estimated in 2000 at over 150,000 (Reeves et al., 2002). **Southern elephant seals** ***(M. leonina)*** were estimated at 750,000 (Reeves et al., 2002). 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 Pacific. 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; Hindell, 2002). Most of the colonies are located on offshore islands. They make long, seasonal migrations between foraging and breeding areas twice a year, returning to their southern breeding grounds to molt (Hindell, 2002). 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 (LeBoeuf, 1994).

Southern elephant seals have a large range and occur on 14 colonies around the Antarctic Convergence, between 40 and 62S (King and Bryden, 1981; Laws, 1994). They are commonly found along the southern coast of Argentina (Reeves et al. 2002). 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 north of the Antarctic Polar Front to the Antarctic pack ice. During non-breeding seasons, both the southern and the northern elephant seals are widely dispersed (Hindell, 2002).

Studies on California rookeries have shown three seasonal changes in the age and sex composition. There are three seasonal peaks in abundance: the first in January during the peak of breeding season, the second in late April or early May when juveniles and females are molting, and the third in October when the females, the pups of the year, and juveniles haul out (Reeves et al., 1992).

Foraging for both northern and southern elephant seals differs between males and females. Male northern elephant seals forage on the continental shelf in the northern parts of their range while the females feed in the middle of their range in deeper oceanic waters (LeBoeuf, 1994). Male southern elephant seals feed in southern waters along the Antarctic continental shelf. They feed on deep-water fish and squid (Hindell, 2002).

Elephant seals spend more than 80 percent of the year at sea, mostly feeding to build up blubber required for breeding and molting. On average, adult females dive for 20 min to depths of 400 to 800 m (1312 to 2325 ft). Adult males make dives on average for 30 min at shallower depths. One recorded dive reached in excess of 1,500 m (4,921 ft) for approximately 120 min (Hindell, 2002). Le Boeuf et al. (1989 *in* Kastak and Schusterman, 1999) reported that northern elephant seals dive to average depths of 500 to 700 m (1,640 to 2297 ft) and may spend as much as 90 percent of their time at sea under water hunting for food, traveling, and resting (Hindell, 2002). Swim speeds were recorded near 1.1 m/s (2.1 knots) for northern elephant seals (Fletcher et al., 1996). Swim speeds were not available for southern elephant seals.

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). The reduction of the external meatus and the presence of cavernous tissue in the ear are likely to be adaptations that minimize water penetration into the ear canal and the size of the middle-ear space. This reduction in the volume of the outer and middle ear air space could enhance underwater sound detection by matching the acoustic impedance of the ear with that of the water (Repenning, 1972 *in* 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). In 1998, Kastak and Schusterman 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 is no direct 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, 2002). In the air, mean frequencies for adult male northern elephant seal vocalizations range from 147 to 334 Hz (LeBoeuf and Petrinovich, 1974; LeBoeuf and Peterson, 1969). 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, 2002). There are no available data regarding seasonal or geographical variation in the sound production of either species.

Ribbon seals *(Phoca fasciata*) occur near the Bering Sea, Okhotsk Sea along eastern Russia, and the southern part of the Chukchi Sea, Japan, and Korea. There are three main populations of ribbon seals, one in the Bering Sea and two in the Okhotsk Sea. Parts of the Okhotsk Sea populations may migrate in the spring and summer with the receding ice to the southern Chuckchi Sea (Fedoseev, 2002). Some also migrate to the Beaufort Sea, the Aleutian Islands, northern Hokkaido, and the central North Pacific Ocean (Reeves et al., 2002). Ribbon seal individuals have also been observed along the California coast in Morro Bay. However, the range of the migration is poorly understood. Pack-ice breeding takes place throughout this range from March to April (Fedoseev, 2002).

Ribbon seals are strongly connected to the ice. However, if the ice is thicker than 10 to 15 cm (3.9 to 5.9 in), ribbon seals have a difficult time making holes. They often inhabit areas with large chunks of stable white ice, which is commonly found along the continental shelf where there is high water circulation (Fedoseev, 2002).

Due to sealing (the hunting of seals) in the Bering Sea in the 1960s, the ribbon seal population severely declined from 115,000-120,000 seals in 1961 to 60,000-70,000 in 1969. Sealing was then limited and in 1987, the population rose to 120,000-140,000 seals. In the Okhotsk Sea, the population fluctuated between 200,000 and 630,000 from 1968 to 1990 (Fedoseev, 2002).

Swim speeds and dive data for this species are not known. Ribbon seals forage primarily on fish, crustaceans, krill, and cephalopods (Riedman, 1990). Pups mostly feed on euphausiids, juveniles feed mostly on shrimp, and adults feed on cephalopods and fish. Adults in the Okhotsk Sea mostly eat Alaskan Pollack and adults in the Bering Sea eat mostly squid and octopus (Fedoseev, 2002).

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 (Watkins and Ray, 1977). According to Reeves et al. (1992), two types of underwater vocalizations produced by ribbon seals have been recorded: 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. Sweeps are diverse and range from 100 Hz to 7.1 kHz. 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 seals (*Phoca largha)*, also called larga seals, occur in temperate to polar regions, spending their time either in open ocean or in pack-ice habitats (Reeves et al., 2002). Populations are found in the Bering, Chukchi, and Beaufort Seas in the summer, and the Sea of Okhotsk, Tartar Strait, the Sea of Japan, the northern Yellow Sea/Bo Hai, and adjacent waters around Korea and China. The southernmost breeding population occurs at 38N and is in the Sea of Japan and the Yellow Sea. They inhabit sea ice throughout the year including the ice over continental shelves during the winter and spring. When the ice cover recedes in the Bering Sea, spotted seals migrate northward into the Chukchi and Beaufort seas. They spend the summer and fall near Point Barrow in Alaska and the northern shores of Chukotka, Russia. Off-shore and near-shore migration patterns are restricted within this range. They migrate southward through the Chukchi and Bering Sea region to maintain association with drifting ice. They rarely haul out during the winter. Their peak haul-out time is during molting and pupping from February to May (Burns, 2002).

Three breeding populations are known in or adjacent to the Okhotsk Sea: in the Shelikhoba Gulf, east of Sakhalin Island, and in Tartar Strait. Other breeding populations exist in Peter the Great Bay in the Sea of Japan and in the Bo Hai Sea of the Yellow Sea (Reeves et al., 1992).

Current population estimates are unavailable. An estimated population of 4,500 in the Bohai Sea was determined during a 1990 survey. The Bering Sea population was estimated at 200,000 to 250,000 in the 1980s. In 1982, the population was estimated to be 130,000 in the Okhotsk Sea (Burns, 2002). However, particularly high densities have been observed in April in outer Bristol Bay, central Bering Sea, and the Karaginskii Gulf. The western stock winters in Karaginskii Gulf and toward the coasts of Koryak and Kamchatka off Russia. The central stock is distributed around the south of Cape Navarin to St. Matthew Island and the Anadyr Gulf in the winter and spring. The eastern stock is distributed around Bristol Bay northward through the Bering Strait and along the Chukchi Sea (Reeves et al., 1992).

