4 IMPACTS OF PROPOSED ACTION AND ALTERNATIVES

This chapter supplements the analyses and results on the potential impacts or effects upon various components of the environment that could result from the implementation of the proposed action and of alternatives to the proposed action. The basis for this analysis is consistent with the SURTASS LFA sonar FOEIS/EIS and has been updated based on the best available literature, the Long Term Monitoring Program of current SURTASS LFA sonar operations, and continuing research. Further, there are no new data that contradict any of the assumptions or conclusions regarding Chapter 4 in the FOEIS/EIS; hence its contents are incorporated by reference herein.

For SURTASS LFA sonar Alternatives, potential impacts should be reviewed in the context of the basic operational characteristics of the system:

- A maximum of four systems would be deployed in the Pacific-Indian ocean area and in the Atlantic-Mediterranean area.
- The R/V *Cory Chouest* and the USNS IMPECCABLE are presently the only vessels equipped with a SURTASS LFA sonar system. Both vessels are U.S. Coast Guard-certified for operations. In addition, they operate in accordance with all applicable federal and U.S. Navy rules and regulations related to environmental compliance. All future vessels to be equipped with SURTASS LFA sonar systems would also be U.S. Coast Guard-certified and compliant with all applicable federal and U.S. Navy environmental rules and regulations. SURTASS LFA sonar vessel movements are not unusual or extraordinary and are part of routine operations of seagoing vessels. Therefore, there should be no unregulated environmental impacts from the operation of the SURTASS LFA sonar vessels.
- At-sea missions would be temporary in nature (see Subchapter 2.2 [Operating Profile]). Of an estimated maximum 294 underway days per year, the SURTASS LFA sonar would be operated in the active mode about 240 days. During these 240 days, active transmissions would occur for a maximum of 432 hours per year per vessel. The FOEIS/EIS analyzed four vessels each with 432 hours of transmission time per year (See FOEIS/EIS Subchapter 2.2). In the ROD, the Navy stated that it would employ only two SURTASS LFA systems because only two systems would be available during the five year period through 2007. In the MMPA Rule, NMFS limited the Navy to two systems, consistent with the ROD, with missions totaling no more than 432 hours of transmissions per vessel per year. Because SURTASS LFA operations were limited to a relatively small area in the northwestern Pacific Ocean by the Court's Permanent Injunction, NMFS restricted the total operating hours to 432 hours for both vessels in the annual LOAs. Because LFA operations are not expected to be geographically restricted (except as noted in the mitigation) in the future, the original planned 432 hours of active transmissions per vessel per year, as analyzed in the FOEIS/EIS, are also

proposed in this SEIS.

- The duty cycle of the SURTASS LFA sonar would be limited (it would generally be on between 7.5 and 20 percent of the time [7.5 percent is based on historical LFA operations since 2003 and the physical maximum limit is 20 percent]). The LFA transmitters would be off the remaining 80-92.5 percent of the time.

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.

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

- **Non-auditory injury**: This includes the potential for resonance of the lungs/organs, tissue damage, and mortality. For the purposes of the SURTASS LFA sonar analyses presented in this SEIS, all marine animals exposed to $\geq$ 180 dB Received Level (RL) are evaluated as if they are injured.
- **Permanent threshold shift (PTS)**: A severe situation occurs when sound intensity is very high or of such long duration that the result is a permanent threshold shift (PTS) or permanent hearing loss on the part of the listener. This constitutes Level A "harassment" under the MMPA, as does any other injury to a marine mammal. The intensity and duration of a sound that will cause PTS varies across species and even between individual animals. PTS is a consequence of the death of the sensory hair cells of the auditory epithelia of the ear and a resultant loss of hearing ability in the general vicinity of the frequencies of stimulation (Salvi et al., 1986; Myrberg, 1990; Richardson et al., 1995).
- **Temporary threshold shift (TTS)**: Sounds of sufficient loudness can cause a temporary condition in which an animal's hearing is impaired for a period of time (TTS – Temporary Threshold Shift). After termination of the sound, normal hearing ability returns over a period that may range anywhere from minutes to days, depending on many factors including the intensity and duration of exposure to the intense sound. Hair cells may be temporarily affected by exposure to the sound but they are not permanently damaged or killed. Thus, TTS is not considered to be an injury (Richardson et al., 1995), although during a period of TTS, animals may be at some disadvantage in terms of detecting predators or prey and thus potentially harmed.
- **Behavioral change**: Various vertebrate species are affected by the presence of intense sounds in their environment (Salvi et al., 1986; Richardson et al., 1995). For military readiness activities, like use of SURTASS LFA sonar, Level B "harassment" under the MMPA is defined as any act that disturbs or is likely to disturb a marine mammal by causing disruption of natural behavioral patterns to a point where the patterns are abandoned or significantly altered. Behaviors include migration, surfacing, nursing, breeding, feeding, and sheltering. The National Research Council

(NRC, 2005) discusses biologically significant behaviors and possible effects. It states that an action or activity becomes biologically significant to an individual animal when it affects the ability of the animal to grow, survive, and reproduce. These are the effects on individuals that can have population-level consequences and affect the viability of the species (NRC, 2005). While sea turtles and fish do not fall under harassment definitions, like marine mammals, it is possible that loud sounds could disturb the behavior of fish and sea turtles in the same way, resulting in the same kinds of consequences as for marine mammals.

- **Masking**: The presence of intense sounds in the environment can potentially interfere with an animal's ability to hear sounds of relevance to it. This effect, known as "auditory masking;" could interfere with the animal's ability to detect biologically relevant sounds, such as those produced by predators or prey, thus increasing the likelihood of the animal not finding food or being preyed upon.

4.1 Potential Impacts on Fish

Since the SURTASS LFA sonar FOEIS/EIS was completed in 2001, there have been a small number of useful studies on the potential effects of underwater sound on fish, including sharks. However, one of these studies (funded by the Navy to provide data for this SEIS) is directly relevant to effects of SURTASS LFA sonar on fish; while the other examined the effects of seismic air guns[1] on fish. Thus, while earlier studies examined the effects of sounds using pure tones for much longer duration than the SURTASS LFA sonar signals, these recent studies provide insight into the impact of each of these sounds on fish. With the caveat that only a few species have been examined in these studies, the investigations found little or no effect of high intensity sounds on a number of taxonomically and morphologically diverse species of fish, and there was no mortality as a result of sound exposure, even when fish were maintained for days post-exposure. This section will provide summaries of the recent research and update the analysis of the potential effects of the alternatives based on the following SURTASS LFA sonar operational parameters:

- Small number of SURTASS LFA sonar systems to be deployed;
- Geographic restrictions imposed on system employment;
- Narrow bandwidth of SURTASS LFA sonar active signal (approximately 30 Hz);
- Slowly moving ship, coupled with low system duty cycle mean fish and sea turtles would spend less time in the LFA mitigation zone (180-dB sound field); further, with a ship moving in two dimensions and animals moving in three dimensions, the potential for animals being in the sonar transmit beam during the estimated 7.5 percent of the time the sonar is actually transmitting is very low; and
- Small size of the LFA mitigation zone (180-dB sound field) relative to fisheries provinces and open ocean areas. Due to the lack of more definitive data on fish/shark

[1] Seismic air guns differ from SURTASS LFA sonar in that they generally transmit in the 5-20 Hz frequency band and their typical air gun array firing rate is once every 9-14 seconds, but for very deep water surveys could be as high as 42 seconds. Air gun acoustic signals are typically measured in peak-to-peak pressures, which are generally higher than continuous sound levels from other ship and industrial noise. Broadband SLs of 248-255 dB are typical for a full-scale array, but can be as high as 259 dB SL.

stock distributions in the open ocean, it is not feasible to estimate the percentage of a stock that could be located in a SURTASS LFA sonar operations area at a potentially vulnerable depth, during a sound transmission.