Swim speeds and dive times of this species are not known. Dive depths have been recorded to at least 300 m (984 ft) (Reeves et al., 1992). Spotted seals forage primarily on fish, crustaceans, and cephalopods (i.e., pollock, herring, cod, sand lance, capelin, eelpout, flounder, shrimp, and crabs). Spotted seal pups will usually begin eating small amphipods or euphausiids (Bigg, 1981; Reeves et al., 1992; Burns, 2002).

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 seals *(Phoca vitulina)* are also known as common seals. They have an estimated population of 500,000 worldwide (Croll et al., 1999). Of this, 300,000 harbor seals are found in the North Pacific and 40,000 to 100,000 were reported in 1993 in Canadian waters. It is estimated that approximately 98,000 harbor seals existed in the eastern Atlantic in the mid-1980s. In 1990, the largest populations occurred in the North Sea and Iceland. The abundance in Great Britain was up to 47,000 harbor seals. Other large populations include Iceland with 28,000, Wadden Sea with 10,000, and Kettega/Skagerrak with 6,000. The smallest populations occur in the Baltic Sea with around 200 individuals and around Svalbald with 500 to 600 individuals. The abundance in the western Atlantic Ocean is unknown. In 1993, an estimated 40,000 to 100,000 harbor seals were reported. Of that, approximately 30,000 to 40,000 lived in Canadian waters. The population in the United States was around 4,700. Harbor seals are abundant in the eastern Pacific Ocean. In the mid-1990s, estimates along the U.S. coast were 34,500 in California, 39,900 in Oregon and Washington, 13,800 in inland waters of Washington, 100,000 in British Columbia, and 35,000 in eastern Alaska. Population numbers are declining in parts of Alaska. 20,000 animals are estimated in the Gulf of Alaska region, including Prince William Sound. In southwestern Alaska, not including the Aleutian Islands, there is a population with an estimated 15,000 individuals. In 1994, the estimated population of harbor seals living on the Aleutian Islands was 3,400. Other abundance estimates include the Commander Islands (1,500), Kamchatka Peninsula (200), Kuril Island (1,900), and northern Japan (300) (Burns, 2002).

Harbor seals are widely distributed in subarctic and temperate waters along the margins of the North Atlantic Ocean between 30N and 80S latitudes and North Pacific Ocean between 28N and 62S latitudes (Burns, 2002; Riedman, 1990). 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. The Atlantic populations are mainly influenced by warm oceanographic features such as the North Water in Baffin Bay and the water carried by the Gulf Stream and gyres (Burns, 2002).

Harbor seals have a very large range with five subspecies. One subspecies occurs from the French coast on the English Channel throughout the North Sea and north to Finmark on the Barents Sea. This also includes the southern Baltic Sea and the waters of Ireland and Great Britain. Individuals have also been seen around Portugal and the eastern Barents Sea. The northernmost breeding point for this population is in western Svalbard. The western Atlantic subspecies ranges from about 40N around New Jersey to about 73N in northern Baffin Island, Canada. This includes the Hudson Bay and southern Foxe Basin. Individuals have been observed as far south as Florida. A freshwater population also exists around the Ungava Peninsula in eastern Canada and in the eastern Hudson Bay.

In the North Pacific, one subspecies of harbor seals inhabits the eastern North Pacific while another inhabits the western North Pacific. Their boundary is thought to be the western Alaskan Peninsula, and the eastern Aleutian Islands. These two population ranges extend from Cedros Island near Baja, California, Mexico (28N) to the Gulf of Alaska and the southeastern Bering Sea and across the Aleutian Ridge to the Kamchatka Peninsula of Russia and south to the Kuril Islands. They are also found beyond Hokkaido Island in northern Japan. In the Pacific region, the northernmost pupping colonies occur in Prince William Sound in Alaska (Burns, 2002).

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. They haul out along lakes, rivers, estuaries, bays, and ocean shorelines (Burns, 2002). Breeding grounds are generally associated with isolated places such as pack ice, offshore rocks, and vacant beaches (Riedman, 1990).

Harbor seals are capable of foraging in deep waters, up to 150 m (500 ft), depending on their location. Their diet varies by season and the region. The harbor seal feeds on pelagic and benthic fish, cephalopods and crustaceans (Bigg, 1981; Reeves et al., 1992; Burns, 2002). They prey on cod, hake, mackerel, herring, sardines, smelts, shad, capelin, sand lance, sculpins, flatfish, salmon, squid, octopus, crab, and shrimp. Shrimp may be particularly important in the diet of pups (Burns, 2002).

Maximum swim speeds have been recorded over 13 km/hr (7 knots) (Bigg, 1981). Harbor seals dive to up to 150 m (500 ft), depending on their location. Seals in southern California have been recorded diving up to 450 m (1,500 ft). Their dives generally last a few min, but the longest dive recorded was 31 min (Reeves et al., 2002).

Underwater, some low-frequency pulse sounds were recorded to threaten other males (Reeves et al., 2002). Hangii 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. (1999) studied male vocalizations as a tool for comparing the distribution of displaying males in two topographically different areas in northern Scotland, an estuarine haul out area in the Moray Firth, and Orkney, which are rocky islands. They aimed to compare the spatial and temporal patterns of male vocalizations in two areas to assess how male display activity varies in relation to geographical differences in female distribution. Harbor seal low-frequency vocalizations were heard for a 40-day period starting in early July through mid-August in the Moray Firth. This was coincidental to the onset of weaning of pups in this population. In Orkney, male harbor seals began vocalizing seven days earlier than in the Moray Firth. This is possibly due to the variation of the timing and duration of the pupping season in the two latitudes, and therefore, different timing of the female estrus. Peak number of pups are seen slightly later in the Moray Firth. Throughout the Moray Firth, there was a temporal pattern in relation to the tidal cycle in the number of male vocalizations. There was an increase in vocalization around high tide. In Orkney, male vocalizations were related to both the tides and the time of day. Diel cycles seem to be more closely related in rocky shore areas where site availability is less influenced by the tidal cycle. Similarly, in Sable Island, Canada, temporal patterns of male behavior during the mating season also varied. Males showed a diurnal relationship in their diving patterns. In the Moray Firth, vocalizing males were found throughout the range known to be used by females at that time of year. The highest densities of males were found in the narrow channels along female transit routes between their haul out sites and feeding grounds. Lower densities were found on female feeding grounds. In Orkney, male harbor seals were found in two areas, around Eynhallow and the channels between Egilsay, Wyre, and Rousay. No males were heard vocalizing at any other sampling stations (Van Parijs et al., 1999).

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 Kovac (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. Vocalizations in-air were predominantly emitted by adult males during agnostic interactions, which suggests that in-air vocalizations are used during male competition. In-air vocalizations were also produced by adult females and subadult 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 Kovac, 2002).

The harbor seal can hear sounds in the range of 75 Hz to a maximum of 180 kHz (Mohl, 1968; Terhune, 1991; Kastak and Schusterman, 1998). Richardson et al. (1995) reported that phocinid seals have a mostly flat audiogram from 1 kHz up to approximately 50 kHz with hearing thresholds between 60 and 85 dB RL. One harbor seal showed a threshold of 96 dB RL at 100 Hz. Although harbor seals can hear up to 180 kHz, this is extreme and most phocids have an upper frequency closer to 60 kHz (Richardson et al., 1995).

Southall et al. (2005) examined the reliability of underwater hearing thresholds in pinnipeds. They found that underwater, low frequency behavioral hearing thresholds from the study years 2000 and 2001 for harbor seals were slightly statistically different compared to studies conducted four to seven years earlier. There was a slight measurable increase in hearing sensitivity (lower hearing threshold) for the frequencies tested despite that the research conducted in 1996 and 2000 involved several hundred controlled noise exposures at similar frequencies resulting in auditory masking and a lesser number of exposures known to induce temporary hearing losses of 6 dB or greater (20 occurrences in harbor seals). The results from these tests suggest that hearing abilities in some mammals, including those regularly exposed to moderate levels of noise, may remain relatively unchanged over multiple years prior to senescence (aging) (Southall et al., 2005).

Gray seals (*Halichoerus grypus*) have an estimated population of 110,000 in British waters, 69,000 in the western North Atlantic, and 85,000 around Sable island. Other large populations are in the Gulf of St. Lawrence (69,000), Iceland (11,600 in 1987), Norway (3,000), Ireland (2,000), and in the White Sea (between 1,000 and 2,000). The Baltic Sea has approximately 5,000 resident seals (Hall, 2002). Other colonies include the Faroe Island, the Hebrides, North Rona Island, the Orkney Shetland, and Farne Islands (Reeves et al., 2002). Gray seals breed on remote islands that are typically uninhabited or on fast ice. The biggest island breeding colony is on Sable Island (Hall, 2002).

Gray seals occur in temperate and sub-polar regions mostly in the Baltic Sea and the eastern and western North Atlantic. 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 knots). Gray seals dive between 4 and 10 min with a maximum dive duration recorded at 30 min (Hall, 2002). A maximum dive depth of 400 m (1,300 ft) has been recorded for this species. Gray seals are demersal or benthic feeders and forage on a variety of fish species and cephalopods, mostly sand eels and sand lance (Hammond et al., 1994). Other prey species include herring, whiting, cod, haddock, saithe, flatfish, and the occasional bird. Gray seals typically forage for one to five days, focusing on discrete areas that are within 40 km (25 mi) of their haul-out site (Hall, 2002).

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 seals (*Cystophora cristata*) have an estimated population of 250,000 near Jan Mayen Island and nearly 300,000 off Newfoundland (Reeves et al., 2002).

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, and Newfoundland (Wynne and Schwartz, 1999). They are also present in the Norwegian and Barents seas. 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. They are also found in the Davis and Denmark straits, Norwegian, and Barents seas (Reeves et al., 2002). Breeding takes place in this range from late March to the beginning of April for a 2 to 3-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 halt 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. They sometimes occur in the Thule district of northwestern Greenland, as well as in Lancaster and Jones sounds. Hooded seals are a migratory species and are often seen far from their haul-outs and foraging sites. They have been observed as far south as Portugal in Europe and as far south as Florida in the Atlantic and California in the Pacific Ocean. Some individuals swim up the St. Lawrence River as far as Montreal (Reeves et al., 1992).

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 more than 52 min. This species typically feeds on squid and fish species of halibut, redfish and cod (Reeves et al., 2002).

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). The dominant frequencies of the sounds produced by hooded seals are below 1000 Hz (Schevill et al., 1966; Terhune and Ronald, 1973; Ray and Watkins, 1975). There are at least three types of LF, pulsed sounds, described as grung, snort, and buzz that are made by the male underwater. The grung 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. This vocalization was typically paired with a defensive posture. Pups are generally silent. The sounds produced by hooded seals have a variety of functions ranging from female-pup interactions to fighting behavior and visual displays among males (Frankel, 2002; Terhune and Ronald, 1973). 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.

Table 3.2-6. Information Summary for Phocidae: True Seals

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Mediterranean monk seal (*Monachus monachus)*	ESA-endangered; CITES-protected IUCN-critically endangered	-Mediterranean and Black Seas, Atlantic coast, and offshore islands of N. Africa -Southern limit is Cape Blanc	Global estimates: less than 500 Cabo Blanco Peninsula: 100 in 1997	Foraging depth: <70 m Average duration: <10 min Average swim speed: Unknown	Hearing No direct data available Sound Production No direct data available
Hawaiian monk seal *(Monachus schauinslandi*)	ESA-endangered; CITES-protected IUCN-endangered	Leeward Chain of the Hawaiian Islands; Nihoa, Necker, French Frigate Shoals, Pearl and Hermes Reef, Kure Atoll, Laysan, and Lisianski islands	Global estimates: 1,400 in 2000	Dive duration: up to 4 minutes Average depth: 60-250 m Max depth: 490 m Max duration: >30 min Average swim speed: Unknown	Hearing Frequency range: 2 kHz- 40 kHz Greatest sensitivity from 12-28 kHz Hearing drops >30 Hz Sound Production Airborne sounds Soft liquid bubble: 100-400 Hz Guttural expiration: <800 Hz Roar: <800 Hz Belch cough

Table 3.2-6. Information Summary for Phocidae: True Seals

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Northern elephant seal (*Mirounga angustirostris*)	No status	-NE Pacific around Oregon, Washington, British Columbia, the Gulf of Alaska, and the Aleutian Islands	Global estimates: 150,000 in 2000	Dive duration female: 20 min Dive duration male: 30 min Dive depth: 400 – 800 m Max depths: 1,500 m Max duration: 120 min Swim Speed: 1.1 m/s	Hearing Frequency range: Underwater 75 Hz- 6.3 kHz Increases for frequencies below 64 kHz More sensitive to anthropogenic LF sound Sound Production No known underwater vocalizations In Air: Frequency range males: 147-334 Hz Male LF Sound: 175 Hz Signal type: Snorting- 200-600 Hz Clap- up to 2.5 kHz Pulse from female- 220-420 Hz Frequency range females: 500-1000 Hz Frequency range pups: up to 1.4 kHz Source level: No direct data available

Table 3.2-6. Information Summary for Phocidae: True Seals

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Southern elephant seal (*Mirounga leonina*)	CITES - protected	-Antarctic Polar Front to Antarctic pack ice- circumpolar between 40^{o} and 62^{o} South; southern coast of Argentina	Global estimates: 750,000	Dive duration: 20-30 min Dive depth: 400 – 800 m Max depths: 1,500 m Average swim speed: Unknown	Hearing No direct data available Most sensitive to anthropogenic LF sound source Sound Production No known underwater vocalizations In air: Frequency range: 175 Hz Signal type: Pulse level: No direct data available
Ribbon seal (*Phoca fasciata*)	No status	-Bering Sea; Okhotsk Sea and Chukchi Sea in Russia, Japan, and Korea	Global estimates: Up to 630,000 in 1990	No direct data available	Hearing No direct data available Sound Production Frequency range: 100 Hz – 7.1 kHz Source level: 160 dB Underwater sound production Short, broadband puffs- <5 kHz Downward-frequency sweeps with harmonics- 100 Hz- 7.1 kHz