4.1.1 Potential Impacts on Fish (Class Osteichthyes) Stocks

4.1.1.1 Non-auditory Injury

A number of investigators have suggested that fish exposed to high intensity sounds could show a range of non-auditory injuries from the cellular level to gross damage to the swim bladder and circulatory system (reviewed in Hastings and Popper, 2005). However, the bulk of the data suggesting such injuries come from studies that tested the effects of explosives on fish (e.g., Yelverton et al., 1975; and see review in Hastings and Popper, 2005). There is less evidence for such damage (albeit, from very few studies) when fish are exposed to sounds similar to those produced by sonars, pile driving, shipping noise, and other anthropogenic sources.

Studies looking at the effects of sound on terrestrial mammals suggest that lungs and other organs are potentially damaged by sound (e.g., Fletcher et al., 1976; Yang et al., 1996; Dodd et al., 1997). There is also some evidence, in "gray" literature reports (i.e., non-peer-reviewed), that high sound pressure levels may cause tearing or rupturing of the swim bladder of some (but not all) fish species (e.g., Gaspin, 1975; Yelverton et al., 1975). Most recently, similar results have been observed in fish exposed to the impulsive sounds from pile driving when fish are at an undetermined range but very close to the pile driving source (e.g., Abbott and Bing-Sawyer, 2002; Caltrans, 2004).

The only studies that examined the effects of sound on non-auditory tissues have been recent work using SURTASS LFA sonar (undertaken by the Navy) and seismic air guns, both of which are reviewed below. The significant point from these studies, however, is that neither source, despite being very intense, had any effect on non-auditory tissues. In all fish, the swim bladder was fully intact after exposure, and in the one study that involved an expert fish pathologist (to ensure that the non-auditory tissues of the fish sacrificed were examined properly), there was no damage to tissues either at the gross or cellular levels. These studies provide the first direct evidence that sounds including seismic air guns and SURTASS LFA sonar may be of concern, but that does not necessarily mean that they kill or damage fish. However, both groups of investigators were careful to note that their studies were done with only a limited number of species, and that extrapolation between species, and to other sound sources (or even to other levels or durations of the same sound sources), must be done with extreme caution, at least until there are more data upon which to base any extrapolations.

4.1.1.2 Permanent Loss of Hearing

A number of studies have examined the effects of high intensity sound on the sensory hair cells of the ear. These cells transduce (convert) the mechanical energy in the sound field into a signal that is compatible with the nervous system. Loss of these cells in terrestrial animals results in permanent hearing loss (e.g., Fletcher and Busnel, 1978; Saunders et al., 1991). Thus, it is likely that comparable damage to sensory hair cells in fish could also result in hearing loss. However, while there are studies, as discussed below, indicating some damage to sensory hair cells in fish resulting from exposure to very intense and relatively long signals, there has yet to be any study that has examined fish hearing before and after such damage. Thus, while it may be speculated that fish with damaged and destroyed sensory hair cells would also have hearing loss, to date this is only conjecture.

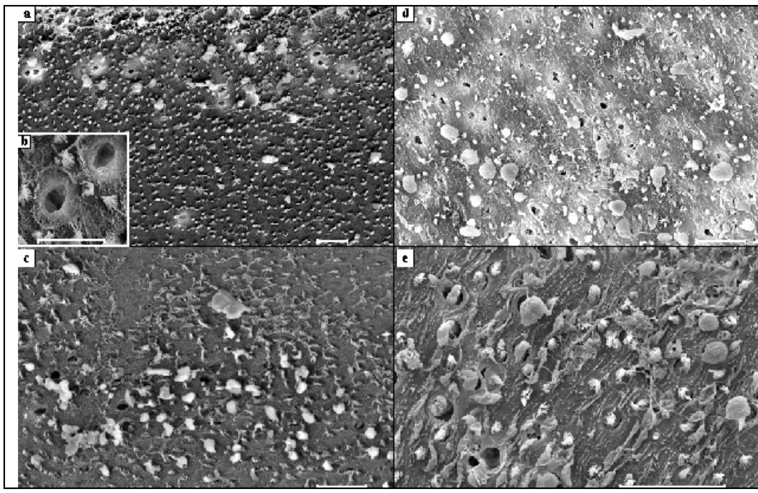
There have been four earlier studies that examined the effects of high intensity sounds on fish ears. Hastings et al. (1996) investigated the effects of intense sound stimulation on the ear and lateral line of a non-specialist freshwater fish (*Astronotus ocellatus,* the oscar). The investigators exposed fish to a sound at 300 Hz and a RL of 180 dB, and found some damage to the sensory hair cells of two of the otolith organs, the lagena and utricle, four days after a continuous signal for one hour. There was no apparent damage with other frequencies, sounds with shorter duty cycles, or shorter stimulation time, or when the ear was studied immediately after the cessation of stimulation. The interpretation of these results by the investigators was that exposure to a high intensity sound has the potential to damage the sensory cells of the ears of fish. However, the sound had to be continuous and had to last at least one hour; and the damage was only evident some time after exposure.

Additional studies suggest that intense sound may result in damage to the sensory hair cells in the ears of other species. Cox et al. (1986a, b; 1987) exposed goldfish (*Carassius auratus*), a freshwater hearing specialist, to pure tones at 250 and 500 Hz at 204 and 197 dB RL, respectively, for two hours. They found some indications of sensory hair cell damage, but these were not extensive. Enger (1981) determined that some ciliary bundles (the sensory part of the hair cell) on sensory cells of the inner ear of the cod (*Gadus morhua*) were damaged when exposed to sounds at several frequencies from 50 to 400 Hz at 180 dB RL for 1 to 5 hours.

McCauley et al. (2003) examined the effects on the sensory tissues of the ears of the Australian fish, the pink snapper (*Pagrus auratus*), as a consequence of exposure to a seismic air gun. Fish were placed in a cage and exposed to emissions of a single seismic air gun that was moved toward and away from the test cage. The air gun used had a SL at 1 m of 222.6 dB (peak to peak), or 203.6 dB (rms). It was deployed at 5 m (16.4 ft) depth and towed from a distance of 400 to 800 m (1312 to 2625 ft) from the cage to a position as close as 5 to 15 m (16.4 to 49.2 ft) to the cage and then back to the starting point. The goal was to present a signal that was similar to that which fish might encounter if they are near an active air gun survey that is moving back and forth over a study site.

The animals were maintained for varying periods of time post exposure. The fish were then sacrificed, and the ears examined using scanning electron microscopy (SEM) as shown in Figure 4.1-1. The investigators reported that there was considerable damage to the ciliary bundles of the sensory hair cells of the saccular sensory epithelium (the other end organs were not examined), and the extent of damage increased with increase in the time the animals were kept post exposure. The animals that were maintained the longest, to 58 days post exposure, had the greatest damage to ciliary bundles according to the investigators. Significantly, all of the experimental animals survived for the full 58 days post exposure and fed and appeared to behave normally. While indirect evidence, these observations suggest that there was no other permanent damage to the fish such as damage to the swim bladder.

Although both the Hastings et al. (1996) and McCauley et al. (2003) studies, as well as a study by Enger (1981), suggested that high-intensity sounds could potentially result in damage to sensory hair cells, it is important to note several caveats in considering these results These caveats (as pointed out by the authors of the two more recent papers) include: (1) the use of only a few species in the studies and that these species may not be representative of other species; (2) the inability of the caged fish in any of the studies to depart the immediate sound field and thus lessen sound exposure and the likelihood of damage; and (3) the relatively long duration of the experimental sounds as compared to the shorter exposures that might be expected in LFA or other types of human-generated sounds at high signal levels.



Scanning electron micrographs of the saccular sensory epithelium of the pink snapper following exposure to a seismic air gun (see text for parameters). (a, b, c) Epithelia from fish sacrificed 18 hours after exposure to the air gun. The photographs show numerous holes and "blebbing." (d and e) Photographs from saccular epithelia of fish sacrificed 58 days after exposure. This tissue shows extensive damage. Scale bars: a, 20 μm; b, 2 μm; c, d, e, 20 μm. (From McCauley et al., 2003).