Table 3.2-6. Information Summary for Phocidae: True Seals

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Spotted seal (*Phoca largha*)	No status	- Temperate to polar waters - Bering Sea, Sea of Okhotsk, Beaufort Sea, Chukchi Sea, Tartar Strait, northern Yellow Sea/ Bo Hai, Sea of Japan, and adjacent waters are Korea and China	Global estimates: No direct data available Bohai Sea: 4,500 in 1990 Bering Sea: 20,000-250,000 in 1980's Sea of Okhotsk: 130,000 in 1982	Dive duration: No direct data available Dive depth: <300 m Average swim speed: Unknown	Hearing No direct data available Sound Production Frequency range: 500 Hz – 3.5 kHz Growls, drums, snorts, chirps, and barks
Harbor seal (*Phoca vitulina*)	No status	- Subarctic and temperate waters - North Pacific Ocean, Eastern Atlantic Ocean, Wadden Sea, Baltic Sea, Western Atlantic Ocean - Northern and Southern boarders of 30° N and 80° S in the Atlantic -28° N and 68° S in the Pacific	Global estimates: 500,000 N. Pacific: 300,000 Canadian Waters: 30,000-100,000 in 1993 W. Atlantic: 40,000-100,000 in 1993 Great Britain: 47,000 Iceland: 28,000 Wadden Sea: 10,000 Kettega/Skagerrak: 6,000 Baltic Sea: 200 Svalbald: 500-600 U.S. 4,700 in 1993	Dive duration: 3-7 min Dive depth: 17-87 m Max depths: 450 m in CA Max duration: 31 min Swim speed: <13 km/hr	Hearing Frequency range: 75 Hz-180 kHz Dominant hearing range: 100 Hz – 2 kHz and 12-40 Khz Sound Production Frequency range: 100 Hz – 150 kHz Dominant frequencies: 100 Hz-2 kHz and 12-40 kHz Signal type: LF pulses, clicks, grunts, groans, creaks Source level: 169 dB

Table 3.2-6. Information Summary for Phocidae: True Seals

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Gray seal (*Halichoerus grypus*)	No status	- Temperate to polar waters in Baltic Sea; E. and W. North Atlantic - Gulf of St. Lawrence, Iceland, Norway, Ireland, White Sea	Global estimates: No direct data available British waters: 110,000 NW Atlantic: 69,000 Sable Island: 85,000 Gulf of St. Lawrence: 69,000 Iceland: 11,600 in 1987 Norway: 3,000 Ireland: 2,000 White Sea: 1,000-2,000 Baltic Sea: 5,000	Dive duration: 4-10 min Max depth: 400 m Max duration: 30 min Swim Speed: 4.5 km/hr	Hearing Frequency range: 2- 90 kHz Dominant hearing range: 20 kHz and 50-60 kHz Sound Production Frequency range: 100 Hz – 16 kHz Dominant frequency: 100 Hz, 4 kHz, and 10 kHz Max frequency: 40 kHz Source level: No direct data available
Hooded seal (*Cystophora cristata*)	No status	-North Atlantic; Canada, Gulf of St. Lawrence and Newfoundland - Norwegian and Barents Sea - As far south as Portugal in Europe and as far south a Florida in the Atlantic and California in the Pacific	Global estimates: No direct data available Jan Mayen Island: 250,000 Newfoundland: 300,000	Dive duration: < 15 min Dive depth: 100 - 600 m Max depth: 1,000 m Max duration: >52 min Average swim speed: Unknown	Hearing No direct data available Sound Production Frequency range: 500 Hz – 6 kHz Dominant frequency: <1kHz Signal type: Pulse Buzz: 1.2 kHz with harmonics of 6 kHz Grung: 0.2-0.4 kHz Snort: 0.1-1 kHz with harmonics as 3 kHz Source level: No direct data available

Table 3.2-6. Information Summary for Phocidae: True Seals

Species	Protected Status	Distribution	Abundance	Diving Behavior And Swim Speeds	Hearing/Sound Production
Source: See individual species descriptions for literature references.					

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3.3 Socioeconomics

3.3.1 Commercial and Recreational Fisheries

Pelagic and demersal fish species have the potential to be affected by SURTASS LFA sonar because some have demonstrate response to and have the potential to be physically affected by LF sound (Subchapter 3.2.2). In addition, the geographic sphere of SURTASS LFA sonar's acoustic influence overlaps the distribution of some fish species. If SURTASS LFA SONAR has the potential to affect fish species, than it follows that this could potentially affect commercial and recreational 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.

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.

Global Data

The general composition of 2002 global marine fisheries catches is presented in Table 3.3-1. As indicated, marine fish, crustaceans, and mollusks represent the majority of the total 84 million mt of nominal catches. Table 3.3-2 shows the capture production by principal species for the top fifteen. Of marine fish, the Peruvian anchovy is by far the largest with over 9 million mt caught in 2002. Other significant catch volumes include pollack, tuna, capelin, herring, mackerel, whiting, sardine, and cod (FAO, 2002a).

Table 3.3-1. Catches in Marine Fishing Areas by type, 2002.

ISSCAAP Division [1]	Catches (mt)	Percent of World Catch
Freshwater Fish	28,132	<0.1
Diadromous Fish	1,141,310	1
Marine Fish	70,177,288	83
Crustaceans	5,781,432	7
Mollusks	6,793,067	8
Whales, Seals, Other Aquatic Mammals[2]	NA	***
Miscellaneous Aquatic Animals	531,258	<1
Miscellaneous Aquatic Products	NA	***
Aquatic Plants[2]	NA	***
Total	84,452,487	100

Notes:
1. ISSCAAP = International Standard Statistical Classification of Aquatic Animals and Plants.
2. Data on aquatic mammals and plants are excluded from all national, regional, and global totals.
NA = Not Available or unobtainable.
Source: FAO (2002a)

Regional Trends

Global production from capture fisheries has remained basically stable since 1996 when the total capture production was 86 million mt and the latest FAO statistics for 2002 were 84 million mt (FAO, 2002a). This followed the oceanic water mass oscillations of the 1994-1998 El Niño event on the Peruvian anchovies (FAO, 2002b).

Nominal catches for each marine fishing zone in 1996 and 2002 are presented in Table 3.3-3. The Northwest Pacific marine fishing area was by far the greatest single contributor to global marine fisheries production, recording over 21 million metric tons of the global totals. This zone, including the marine waters of China and the Russian Federation, has been the world's most productive fishing zone since 1971 (Grainger, 1997).

Table 3.3-2. Marine capture production by principal species, 2002 (Top 15).

Species Name	**Scientific Name**	**Capture Production (mt)**
Peruvian anchovy	*Engraulis ringens*	9,702,614
Alaska Pollock (Walleye)	*Theragra chalcogramma*	2,654,854
Skipjack tuna	*Katsuwonus pelamis*	2,030,648
Capelin	*Mallotus villosus*	1,961,724
Atlantic herring	*Clupea harengus*	1,872,013
Japanese anchovy	*Engraulis japonicus*	1,853,936
Chilean jack mackerel	*Trachurus murphyi*	1,750,078
Blue whiting	*Micromesistius poutassou*	1,603,263
Chub mackerel	*Scomber japonicus*	1,470,673
Largehead hairtail	*Trichiurus lepturus*	1,452,209
Yellowfin tuna	*Thunnus albacares*	1,341,319
European pilchard (Sardine)	*Sardina pilchardus*	1,089 836
Atlantic cod	*Gadus morhua*	890,358
Atlantic mackerel	*Scomber scombus*	769,068
California pilchard	*Sardinops caeruleus*	722,071
Reference: FAO (2002a)		

The southeast Pacific zone also was a major contributor to global marine fisheries catches in 2002, providing catches of over 13 million mt. This has historically been the most dynamic zone and is dominated by small pelagic species (Grainger, 1997). In 2002, the combined zones of the Pacific Ocean yielded the majority of all marine catches, with over 51 million mt, or 61 percent of the world’s catches in marine waters.

Table 3.3-3. Nominal catches in Marine Fishing Areas.

Marine Fishing Area	FAO Area	1996 Catches (mt)	2002 Catches (mt)
Arctic Sea	18	0	0
Atlantic, Northwest	21	2,069,186	2,245,008
Atlantic, Northeast	27	11,066,088	11,048,962
Atlantic, Western Central	31	1,720,699	1,764,352
Atlantic, Eastern Central	34	3,572,444	3,373,623
Mediterranean and Black Sea	37	1,531,975	1,550,099
Atlantic, Southwest	41	2,479,862	2,089,660
Atlantic, Southeast	47	1,325,437	1,701,440
Atlantic, Antarctic	48	95,088	134,595
Indian Ocean, Western	51	3,897,309	4,243,330
Indian Ocean, Eastern	57	4,190,529	5,100,261
Indian Ocean, Antarctic	58	5,689	8,004
Pacific, Northwest	61	23,542,610	21,436,229
Pacific, Northeast	67	2,833,342	2,702,885
Pacific, Western Central	71	8,730,620	10,510,202
Pacific, Eastern Central	77	1,619,642	2,037,267
Pacific, Southwest	81	663,750	739,868
Pacific, Southeast	87	17,068,356	13,765,143
Pacific, Antarctic	88	NA	1,559
Reference: FAO (2002a)			

Fishery Trends by Country

Table 3.3-4 shows the total capture of marine fisheries for the top ten fishing nations for 1996 and 2002 (FAO, 2002a). Brief descriptions of the fishing industries of these nations are discussed below. Information on other world fisheries is provided by the FAO on their Fisheries Country Profile website at http://www.fao.org/fi/fcp.asp.

Table 3.3-4. Top 10 fishing nations.

Country	Total 1996 Capture (mt)	Total 2002 Capture (mt)
China	14,182,107	16,553,144
Peru	9,515,048	8,766,991
USA	5,001,191	4,937,305
Indonesia	3,604,795	4,505,474
Japan	5,931,872	4,443,000
Chile	6,690,665	4,271,475
India	3,447,954	3,770,912
Russian Federation	4,675,738	3,232,295
Thailand	3,013,961	2,921,216
Norway	2,648,457	2,743,184
Reference: FAO (2002a)		

China

China has seen a rapid increase in the fishing industry. The total capture production for 1993 was 9.4 million mt compared to the 2002 output of 16.6 million mt (FAO, 2002a). However, there are indications that capture fishery production and aquaculture statistics have been misreported since the early 1990s and thus the values may be too high (Watson and Pauly, 2001; FAO, 2002b). In 1999, an estimated 6.05 million people were employed in either the primary or secondary sector with approximately 470,700 fishing vessels. China consumes 36,493 tons of fish and marine products per year and exports an additional $2.96 billion worth of goods. Their main-targeted species include hairtail, chub, mackerel, mackerel scad, Chinese herring, sea eel, yellow croaker, porgy, silvery pomfret, mullet, flukes, cuttlefish, squid, octopus, abalone, Chinese shrimp, northern maoxia, shrimp, rough shrimp, swimming crab, mud crab, sea cucumber, and jellyfish. While total catch output has been increasing, the numbers of highly valued species have been decreasing. More attention is being paid to sustainable fishing and environmental protection.

Peru

Peru is considered a major-scale industrial fleet, being composed of 677 purse seine vessels, 70 trawl fleet vessels, and 30 multipurpose vessels. The purse seine fleet primary catches are anchovy, sardine, Inca scad, and Atlantic mackerel. The trawl fleet primary captures are mainly hake, Inca scad, and Atlantic mackerel. The multipurpose vessel catches include common dolphinfish and shark. In 2002 Peru was second in total capture (Table 3.3-4), and her major exports are fishmeal and oil. Their fishing industry is one of the most adaptable in the world, having to withstand the effects of climatic variations, such as El Niño, that affect coastal upwelling, and fluctuations of the market conditions for fishmeal and oil.

United States

Commercial fishing in the U.S. is a multibillion-dollar industry closely connected to the world economy. More than a fifth of the world's most productive marine fisheries lie within the U.S.

EEZ (NMFS, 2002). Based on total capture as reported by the FAO (Table 3.3-4), the U.S. is the third ranked fishing nation in the world. In 2001, there were over 170,000 people and 123,000 commercial fishing vessels employed by the commercial fishing industry (NMFS, 2002). In addition, 82,582 people were employed by wholesalers and processors in 2000 (FAO, 2003). Another 20,108,000 people fish recreationally. In 2001, the contribution of the domestic commercial seafood industry to the U.S. Gross National Product (GNP) was $28.6 billion, with recreational fisheries contributing an additional $25 billion to the GNP (NMFS, 2002; PEW Oceans Commission, 2003; Panetta, 2003). The U.S. is the fourth largest exporter, with $11.8 billion in fish products sent to countries such as Japan, Canada, South Korea, China, and Germany (FAO, 2003).

Fisheries contribute less than one percent of the U.S. economic activity. However, for many coastal cities, a major contribution to the economy comes from fishing. Major U.S. domestic species landed in 2001 included pollack, menhaden, salmon, cod, hakes, flounders, shrimp, herring (sea), crabs, squid, lobsters, scallops, calms, and halibut (Holiday and O'Bannon, 2002).

U.S. fisheries are divided into regions. The **Northeast** region includes mixed-species groundfish, American lobsters, and Atlantic sea scallops. Recreational fisheries include Atlantic cod, winter flounder, Atlantic mackerel, striped bass, bluefish, and bluefin tuna. The **Southeast** region covers the Gulf of Mexico, U.S. Southeast Atlantic, and the Caribbean Sea. Important resources in this region are Atlantic sharks, Atlantic and Gulf of Mexico reef fish, drum and croaker, menhaden, Southeast Atlantic and Caribbean invertebrates, and highly migratory pelagic fish. Shrimp lead the region's fisheries in value. The **Alaska** region's major resources include Pacific salmon, groundfish, Pacific halibut, shellfish, and herring. This region has the potential to dominate tonnage of fisheries captured in the long term for the U.S because many resources are underutilized. The **Pacific Coast** region's major species are Pacific salmon, coastal pelagic fish, groundfish, and Pacific halibut. Recreational fisheries are important, especially in Southern California, where gamefish include albacore, billfish, rockfish, and salmon. Recreational crabbing, clam digging, and abalone diving activities are also significant. The **Western Pacific** region stretches across the central and western Pacific Ocean including the Hawaiian Islands, American Samoa Islands, Guam, and Northern Marianas. These tropical and subtropical island waters are known for the large diversity of species but low yields due to limited nutrients. Targeted species include tuna, billfish, swordfish, sharks, snapper, jack, grouper, emperors, and spiny and slipper lobsters.

Indonesia

Indonesian fisheries, which are ranked fourth in 2002 for total capture, are very complex and diverse, reflecting the countries extraordinary varied geography and great variations in species and population densities. Over 90 percent of the fisheries production is from small-scale operations, which focus on high-value shrimp and tuna. A large percentage of the vessels in this portion of the industry are non-powered. About half of the fish capture ends up as consumed fresh.