Figure 4.1-1: Scanning electron micrographs of the saccular sensory epithelium of the pink snapper following exposure to a seismic air gun.

As will be discussed below, a recent study on the effects of SURTASS LFA sonar sounds on two species of fish, rainbow trout and channel catfish, also examined long-term effects on sensory hair cells of the ear. In both species, even up to 96 hours post-exposure, there were no indications of any damage to sensory cells (Popper et al., in prep.)

Another potential issue with regard to damage to the ear is that it may be possible for fish to regenerate or repair damaged sensory cells resulting from exposure to intense sounds. While this does not occur in mammals (where hair cell loss leads to permanent deafness), regeneration and restoration of hearing appears to occur in birds (reviewed in Dooling and Dent, 2001). Moreover, Lombarte et al. (1993) found that sensory hair cells in the ear of the oscar (*Astronotus*) that have been damaged by the ototoxic drug[2] gentamicin sulphate will regenerate within 10 to 15 days of the termination of the drug regime. Unlike mammals, fish continue to produce sensory hair cells throughout much of their lives (Lombarte and Popper, 1994; Higgs et al., 2001). Since hair cells recover from drug damage, it may be speculated that there might be recovery from at least some

[2] Ototoxic drugs are drugs that can cause temporary or permanent hearing loss. They can also make an existing hearing loss worse.

levels of noise injury since fish, unlike mammals, appear to maintain the ability to produce sensory hair cells for a long period of life after hatching. It is not possible to say, however, if replacement would occur after very high magnitudes of damage, or if the recovery would be fast enough to prevent mortality if the fish could not adequately hear prey or predators. Moreover, the results from the McCauley et al. (2003) study showed no signs of recovery 58 days after damage from air gun exposure and, in fact, there was more damage at 58 days than immediately after exposure.

Few studies have directly examined the effects of sound on fish mortality (see review in Hastings and Popper, 2005). One such study by Turnpenny et al. (1994) suggested that sound exposure could produce substantial damage in caged fish. In the Turnpenny study, brown trout (*Salmo trutta*) and whiting (*Merlangius merlangus*) died within 24 hours of being exposed for five minutes to various tones at frequencies from 95 to 410 Hz and at RLs as low as 170 dB (assumed to be rms, but not reported as such). This study does not appear to be the best available science on this issue for several reasons. First, sound pressure levels in the test chamber, a 30 cm x 30 cm x 30 cm mesh cube suspended near the water surface and ensonified by four sound projectors, could not be controlled (Ellison, unpub., 2005). Second, it is likely that the investigators failed to take into account substantial mechanical energy in the tank created by pressure gradients that created oscillatory (i.e., fluctuating) fluid motion. As a result the stimulus sound field would have been unlike any that fish would encounter outside the laboratory. Indeed, several scientists working in this field have criticized the experimental design, acoustic environment, data analysis, and controls used in this study (Popper, 2003; Myrberg, 2003; Ellison, unpub., 2005). Furthermore, no other studies on the potential impacts of underwater sound on fish have reported physical damage or mortality after exposure to such a low sound pressure level for only five minutes. In fact, more recent studies reported by Popper et al. (in prep.) and Wysocki et al. (in prep.) using an LFA sound source transmitting 193 dB RL on rainbow trout, a reasonably close relative to brown trout, in a normal free field resulted in no damage.

In response to the Popper (2003) and Myrberg (2003) critiques of the Turnpenny et al. (1994) study, Turnpenny (2003) provided counter-comments to support his re-affirmation of the report's conclusions via declaration. In a recent memorandum, Popper (unpub., 2005) responds to the Turnpenny (2003) declaration:

> "Turnpenny does clarify some of the issues I raised with respect to the controls and other aspects of the work described in the report, but nothing in the declaration changes the view I expressed in my original declaration that: 'The overall idea behind the experiments reported here are of some interest, and had the studies been executed properly…some interesting (though *very* limited) information might have been provided. However, the experiments…are poorly designed and the results are insufficient to enable anyone to reach any conclusions regarding the effects of sound on fish studied. Most importantly, there is no basis to extrapolate from these results to any potential effects of air guns, sonars, or other anthropogenic sounds on these or any other species of fish.'"

4.1.1.3 Temporary Loss of Hearing

In addition to the possibility of causing permanent injury to hearing, sound may cause temporary threshold shift (TTS), a temporary and reversible loss of hearing that may last for minutes to hours. TTS is quite common in humans and often occurs after being exposed to loud music, such as at a rock concert. The precise physiological mechanism for TTS is not understood. It may result from fatigue of the sensory hair cells as a result of their being over-stimulated or from some small damage to the cells that is repaired over time. The duration of TTS depends on a variety of factors including intensity and duration of the stimulus, and recovery can take minutes, hours, or even days.

Experimental Results

The first TTS study on fish showed that a 149 dB RL exposure to a pure tone for eight continuous hours might cause TTS of more than 10 dB in goldfish (Popper and Clarke, 1976). More recently, a series of studies have further demonstrated TTS in a number of different species using both continuous tones and various noises.

Smith et al. (2004a, b) examined the effects of increased background noise on hearing capabilities of the goldfish (*Carassius auratus*) and of tilapia (*Oreochromis niloticus*). The purpose of these studies was to determine the detailed parameters of hearing loss that might be expected from exposure to sounds that differ in duration, and in which animals were tested over different recovery times post exposure. Smith et al. found that goldfish showed a 5-dB TTS after only 10 min of exposure to band-limited noise (0.1 to 10 kHz, approximately 170 dB RL overall spectral sound pressure level). Following three weeks of exposure to the same stimulus, goldfish had a 28-dB TTS and the fish took more than two weeks to return to normal hearing. These results should be noted in context with those for tilapia cited below.

Generally similar results were obtained for goldfish exposed to white noise at 158 dB RL for 24 hours by Wysocki and Ladich (2005). In this study, the investigators found that recovery of full hearing sensitivity took up to two weeks. They also investigated temporal resolving power[3] of goldfish before and after noise exposure and found a decrease in temporal resolution capabilities that continued up to three days. This kind of hearing loss could be critical since many species of fish appear to use temporal patterns of sounds to discriminate between sounds (e.g., sounds of different species) (Myrberg and Spires, 1980). Thus, the effects of noise exposure in fish may not only result in effects on the lowest sound detectable (threshold), but also the way that fish resolve signals from one another.

In contrast to hearing losses in goldfish as reported by Smith et al. (2004b) and Wyosckі and Ladich (2005), Smith et al. (2004a) showed no TTS after up to 21 days of noise exposure at 170 dB RL by the hearing generalist tilapia. It is not particularly surprising that the results differ

[3] Temporal resolving power is the ability to discriminate between time intervals of different lengths. If a time interval is too short, then a sound will be heard as continuous rather than being made up of pulses. Fish sounds are often pulses that are repeated rather quickly, and different sounds, or sounds of different species, may have different pulse intervals. If a fish cannot discriminate between different intervals, it has poor ability to discriminate between different sounds.

between goldfish and tilapia since the former is a hearing specialist with high sound sensitivity while tilapia is a hearing generalist and does not hear as well as goldfish.

These findings were also partly supported by Scholik and Yan (2001) who studied another hearing specialist, the fathead minnow (*Pimephales promelas*), and found that there was substantial hearing loss that continued for more than 14 days after termination of a 24-hour exposure to white noise from 0.3 to 2.0 kHz with an overall spectral sound pressure level of 142 dB RL. In contrast, Scholik and Yan (2002) studied effects of sound exposure in a hearing generalist, the bluegill sunfish (*Lepomis macrochirus*) and found no TTS.

While these earlier studies demonstrated TTS in some species and not in others, all of them used relatively low intensity sounds that are well below the levels that fish might encounter when exposed to signals such as those produced by SURTASS LFA sonar, pile driving, or seismic exploration using air guns (or nearby movement of larger shipping). Several recent studies, however, tested the effects of such high-intensity sound not only on hearing, but also on other non-auditory structures. In each case, the study was designed to provide what might be considered "worst-case" sound exposure and to have all appropriate controls to ensure that the results were from the noise and not from handling or other factors. The first study, dealing with seismic air guns, is of interest from a scientific sense regarding SURTASS LFA sonar, and that it showed there were differences in the effects of air guns on the hearing thresholds of different species. The second study deals directly with SURTASS LFA sonar.