Japan

Japan is one of the top consumers of fisheries products, which play an important role in food security in Japan, accounting for nearly 40 percent of the animal protein in the Japanese diet. Fisheries are an important industry in coastal areas and are vital to the preservation of local traditional culture and regional economics. Japanese fisheries are divided into three categories:

- Distant water fisheries—Operated mainly on the high seas, as well as foreign countries' EEZs;
- Offshore fisheries—operated mainly in the Japanese EEZ, as well as the EEZs of neighboring countries; and
- Coastal fisheries—operated mainly in waters adjacent to fishing villages.

Japanese fisheries are in decline, with reductions in captures from 7.3 mt in 1993 to 4.4 mt in 2002. This is attributed to a combination of factors, including the decline of fisheries resources in coastal, offshore, and distant fisheries. The industry is in depression and there is a decline in the number of fishermen. The major species fished in Japanese waters are silver anchovy, skipjack, tunas (bluefin, albacore, big eye, yellow fin), mackerel, squid, saury, salmon, Japanese horse mackerel, atka mackerel, sand lance, oriental sardine, halibut, cod, red pargo, and flounder.

Chile

Chile is ranked sixth in 2002 for marine fisheries based on total capture. Their fleet consists of approximately 500 vessels. Major pelagic captures include the Chilean jack mackerel, Peruvian anchovy, and Chilean sprat. Main demersal resources are the Chilean hake and New Zealand hake. Their fishing industry is also subject to fluctuations due to the environmental influences of El Niño.

India

India has had a gradual increase in fisheries capture with 3.1 million mt in 1993 and 3.8 million mt in 2002. There are a total of 6 million fishermen in the country with 2.4 million being full-time. Species caught include Indian oil sardine, Indian mackerel, croakers, Bombay duck, anchovies, cephalopods, perches, jacks, and shrimp. India's exported $1.4 billion in fisheries commodities.

Russian Federation

The Russian Federation extends from the Baltic Sea to the Pacific Ocean and from the Arctic Ocean to the Black Sea. As such, its fisheries include the northeastern Atlantic (Barents, White and Baltic seas); Caspian, Black, and Azov seas; and northwestern Pacific (Bering, Okhotsk, and Japanese seas and oceanic waters). The Russian federation is ranked seventh in total capture for marine fisheries in 2002. Catches include Alaska pollock, Arcto-Norwegian and Pacific cods, herring (mostly Pacific herring), Pacific salmon, king and snow crabs, flounder, halibut, and haddock.

Thailand

Marine fisheries have a significant socio-economic role in Thailand. The marine catch is composed of tropical multi-species, including food fish, trash fish, squid and cuttlefish, shrimp, shellfish, and crab. Food fish are composed mainly of sardinellas, anchovies, Indo-Pacific mackerel, scads, threadfin breams, big-eyes, lizard fish, etc.

Norway

Norway is the biggest fishing nation in Europe and fisheries are the major economic activity along its vast coast. The adjacent waters are highly productive, producing herring, sprat, cod, capelin, shrimp, and mackerel. The Norwegian fleet of about 4,000 vessels is classified by function as: large purse seiners fishing for pelagic species; large factory trawlers fishing either for shrimp or demersal species (finfish); smaller wet-fish steel trawlers; smaller purse seiners; smaller shrimp trawlers; and a diverse coastal fleet.

3.3.1.2 Fisheries Trade

In 2000 more than 22 million persons worldwide were estimated to be employed by the marine capture fisheries (FAO, 2002b). In 2002, total exports of fish and fishery products were $58.3 billion in U.S. dollars (FAO, 2002a).

Fish-related import and export values for major regions of the world as expressed in millions of U.S. dollars are presented in Table 3.3-5. As can be seen, fish export values were highest in Europe and Asia at $20.5 billion and $19.6 billion respectively. The Americas followed with $13.2 billion. Africa and Oceania had the lowest fish-related trade.

Of the almost 200 countries with separate fisheries import/export statistics in the 2002 FAO report, 20 had export volumes above $1 billion including China, Thailand, Norway, U.S., Canada, Denmark, Vietnam, Spain, Chile, Netherlands, Taiwan, Indonesia, Iceland, India, Russian Federation, UK, Germany, France, Peru, and the Korean Republic. China generated the highest export volume in fish-related commodities at $4.5 billion.

Table 3.3-5. Total fish imports and exports by region for 2002.

Region	Total Imports (U.S. million dollars)	Total Exports (U.S. million dollars)
Africa	1,070,141	3,153,171
North America	11,923,641	7,999,607
South America	474,498	5,177,442
Asia	23,026,757	19,596,752
Europe	24,270,926	20,469,131
Oceania	679,650	1,815,036
Reference: FAO (2002a)		

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) which, among other things, designates whale sanctuaries, sets limits on the numbers and sizes of whales that may be captured, and provides 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 in commercial whaling, which took affect during the 1985-1986 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

The objectives for subsistence hunting are to ensure that the risk of extinction is not increased, to enable harvests that are appropriate for cultural and nutritional requirements, and to maintain stocks at their highest recruitment level or to ensure that stock numbers are increasing toward this level. The reported takes for aboriginal subsistence hunting can be seen in Table 3.3-6.

Aboriginal subsistence whaling of specific species is allowed in certain countries as follows:

- Denmark and Greenland - fin and minke whales;
- Russian Federation (Siberia) - gray whales;
- St. Vincent and The Grenadines - humpback whales; and
- U.S. (Alaska and Washington) - bowhead and occasionally gray whales.

Table 3.3-6. Aboriginal subsistence hunting for the 2001 and 2002 hunting seasons as reported by the IWC.

Country	Fin	Humpback	Gray	Minke	Bowhead	Total
2001						
Denmark- West Greenland	8	2	0	139	0	149
Denmark- East Greenland	0	0	0	17	0	17
St. Vincent	0	2	0	0	0	2
Russia	0	0	112	0	1	113
US	0	0	0	0	75	75
2002						
Canada	0	0	0	0	1	1
Denmark- West Greenland	13	0	0	139	0	152
Denmark- East Greenland	0	0	0	10	0	10
St. Vincent	0	0	0	0	0	0
Russia	0	0	131	3	0	134
US	0	0	0	0	50	50

Scientific Research

Scientific research permits are issued for the killing of whales for scientific purposes. In order to obtain a permit, the specific aim, samples, and methodology must be justified including determining that the research is essential for rational management, the methodology and samples are likely to provide answers for the questions asked, the questions cannot be answered non-lethally, the catches will not have an adverse impact on the stock, and scientists from other nations may join the research program.

IWC scientific research permits have been issued as follows:

- Iceland - 292 fin and 70 sei whales;
- Norway - 289 minke whales; and
- Japan - 400± minke whales in the Antarctic and 100 minke whales around Japan.

The data in Table 3.3-7 state the reported whale catches under special permits for scientific research by year from 1999 to 2002.

Table 3.3-7. Japanese Scientific Research Permit whale catches as reported by the IWC.

Country	Fin	Sperm	Sei	Brydes	Minke	Total
1999						
Japan	0	0	0	0	100	100
Japan Pelagic	0	0	0	0	439	439
2000						
Japan	0	5	0	43	40	88
Japan Pelagic	0	0	0	0	440	440
2001						
Japan	0	8	1	50	100	159
Japan Pelagic	0	0	0	0	440	440
2002						
Japan	0	5	39	50	150	244
Japan Pelagic	0	0	0	0	440	440

Norway has objected to the IWC's moratorium on whaling and continues to "take" whales, claiming its right to national catch limits for minke whales as shown in Table 3.3-8. The IWC Commission opposes this right and has called for Norway to stop all whaling activities.

Table 3.3-8. Norway's total minke whale catches from 1993 to 2002.

Year	Total Whales
1993	226
1994	280
1995	218
1996	388
1997	503
1998	625
1998	591
2000	487
2001	552
2002	634

IWC Whale Sanctuaries

The IWC also establishes sanctuaries. The first IWC sanctuary was established in the Antarctic in 1938, south of 40S between longitudes 70W and 160W. The original reason for this was that in this sector commercial whaling had not hitherto been prosecuted and it was thought highly desirable that the immunity that whales in this area had enjoyed should be maintained.

The Indian Ocean Sanctuary was established by the IWC in 1979, extending south to 55S latitude, as an area where commercial whaling is prohibited. This was initially established for 10 years and its duration has since been extended twice.

At the 46th (1994) Annual Meeting the IWC adopted the Southern Ocean Sanctuary as another area in which commercial whaling is prohibited. The northern boundary of this Sanctuary follows the 40S parallel of latitude, except in the Indian Ocean sector where it joins the southern boundary of that sanctuary at 55S, and around South America and into the South Pacific where the boundary is at 60S. This prohibition is reviewed at ten-year intervals. In fact, at the 54th meeting in 2002 the IWC's Scientific Committee established a Working Group to review existing IWC sanctuaries and sanctuary proposals and carried out a review of the Indian Ocean Sanctuary.

Two additional proposals for the establishment of sanctuaries in the South Atlantic and South Pacific have been under review by the Commission for a number of years. To date, both have failed to achieve the three-quarters majority of votes needed to become designated IWC Sanctuaries.

Marine Mammal Bycatch

The PEW Oceans Commission reported in America's Living Oceans: Charting a Course for Sea Change (2003) that fishermen accidentally catch, injure, and kill marine life that they do not intend to capture. They reported that an estimated 2.3 billion pounds of marine wildlife bycatch were discarded, injured or dead, in 2000. This is estimated to be approximately 25 percent of the worldwide catch. Bycatch is not only a concern for commercial marine wildlife; non-commercial wildlife, such as marine mammals, sea birds, sea turtles, blue marlin, smalltooth sawfish, and barndoor skate have also shown signs of decline (PEW Oceans Commission, 2003).

The FAO published a technical paper in 1991, which discusses the conflicts between marine mammals and fisheries (Northridge, 1991). This paper, which has not been recently updated, reports that in the northwest Atlantic Ocean, harbor porpoises are the most common marine mammal caught in fishing gear. To a lesser extent larger whales and bottlenose dolphins are also affected in this region. In the northeast Atlantic, harbor porpoises and common dolphins are most affected, although the grey seal is thought to compete with fisheries. Bottlenose dolphins comprise the largest bycatch in the western central Atlantic Ocean. Very little information exists on the eastern central Atlantic. The Atlantic humpbacked dolphin and West African manatee are coastally distributed and could be affected by fisheries. In the Mediterranean and Black Seas, monk seals, striped dolphins, and sperm whales are the most affected by interaction with fisheries. Bottlenose dolphins are also taken in a variety of fishing gears. Commerson's dolphin is reportedly caught in the southwest Atlantic. Few recent studies have been conducted in the southeastern Atlantic.

In the eastern Indian Ocean, the species most heavily impacted by fisheries interactions are the spotted and spinner dolphins, the dwarf and pygmy sperm whale, and the bottlenose and humpbacked dolphins. The finless porpoise and the Irrawaddy dolphins are affected in the western Indian Ocean.

The information from the northwest Pacific came from data on incidental captures by the Japanese, Chinese, and Russian fisheries. The Baiji is the species most severely impacted, but the Kuril seal and Dall's porpoise are also frequently caught. In the northeast Pacific Ocean, the main species affected by the fisheries are the northern right whale dolphin, the Pacific white-sided dolphin, the harbor seal, and the northern fur seal. Bottlenose dolphins are the most heavily affected by fisheries, but Irrawaddy and finless porpoises are affected on a lesser extent in the western central Pacific area. Spotted dolphins, Vaquita, and harbour porpoises are the most affected species in the eastern central Pacific. In the southwest Pacific, Hector's dolphin and Hooker's sea lions are affected by driftnet fisheries and trawl fisheries. Finally, in the southeast Pacific, the dusky dolphin, Burmeister's porpoise, the Chilean dolphin, and possibly southern right whale dolphins, Peale's, and Commerson's dolphins are the most affected by fisheries interactions.

Under Section 118(b) of the MMPA, entitled Zero Mortality Rate Growth (ZMRG), NMFS must review the progress of all commercial fisheries to ensure the reduction of incidental mortality of marine mammals. In August, 2004, NMFS published the "Report to Congress: Review of Commercial Fisheries' Progress Toward Reducing Mortality and Serious Injury of Marine Mammals Incidental to Commercial Fishing Operations" (NMFS, 2004). The short-term goal is to reduce, within six months of implementation, the incidental mortality and serious injury of marine mammals incidentally taken by commercial fisheries, to levels less than the Potential Biological Removal (PBR) level. The long-term goal is to reduce incidental mortality and serious injury of marine mammals to insignificant levels, approaching a zero rate of mortality and serious injury within five years of implementation. NMFS concludes that in the 2004 List of Fisheries, 175 of the 216 fisheries are in Category III, which have a remote likelihood of killing or seriously injuring marine mammals. A remote likelihood is defined as having a mortality less than or equal to ten percent of the stock's PBR. Thirty four fisheries are in Category II, which includes combined fisheries that have occasional mortality and serious injury of marine mammals, causing mortality or serious injury above ten percent of a stock's PBR. Finally, seven fisheries are in Category I, which includes fisheries that have frequent mortality and serious injury of marine mammals which is quantified as being greater than or equal to 50 percent of the PBR.

The results of the 2004 review and report to Congress concluded:

- Most fisheries have achieved levels of incidental mortality consistent with the ZMRG, with greater than 80 percent in Category III.
- Substantial progress has been made through Take Reduction Plans (TRPs). For example, incidental mortality of harbor porpoise incidental to fisheries in New England and the mid-Atlantic states has been reduced from more than five times the stock's PBR to less than half of the stock's PBR. Under the Pacific Offshore Cetacean TRP, the California and Oregon drift gillnet fishery has reduced incidental mortality to levels that have allowed the fishery to be reclassified as Category II from Category I.
- Additional information is needed for most fisheries and marine mammal stocks to accurately assess whether mortality incidental to commercial fishing is at insignificant levels, approaching a zero mortality and serious injury rate.

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 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 nm) 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 the 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 approximately 277,400 diving certifications in 1986 and 854,052 in 2000, reflecting a 32 percent increase during those years (PADI, 2004). In fact, between 1967 and 2000, PADI issued a cumulative total of nearly 10,151,141 diving certifications. The National Association of Underwater Instructors (NAUI) issues approximately 130,000 certifications annually (Davis and Tisdell, 1995).