Effects of seismic air guns on fish hearing

Popper et al. (2005) examined the effects of exposure to a seismic air gun array on three species of fish found in the Mackenzie River Delta near Inuvik, Northwest Territories, Canada. The species included one hearing specialist, the lake chub (*Couesius plumbeus*), and two species that are not known to have specializations that would enhance hearing, the northern pike (*Esox lucius*), and the broad whitefish (*Coregonus nasus*). In brief, caged fish were exposed to 5 or 20 shots from a 730 in^3 (12,000 cc) air gun array. The signals were fully calibrated and, unlike in earlier studies, exposure was determined not only for rms sound pressure level, but also for peak sound levels and for sound exposure levels (SEL). In this study, average mean peak SPL was 207 dB RL, the mean 90 percent RMS sound level was 197 dB RL, while the mean SEL was 177 dB SEL.

The study was designed so that the level of sound exposure would be as substantial as any that these species are likely to encounter in a riverine seismic survey where there is a single pass of the fish by the seismic device.[4] Fish were placed in a test cage, exposed to the air gun array, and then tested for hearing immediately after sound exposure and then 24 hours post exposure. Testing was done using the auditory brainstem response (ABR)[5] method used by Smith et al.

[4] In oceanic seismic surveys, the survey boat pulls the seismic device back and forth across the survey area in repeated paths, with each path parallel to, but some distance from, the previous path. Thus, an animal in the middle of the survey area would be exposed to repeated signals for a far longer time than in a river survey were the survey boat moves continuously in one direction. The McCauley et al. (2003) study was designed to more closely resemble an ocean survey, though it only pulled the air gun to and from the fish twice.

[5] 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

(2004a) and Scholnik and Yan (2001, 2002). In addition, the experiment used baseline animals that were never placed in the test cage and control animals that were handled in precisely the same way as test animals, other than for exposure to the air gun sound.

The results (Figure 4.1-2) showed a temporary hearing loss for both lake chub and northern pike, but not for the broad whitefish, to both 5 and 20 air gun shots. There was no hearing loss in the broad whitefish, a relative of salmon. Hearing loss was on the order of 20 to 25 dB at some frequencies for both the northern pike and lake chub, and recovery took place within 24 hours and fish hearing returned to normal. While a full pathological study was not conducted, fish of all three species survived the sound exposure and were alive more than 24 hours after exposure. Those fish of all three species sacrificed after ABR testing had intact swim bladders and there was no apparent external or internal damage to other body tissues (e.g., no bleeding or grossly damaged tissues), although it is important to note that the observer in this case (unlike in the following LFA study) was not a trained pathologist.

Most importantly, this study showed that there were differences in the effects of air guns on the hearing thresholds of different species. In effect, these results substantiate the argument made by Hastings et al. (1996) and McCauley et al. (2003) that it is difficult to extrapolate among species with regard to the effects of intense sounds.

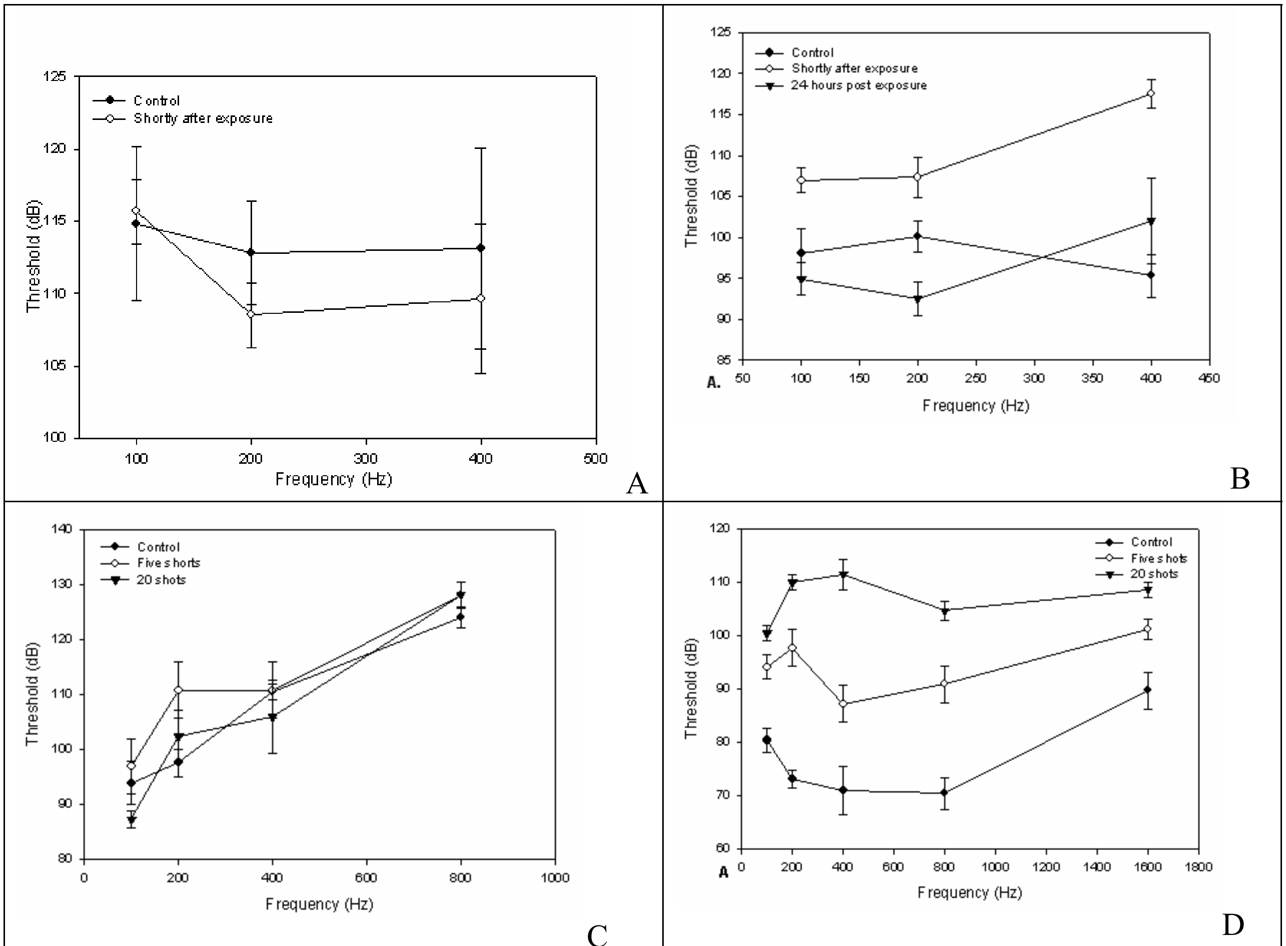
Effects of SURTASS LFA sonar on fish hearing

Dr. Popper and his colleagues (Popper et al., in prep.) have been examining whether exposure to high-intensity, low frequency sonar, such as the Navy's SURTASS LFA sonar, will affect fish. An LFA sonar array has the potential to ensonify fish with sound levels over 180 dB RL within 1 km from the array. Moreover, the LFA sonar uses frequencies from 100 to 500 Hz (the range in which most fish are able to detect sound) and the range of best hearing of many species (Fay, 1988; Popper et al., 2003; Ladich and Popper, 2004). Thus the sonar not only has the hypothetical potential to damage organ systems in fish due to the signal intensity, but it has the direct potential of affecting hearing because the auditory system of fish is most sensitive in the frequency range in which the sonar operates.

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.

Fish species studied[6]

This study examined the effect of LFA on hearing, the structure of the ear, and select non-auditory systems in the rainbow trout (*Onchorynchus mykiss*) (Popper et al., in prep.) and channel catfish (*Ictalurus punctatus*) (Halvorsen et al., in prep.). The study also included analysis of fish behavior before, during, and after sound exposure (Wysocki et al., in prep.).



(A) Thresholds of broad whitefish for control and experimental animals showing no statistically significant hearing loss. (B) Thresholds from northern pike just after exposure and 24 hours post exposure. Fish showed a significant hearing loss just after exposure, but thresholds were not significantly different from controls at 24 hours. (C) Thresholds for small, young of the year, northern pike. Interestingly, these fish showed no hearing loss compared to controls after exposure to 5 or 20 air gun shots. (D) Lake chub, a hearing specialist, showed substantial hearing loss after 5 shots of the air guns and even more loss after 20 shots. Both groups of animals, however, showed full recovery of hearing loss within 24 hours. (All figures from Popper et al., 2005[7])

Figure 4.1-2. Hearing thresholds for different fish in a study investigating the effects of exposure to a seismic air gun array on fish hearing.

[6] Information, data and preliminary results from the three "in prep." papers are presented in this section. *These data are not authorized for further citation or other use until officially published.*

[7] Popper, A.N., Smith, M.E., Cott, P.A., Hanna, B.W., MacGillivray, A.O., Austin, M.E., Mann, D.A. 2005. Effects of exposure to seismic airgun use on hearing of three fish species. J. Acoust. Soc. Am., 117: 3958-3971.

The rainbow trout is a hearing generalist (or "non-specialist"), while the channel catfish is a specialist. These two species were chosen since there is evidence that there may be a significantly different impact of noise exposure on fish that hear well and those that do not hear well, as discussed above with regard to TTS as a result of exposure to lower intensity sounds (e.g., Hastings et al., 1996; Smith et al., 2004a, b; Popper et al., 2005).

Most importantly, rainbow trout were chosen for study since they are excellent surrogates for listed salmonids from the U.S. west coast, all of which are of the same genus as rainbow trout. Listed species of this genus could not be tested in the Seneca Lake study since it would have been too difficult to import the fish to the experimental site in the numbers needed for study. In addition, since there is a chance that fish could escape from the experimental apparatus, it was not appropriate to use species that are not already endemic to the test site. Adding new species to Seneca Lake could potentially impact the lake ecosystem in unpredictable ways.

In addition to being in the same taxonomic genus, rainbow trout are also a good surrogate for listed salmonids because the species have similar, if not identical, ears and hearing sensitivity (Song and Popper, in prep). Hearing tests of hatchery-raised chinook salmon (*Oncorhynchus tshawytscha*) show that hearing sensitivity and range of hearing is very similar to that of rainbow trout (Popper et al., in prep.). Since the ears and hearing sensitivity are essentially the same for the rainbow trout and another member of the genus *Oncorhynchus*, it is likely that the rainbow trout can serve as the model system in other anthropogenic sound studies, as in the LFA study.

Experimental overview

The SURTASS LFA sonar study was conducted in an acoustic free-field environment that enabled the investigators to have a highly calibrated sound source and to fully monitor the sound field and the behavior of the fish throughout the experiments. The work was conducted at Seneca Lake, Dresden, N.Y. The facility has a large barge in the middle of the lake and a nearby shore support facility that has room for holding animals and doing all hearing and other tests.

In brief, experimental fish were placed in a test tank that was 1 m on a side and made of 1.27 cm (0.5 inch) thick Lexan® clear plastic sheets (see Figure 4.1-3). The tank was designed to allow for free flow of water throughout the tests to ensure that fish were at the best experimental temperature and had oxygenated water. Two video cameras external to the test tank were used to observe the behavior of the fish (with images and sounds recorded on digital tape) as the test tank was raised and lowered, and during sound presentations.

Prior to conducting experiments with live animals, extensive calibration tests were performed on the sound field inside and around the fish test tank. These data showed that the variation in sound level was small in different regions of the test tank, indicating that the acoustic field inside was sufficiently uniform for the studies. For a single tone, the maximum RL was approximately 193 dB at 196 Hz and the level was uniform within the test tank to within approximately ±3 dB.

Figure 4.1-3: Photograph of experimental tank (with rainbow trout) being lifted out of the water.

The photo shows the test tank. The braces to the left and right support the video cameras (black) used to monitor fish behavior throughout the experiments. The small black objects suspended from cables in the test tank are an array of hydrophones used to monitor the sound throughout the experiments. An additional hydrophone (right) monitored the sound outside of the tank.

The experimental sounds were produced using a single SURTASS LFA sonar transmitter excited at 1,600 V, giving an approximate SL of 215 dB. The signal used was generated electronically and was very similar to the actual sonar signal train used by the Navy. The bandwidth of the signal was from 170 to 320 Hz.

All fish were from the same supplier. They were randomly assigned to one of the three experimental groups. Baseline group animals were received directly from the supplier with no handling other than moving to the Seneca Lake facility. Experimental group animals were placed in the test tanks and exposed to sound. Control group animals were handled in precisely the same way as experimental animals but without the sound presentation.

Experimental groups were exposed to one of three test signals. These included: (1) MAX – maximum sound level; (2) MAX-6, 12, or 18 – the maximum signal lowered by 6, 12, or 18 dB; and (3) MAX*2 – the maximum signal but at twice the duration of the MAX signal.

Each test consisted of three presentations of the LFA signal separated by a quiet period. In all but the MAX*2 experiment, sound presentations were 108 sec long and separated by 9 min of silence. In the MAX*2 trials, the LFA sound duration was 216 sec with an 18 min quiet period. The longer quiet interval was required with MAX*2 in order to allow the LFA transducer to cool (as per a required 20 percent maximum duty cycle). The overall test sequence for each tank was: slowly lower tank to depth – transmit signal – quiet – repeat signal – quiet – repeat signal – and then slowly raise the test tank to the surface.

The test signal consisted of three hyperbolic frequency-modulated (HFM) sweeps centered at 185 Hz with a 30-Hz bandwidth, 210-Hz tone, 220-Hz tone (labeled as Tone 2), 230-Hz tone, and three more HFM sweeps centered at 295 Hz with a 30-Hz bandwidth (see Figure 4.1-4).

All test, control, and baseline animals were evaluated to determine hearing sensitivity using the ABR method. Fish were then sacrificed to determine any effects on inner ear structure. Additional fish from each group were sacrificed for analysis by a highly skilled fish pathologist to determine any effects on gross structure and on tissue pathology.

Results of SURTASS LFA sonar study

As of 30 June 2005, there have been four sets of studies (each lasting one week) on rainbow trout and two on channel catfish. There are several significant findings.

(1) No fish died as a result of exposure to the experimental source signals. Fish all appeared healthy and active until they were sacrificed or returned to the fish farm from which they were purchased.

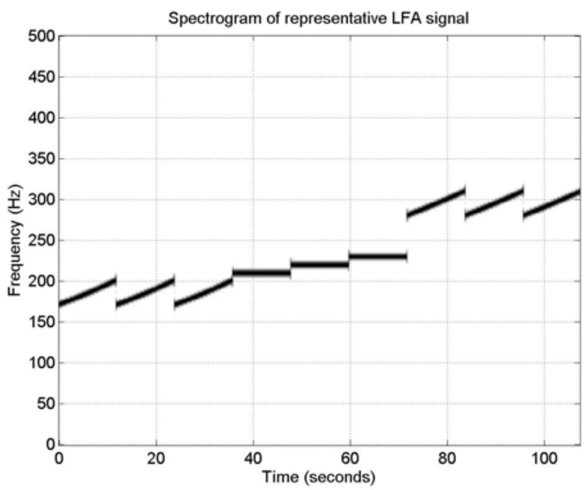


Figure 4.1-4. Schematic of one presentation of the LFA signal used in the SURTASS LFA sonar experiments.

The signal was 108 sec long (except in MAX*2 tests where the signal was 216 sec long). Each test consisted of three presentations of this signal, separated by a 9 or 18-minute silent interval during which time the projector cooled down.