It is estimated that over 1.2 million dive trips are taken to warm-water destinations each year (Simmons, 1997), including the Caribbean, Gulf of Mexico, south Pacific Ocean, Mediterranean Sea, and Indian Ocean, as well as other locations (see text box below). Surveys of the demographics of diving students and instructors conducted by PADI in 1991 and 1996 revealed that most divers are males between 18 and 29 years old.

Diving Locations			
Anguilla and Antigua	Aruba	Australia	Bahamas
Barbados	Belize	Bermuda	Bonaire
British Virgin Islands	Canada	Cayman Islands	Columbia
Costa Rico	Cuba	Curacao	Cyprus
Dominican Republic	Dutch Antilles	Ecuador	Egypt
England	Fiji	France	Fr. Polynesia
Galapagos Island	Greece	Grenada	Guam
Haiti	Honduras	Indonesia	Israel
Italy	Jamaica	Jordan	Kenya
Madagascar	Malaysia	Malta	Maldives
Marshall Islands	Martinique	Mauritius	Mexico
Micronesia	Mozambique	Netherlands Antilles	New Zealand
Oman	Papua New Guinea	Puerto Rico	Philippines
Reunion	Saudi Arabia	Scotland	Seychelles
Solomon Islands	South Africa	Spain	Sri Lanka
St. Kitt and Nevis	St. Lucia	St. Vincent	Sudan
Thailand	Tonga	Trinidad and Tobago	Tunisia
Turkey	Turks and Caicos	United Kingdom	United States
U.S. Virgin islands	Vanuatu	Venezuela	Yemen
Sources: PADI, 2004; Simmons, 1997; Taylor, 1982			

3.3.2.3 Whale Watching

Whale watching worldwide has been expanding rapidly in recent years and is considered a valuable industry in a commercial, educational, environmental, and scientific sense. In 1994, an estimated 5.4 million people in 65 countries or territories participated in whale-watching excursions, a figure that has been growing at about ten percent per year (Whale and Dolphin Conservation Society, 1997). Statistics from Iceland also are illustrative of the growth of whale watching. In 1995, the total number of passengers on whale-watching trips in Iceland was 2,200; in 1996 that number had grown to about 9,700. By 1997 Iceland recorded 20,540 passengers, reflecting an increase of 110 percent over 1996 data, and an increase of over 800 percent when compared with 1995 data (Cetacean Society International [CSI], 1998).

According to the International Fund for Animal Welfare (Hoyt, 2001), whale watching has grown to be at least a $1 billion (USD) industry with 87 countries and territories promoting tours and over 9 million people participating in the tours, growing at an average of 12.1 percent per year since 1991.

Due to the seasonal migration of whales, the location of whale-watching activities varies by season, and the employment associated with the industry is temporary; however, it is expanding with the growing industry. Most whale-watching activities focus on humpback whales, gray whales, northern and southern right whales, blue whales, minke whales, sperm whales, short-finned pilot whales, orcas, and bottlenose dolphins (Hoyt, 2001). The IWC and other whale preservation organizations support whale watching as a sustainable use of cetacean resources (IWC, 1998; CSI, 1998; Spalding, 1998). In 1996 the IWC adopted the following general principles for managing this emerging industry in order to help minimize adverse effects on whale populations:

- 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, 1998).

There are, however, costs to whale watching. These costs include pollution due to the use of boats, trash thrown into the water by the observers, trampling coastal areas, the effects of petroleum products on the environment when you drive or fly to the site, effects on the community of marine mammals, and the risk of harassment to marine mammals. Ship strikes are also a risk associated with whale watching. Of the 134 ship strike accounts where the type of vessel is known, there have been 19 reports of ship strikes 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

Oceanographic research, much of it sponsored by the world’s governments, is conducted in all oceans of the world. This research is geared to refining and expanding our knowledge of marine biology (including the life habits and physiology of marine mammals, fish, and reptiles), and marine geophysics (history, morphology and chemistry of the earth’s crust and the potential for natural hazards) (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 (WHOI), the Scripps Institution of Oceanography at the University of California, the Lamont-Doherty Earth Observatory at Columbia University, and several science centers operated by NMFS, conduct research each year over the world’s oceans.

Deployment of unmanned diving vessels from research ships constitutes a significant part of ocean research. Unmanned remotely operated vehicles (ROVs) carry television cameras and other equipment such as water samplers. ROVs are 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.

U.S., Canadian, Australian, Japanese, and several European governmental agencies conduct research with ROVs. The Canadian deep-sea vehicle ROPOS (Remotely Operated Platform for Ocean Science), for example, has conducted research at depths as great as 4,960 m (16,270 ft) in the Pacific and North Pacific near Oregon, Washington, and the Aleutians. There are about 16 manufacturers and 30 operator/marine service companies active with ROVs on a year-round basis in the oceans (Ontini, 1998).

Manned submersible vehicles are also used in ocean research. These vehicles communicate with their deployment ship using radios. Of the estimated 160 commercial and scientific submersibles built since 1960, approximately 40 are still operating.

The Autonomous Undersea Systems Institute (AUSI) is an independent research institute that coordinates research for autonomous underwater vehicles (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.

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 HF. The sub-bottom profiler maps the bottom topography while supplying information on sedimentary features (LGL Limited, 2003).

Ocean acoustic tomography (OAT) 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. The Acoustic Thermometry of Ocean Climate (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 new program, Scripps is reusing the sound source in Hawaii for its North Pacific Acoustic Laboratory (NPAL). NPAL's objectives combine:

- 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 University-National Oceanographic Laboratory System (UNOLS) is a consortium of 61 academic institutions involved in federally-funded oceanographic research. Twenty of these institutions operate the 28 ships of the UNOLS Fleet. Ship schedules, geographic locations of proposed cruises, and other information 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. A drilling record was set in 1998 by Chevron U.S.A. for drilling a well at a depth of 2,352 m (7,718 ft) southeast of New Orleans.

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 collect data up to 300 m (9,845 ft) deep and are used for the initial site evaluation for drill rig emplacement and platform design. Deep seismic surveys obtain data up to several thousands of meters deep and 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 that can be longer than 3 km (1.6 nm) (U.S. Dept of Interior, 1997). 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 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.

Construction of five to seven percent of wells involves the use of subsea systems to install wellhead and related equipment on the ocean floor. The remaining systems use surface wellhead equipment. Both types 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.

3.3.4 Coastal Zone Management

Since 1972, 33 coastal states and territories have developed and implemented programs to ensure appropriate resource protection and compatibility of uses in their coastal zones. The programs are linked to existing state/territorial laws and authorities, such as tidal wetland statutes, regional agreements, and water quality certification under Section 401 of the Clean Water Act of 1977. The enforcement authority for the program is often a state coastal commission. Federal lands are excluded from the jurisdiction of the state coastal zone management programs, but activities on federal lands are subject to the Coastal Zone Management Act (CZMA) federal consistency requirements if the federal activity will affect land or water or natural resources of the state's coastal zone, including reasonably foreseeable effects.

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;
- 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 addressing 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 three geographic (nautical) miles into the Atlantic or Pacific oceans or three marine leagues (10.35 nm) into the Gulf of Mexico.

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.