(2) There were no pathological effects from sound exposure. Despite the high level of sound exposure (193 dB RL at the fish), there were no gross effects on fish. Histopathology was done on all major body tissues (brain, swim bladder, heart, liver, gonads, blood, etc.) and no differences were found among sound-exposed fish, controls, or baseline animals.

(3) There were no short- or long-term effects on ear tissue (see Figure 4.1-5). The sensory cells of the ears of both species were healthy and intact both immediately post exposure and then 96 hours after the end of exposure. All earlier studies looking at effects of sound on fish ears only found damage within 96 hours (e.g., Hastings et al., 1996; McCauley et al., 2003) and in each case that was to much more extensive sound exposure.

Figure 4.1-5: Scanning electron micrograph from an experimental rainbow trout that had been exposed to the MAX signal.

The image shows the ciliary bundles that are atop the sensory hair cells and which serve as the transducing portion of the sensory cell (see Chapter 3). While the cilia are somewhat splayed due to processing of the tissue, they are no different than tissue from baseline and control animals.

(4) Fish behavior after sound exposure was no different than behavior prior to or after tests. At the onset of the sound presentation the trout would tend to move to the bottom of the

experimental tank, but this did not last for the duration of the sound, and immediately after the sound was turned off the fish would mill around the tank in the same pattern as they did prior to sound presentation. Catfish showed an immediate quick "startle[8]" response and slight motion of the body, but then the fish tended to line up facing the signal source and generally stayed in that position for the duration of the sound. Once the sound was turned off, the catfish would return to normal "milling" around the tank in a pattern that was statistically no different than pre-sound patterns.

(5) Catfish and some specimens of rainbow trout showed 10-20 dB of hearing loss immediately after exposure to the LFA sound when compared to baseline and control animals (see Figure 4.1-6), but hearing appears to return to, or close to, normal within about 24 hours for catfish. Other rainbow trout showed minimal or no hearing loss. Recovery data on rainbow trout that had a hearing loss is still insufficient to reach firm conclusions on the time for recovery, but preliminary data lead to the suggestion that recovery is likely to occur in less than 96 hours. Moreover, there is evidence that hearing loss in the trout, when it occurs at all, is primarily at 400 Hz, while it is over the complete range of frequencies (200-1000 Hz) tested for catfish.

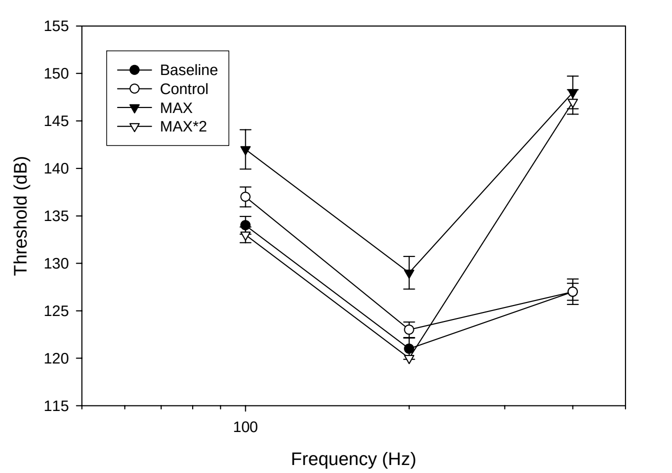


Figure 4.1-6: Examples of hearing data obtained in the SURTASS LFA sonar studies.

These data are for rainbow trout and compare hearing for baseline and control animals and animals that received MAX and MAX*2 signals. Data represent means and standard errors of the means. Note that maximum hearing loss occurred at 400 Hz where there was over a 20 dB TTS. It is not clear why there was more hearing loss after MAX stimulation than MAX*2 but this could be related to signals being closer together in the former. (Note, the "thresholds" shown are not calibrated and so do not reflect the lowest sounds that fish necessarily hear at these frequencies.)

(6) There is potentially interesting variation in the effects of exposure on trout. At some times of the year the trout showed hearing loss, while at other times they did not. All animals received identical treatment, and the only variables between experimental times may have been water temperature and/or how the fish were raised prior to their being obtained for study. The significance here is that not only are there differences in the effects of sound on different species, but there may also be differences within a species, depending on environmental and other variables. However, and most importantly, under

[8] The word "startle" is used with caution. The behavior of the fish was, indeed, one that indicated detection of something unknown – a rapid movement over a short distance. However, the word "startle" has taken on a very specific meaning for some fish biologists and includes a twist of the body (c-start) at the onset of a stimulus and then rapid movement away from the stimulus. In these experiments, the video recording was not fast enough to determine if an actual c-start occurred.

no circumstances did exposure to LFA sound result in unrecoverable hearing loss in rainbow trout, and there was no effect on any other organ systems.

Conclusions from SURTASS LFA sonar study

The critical question addressed in the SURTASS LFA sonar study is whether this kind of sound source impairs the survival of fish and, more importantly, whether survival would be impaired in a normal environment when a ship using SURTASS LFA sonar is in the vicinity of a fish. In answering this question, several factors must be taken into consideration.

First, the sound level to which fish were exposed in these experiments was 193 dB RL, a level that is only found within about 100 m (328 ft) of a ship using SURTASS LFA sonar. Thus, the likelihood of exposure to this or a higher sound level is small, considering all the possible places a fish might be relative to the sound source. The volume of the ocean ensonified by a single SURTASS LFA sonar source at 193 dB RL or higher is very small compared to the ocean area ensonified by the LFA source at lower sound levels.

Second, the LFA sound used in the study can be considered to represent a "worst-case" exposure. In effect, the exposure during the experiments were most likely substantially greater than any exposure a fish might encounter in the wild. In the study described here, each fish received three exposures to a high-level LFA sound (a total of 324 sec in the MAX tests and 628 sec in the MAX*2 tests). However, under normal circumstances the SURTASS LFA sonar source is on a moving ship. A fish in one location will only receive maximum ensonification for a very few seconds (depending on ship speed and whether the fish is moving or not, and its direction of motion and speed). Prior to getting the closest distance to the fish, or after the boat has moved on, the sound level would be much lower. Thus, rather than receiving 108 sec of maximum exposure, a fish would receive much less exposure. Since exposure at maximum level did not cause damage to fish, and only what appears to be a temporary limited hearing loss, it is unlikely that a shorter exposure would result in any measurable hearing loss or non-auditory damage to fish unless they were so close to the SURTASS LFA sonar source that they received a maximum output. And, even then, exposure at maximum output would be for a minimal period of time. It should also be noted that 193 dB RL had no real adverse effects on the fish tested. While it was not possible to present a higher sound level to the fish in this experiment, it is very likely that a shorter exposure than 108 sec to an even higher sound level may not have adversely affected the fish. In effect, it is likely that fish could be even closer than 100 m to the sonar and not be damaged by the sounds.

Additional Sonar Data

While there are no other data on the effects of LFA on fish, there is a recent study of some relevance since it examined the effects on fish of a sonar that will apparently be used by the Norwegian Navy in the near future. In an as yet unpublished report, fish larvae and juvenile fish were exposed to simulated sonar signals in order to investigate potential effects on survival, development, and behavior (Jørgensen et al., 2005). The study used herring (*Clupea harengus*) (standard lengths 2 to 5 cm, 0.79 to 2.0 in), Atlantic cod (*Gadus morhua*) (standard length 2 and 6 cm, 0.29 and 2.4 in), saithe (*Pollachius virens*) (4 cm, 1.6 in), and spotted wolffish

(*Anarhichas minor*) (4 cm, 1.6 in) at different developmental stages. While the study's authors referred to these sonar sounds as low frequency, the Norwegian sonar signal is higher frequency (1.5 to 6.5 kHz) than the signal used by SURTASS LFA sonar (100-500 Hz) and closer in frequency to the signals used by mid-frequency sonar.

Fish in this study were placed in plastic bags 3 m from the sonar source and exposed to between four and 100 pulses of 1-second duration of pure tones at 1.5, 4 and 6.5 kHz. Sound levels at the location of the fish ranged from 150 to 189 dB RL. The sounds were designed to mimic those of actual sonar signals that will be used by the Norwegian Navy. The investigators found no effects on fish behavior during or after exposure to sound (other than some startle or panic movements by herring for sounds at 1.5 kHz), and the investigators found no effect on behavior, growth (length and weight), or survival of fish kept as long as 34 days post exposure. All exposed animals were compared to controls that received similar treatment other than for exposure to the actual sound. Similar to the LFA work done by Popper et al. (in prep.), pathology of internal organs showed no damage as a result of sound exposure. The only exception to almost full survival was exposure of two groups of herring tested with SLs of 189 dB, where there was a post-exposure mortality of 20 to 30 percent. While these were statistically significant losses, it is important to note that this sound level was only tested once and so it is not known if this increased mortality was due to the level of the test signal or to other unknown factors.

Extrapolation to Other Species

The results of the SURTASS LFA sonar study, as well as the recent study on seismic air guns (Popper et al., 2005), should only be extrapolated to other species with considerable caution. This caution is based on potential differences among species in structure of the auditory system and hearing capabilities. As discussed below, the degree of hearing loss in a species may vary depending upon the level of the signal above the hearing threshold of the fish. Other variables that may ultimately be involved in the amount of hearing loss are signal duration, frequency characteristics of the sound, and whether the sound is impulsive or continuous. The same variables may also impact the amount of non-auditory damage that might occur.

At the same time, the rainbow trout in the LFA study and the lake chub, northern pike, and broad whitefish in the seismic study are species that differ considerably from one another in hearing structures, distribution of fish taxa, and hearing capabilities. None of these fish showed any tissue damage as a result of sound exposure, and hearing loss was relatively small and recovery fairly rapid. Thus, recognizing the need for caution when extrapolating among species, these results strongly indicate that SURTASS LFA sonar is likely to have a negligible impact on fish when they are exposed to underwater sound signals within the decibel levels used in these studies.

Overview of Hearing Effects of Noise Exposure

In reviewing the results of their study and that of the few previous studies, Hastings et al. (1996) suggested that sounds 90 to 140 dB above a fish's hearing threshold may potentially injure the inner ear of a fish. This suggestion was supported in the findings of Enger (1981) in which injury occurred only when the stimulus was 100 to 110 dB above threshold at 200 to 250 Hz for the cod. Hastings et al. (1996) derived the values of 90 to 140 dB above threshold by examining the RLs that caused minimal injury in their test fish, the oscar, and then hypothesizing that extensive injury would require more energy. They suggest that RLs of 220 dB to 240 dB would potentially cause extensive damage to sensory hair cells in non-specialist fish. Calculations for a hearing specialist such as the squirrelfish (*Myripristi berndti*) using the Hastings et al. (1996) values (i.e., 90 to 140 dB above threshold) (see Figure 3.2-2) indicate RLs of 140-190 dB continuously for at least one hour would be necessary to induce damage to inner ear sensory cells.

The results of Smith et al. (2004a, b) and Scholik and Yan (2001, 2002) provide experimental evidence in support of the hypothesis proposed by Hastings et al. (1996). Moreover, Smith et al. (2004b) were able to use their data to hypothesize that noise-induced threshold shifts in fish are linearly related to the Sound Pressure Difference (SPD) between that of the noise and the baseline hearing threshold of the fish. They called this the *LIN*ear *T*hreshold *S*hift (LINTS) hypothesis. A similar finding has been reported in birds and mammals. The actual SPD required to cause TTS in a fish is very likely related to frequency since the baseline threshold in fish varies by frequency. Other variables are likely to be the duration of sound exposure, whether the sound is continuous (as in the Smith et al., 2004a, b experiments), or whether they are impulsive.

While these variables need further study, there is preliminary evidence that the LINTS hypothesis (Smith et al. 2004b) holds for impulsive as well as continuous signals. In an analysis of their air gun results, Popper et al. (2005) found the same relationship for these sounds as found by Smith et al. (2004b) for continuous noise. Moreover, the Popper et al. (2005) work examined several hearing generalists and, for the first time, used RLs that were sufficiently above threshold (therefore a large SPD) to result in TTS in such species. This is in contrast to the studies by Smith et al. (2004a, b) and Scholik and Yan (2002) where there was no TTS in hearing generalists. Presumably, the lack of TTS in those generalists was because of an insufficiently high SPD between noise and the baseline threshold.

Finally, the results from the SURTASS LFA sonar study further support the LINTS hypothesis since both species used generally followed predictable amounts of threshold shift based on the levels of the sound exposure. This is significant since it extends the usefulness of the hypothesis beyond continuous pure tones and impulsive noise to modulated signals. At the same time, it is very likely that with a more detailed analysis of the hypothesis it will be possible to more broadly understand the effects of sounds of different frequencies, intensities, durations, and waveform on hearing loss. However, at this point it would not be reasonable to use the LINTS hypothesis in any but the broadest sense here since there are too few data to permit ready extrapolation among species.

4.1.1.4 Behavioral Change

This issue concerns the behavior of fish near a high intensity sound source, beyond effects on the ear itself. That is, the potential behavioral impacts range from the possibility of fish avoiding the sound and thus changing their habitat (potential economic impact to subsistence fisheries) to possibly preventing fish from engaging in basic life functions such as breeding, feeding and sheltering (which could presumably result in fish stock declines). There are only a few studies relevant to this issue. Klimley and Beavers (1998) played back a 75 Hz phase-modulated signal

(37.5-Hz bandwidth) to three species of rockfish (*Sebastes flavidus*, *S. ariculatus,* and *S. mystinus*) (presumably, but not demonstrated to be, non-specialists) in a pen in Bodega Bay, California. The RLs were 145 to 153 dB. The fish exhibited little movement during the playback of the low frequency signals, and the behavior did not differ from that exhibited during a control period during which the sound was not played. Fish that started out close to the sound source did not move away, nor was there any apparent movement to the source during playback. Indeed, most fish occupied the zone closest to the sound projector the entire duration of the test and control periods. While these results are of considerable interest, and support the idea that fish do not necessarily try and avoid sounds, it must be noted that the work involved three species of fish in an artificial environment (cage); thus, it is unknown whether the behavioral responses to LF sounds by this species, and under these conditions, can be extrapolated to other species and/or to fish in a normal (open ocean) environment.

These results are somewhat supported by findings during the investigations of the effects of SURTASS LFA sonar sounds on rainbow trout and channel catfish (Popper et al., in prep.; Wysocki et al., in prep.). These studies used video to observe and record the behavior of both species before, during, and after exposure to sounds that were at 193 dB RL. Preliminary quantitative analysis of the results of these studies show that while rainbow trout exhibited a small response at the onset of the sounds, they quickly returned to their pre-stimulus behavior and continued this way for the duration of the sound presentation, and even when the specific components of the sound changed. Channel catfish, in contrast, generally showed an initial "startle[9]" response to the sound and then moved to the bottom of the test tank while most fish oriented themselves toward the sound source, and stayed in that position for the duration of the signal. Furthermore, they would show a "startle" response each time the specific sound changed. As soon as the sound was turned off the fish would resume pre-stimulus patterns of swimming.

It should be noted that in both the Klimley and Beaver (1998) study and the more recent SURTASS LFA sonar study (Wysocki et al., in prep.), fish were restrained in tanks and could not move away from the source. How the fish might have reacted if they were able to swim away is not known. However, both of these investigations provide some initial evidence that the sounds used in the studies did not have a marked effect on behavior of the fish studied. One point of interest, however, is that in the case of the rainbow trout, the signal level was much closer to the threshold of hearing than it was in the channel catfish. And, while data are not available on rockfish hearing (something that is very much needed), if these are indeed non-specialist fish, their hearing thresholds are probably more alike those of the rainbow trout than the catfish. Thus, the 153 dB RL signal used by Klimley and Beaver (1998) was possibly not sufficiently above the animal's threshold to result in behavioral changes. It is possible, however, that if the sounds presented to the rockfish or rainbow trout were as far above threshold as it was for catfish, the responses of both species might have been different, and perhaps more like that of the catfish.

[9] The word "startle" is used with caution. The behavior of the fish was, indeed, one that indicated detection of something unknown – a rapid movement over a short distance. However, the word "startle" has taken on a very specific meaning for some fish biologists and includes a twist of the body (c-start) at the onset of a stimulus and then rapid movement away from the stimulus. In these experiments, the video recording was not fast enough to determine if an actual c-start occurred.

Other studies, however, provide some evidence that the LF noise produced by fishing vessels and their associated gear results in fish avoiding the vessels (Maniwa, 1971; Suzuki et al., 1979; Konigaya, 1980; Soria et al., 2003; and see review in Mitson, 1995). Similar results have been found for incoherent, impulsive air gun sounds (Engås et al., 1995; McCauley et al., 2000; Engås and Løkkeborg, 2002; Slotte et al., 2004). However, in each of these studies (other than McCauley et al., 2000), fish behavior was not actually observed and results were based on fish catch rates before and after presentation of sounds from a seismic air gun. Aside from the McCauley et al. (2000) study (which included fish behavior observations), it is possible that the other three studies (which used fish catch rates as a metric), may have perceived temporary changes in fish responses to trawls and long-lines, and that there was no other alteration in behavior or movements of the fish from the fishing sites. It is interesting, however, that using sonar, Slotte et al. (2004) found that fish in the vicinity of the air guns appeared to go to greater depths after air gun exposure compared to their vertical position prior to the air gun usage. It should be noted, however, that the statistics in the fishing reports have been criticized by Gausland (2003) in a non-peer reviewed report that suggested that declines in catch rate may be explained by other factors and that catch rates do not differ significantly from normal seasonal variation over several fishing seasons.

While not directly related to sonar, but of scientific interest, Wardle et al. (2001) used a video system mounted on a reef to examine the behaviors of fish and invertebrates after exposure to emissions from seismic air guns (peak RL of 210 dB at 16 m from the source and 195 dB RL at 109 m from the source). The results showed no observable damage to any animals or that there were changes in behavior, or that any animals left the reef during the course of the study.

The aforementioned studies support the conclusions presented in Subchapter 4.1.1.6 below.

4.1.1.5 Masking

A sound reaching a fish, even at levels lower than those that could potentially cause PTS or TTS, may have a significant impact by preventing the fish from detecting sounds that are biologically relevant, including communication sounds, sounds of prey, or sounds of predators (Myrberg, 1981; Popper et al., 2004). The decrement in ability to detect signals because of other sounds is called masking, which can take place whenever the received level of signal exceeds ambient noise levels or the hearing threshold of the animal.

The studies on auditory masking in fish have been limited in the number of species studied. The results show that species that have been studied are generally affected by masking signals in much the same way as are terrestrial animals; most masking occurs when the masking sound is close in frequency to the sound being tested (Fay, 1974, 1988b; Fay and Megela-Simmons, 1999). If the masking signal is of significantly different frequency from the frequencies of importance to the fish, then much less (or no) masking may occur, although there is also some evidence that in at least some species, any noise signal will mask other signals, and that the degree of masking may be frequency-independent.

One of the problems with existing masking data is that the bulk of the studies have been done with goldfish, a freshwater hearing specialist, where there may be a correlation between the degree of masking and how similar the masking signal and test signal are. The data on other species are much less extensive. As a result, less is known about masking in non-specialist and marine species. Tavolga (1967) was the first to study the effects of noise on pure-tone detection in two non-specialists. He reported that the masking effect was generally a linear function of masking level, independent of frequency. His measurements were of tonal thresholds at the edges of a masking band centered at 500 Hz for the blue-striped grunt. Results suggested that there are critical bands for fish, as in mammals, and these have now been confirmed in other species (reviewed by Fay and Megela Simmons, 1999). In addition, Buerkle (1968) studied five frequency bandwidths for Atlantic cod in the 20 to 340 Hz region. Chapman and Hawkins (1973) found that ambient noise at higher sea states in the ocean have masking effects in cod, haddock, and pollock. Thus, based on limited data, it appears that for fish, as for mammals, masking may be most problematic in the frequency region of the signal. Thus, for SURTASS LFA sonar this would be whatever 30-Hz bandwidth signal is being transmitted (within the 100-500 Hz frequency band); although each transmitted signal changes frequency band within ten seconds, which would diminish the potential for any masking effects.

Therefore, existing evidence supports the hypothesis that masking could have an effect on fish, particularly those where predominant biological signals and best hearing frequencies occur at similar frequencies as the SURTASS LFA sonar. However, given the estimated 7.5 percent duty cycle and 60-second signal duration (average), masking would be temporary. Additionally, the 30-Hz (approximate maximum) bandwidth of SURTASS LFA sonar is only a small fraction of the animal's hearing range. Most fish have hearing bandwidths >30 Hz. In summary, masking effects are not expected to be severe, because the SURTASS LFA sonar bandwidth is very limited, signals do not remain at a single frequency for more than ten seconds, and the system is usually off over 90 percent of the time.

4.1.1.6 Conclusions

If SURTASS LFA sonar operations occur in proximity to fish stocks, members of some fish species could potentially be affected by LF sounds. Even then, the impact on fish is likely to be minimal to negligible since only an inconsequential portion of any fish stock would be present within the 180-dB sound field at any given time. Moreover, recent results from direct studies of the effects of LFA sounds on fish (Popper et al., in prep.) provide evidence that SURTASS LFA sonar sounds at relatively high levels (up to 193 dB RL) have minimal impact on at least the species of fish that have been studied. Nevertheless, the 180-dB criterion is maintained for the analyses presented in this SEIS, with emphasis that this value is *highly conservative* and protective of fish. This conclusion supports the discussion at Subchapter 2.5.2.2 on the possibility of employing source shutdown procedures for schools of fish.

To quantify the possible effect of SURTASS LFA sonar on fish catches, an analysis of nominal SURTASS LFA sonar operations in a region off the Pacific Coast of the U.S. was presented in the FOEIS/EIS Subchapter 4.3.1 for the NMFS Fisheries Resource Region—Pacific Coast, defined here to encompass the area from the Canadian to Mexican border, from the shoreline out to 926 km (500 nm). The results of this analysis–that the percent of fish catch potentially affected would be negligible compared to fish harvested commercially and recreationally in the region–remain valid. In fact, because this analysis was based on 180-dB injury level and a 20 percent duty cycle, the results are *highly conservative.*

4.1.2 Potential Impacts on Fish (Class Elasmobranch/Shark) Stocks

It is important to note that unlike other fish species, there is no species of shark protected under the ESA. The analysis for sharks is conducted under NEPA.

4.1.2.1 Non-auditory Injury

In the absence of published, peer-reviewed reports on the potential for low frequency underwater sound to cause non-auditory injury to sharks, the discussion regarding fish in Subchapter 4.1.1.1 of this SEIS will be considered to also apply here. Earlier thinking had been that the primary potential for non-auditory impacts to fish would be resonance of the swim bladder, although the preponderance of recent evidence suggests this is not the case for SURTASS LFA sonar (or for seismic air guns). Moreover, sharks do not have a swim bladder.

4.1.2.2 Permanent Loss of Hearing

Hearing capability in sharks is on a par with or poorer than that of hearing non-specialist bony fish, and there is no evidence that any shark is a hearing specialist. There are also no data on permanent hearing loss, including PTS, in sharks or on damage to the ears. Nevertheless, the utilization of the 180-dB criterion for analysis is also be applied to sharks, and its conservativeness is emphasized. A very small fraction of any shark stock would be exposed to these levels, even in the absence of mitigation. While extrapolation from fish to sharks is something that should be done only with caution, since the ears and auditory systems are so different, the lack of substantive effect on non-specialist fish may also be the same for sharks.

4.1.2.3 Temporary Loss of Hearing

There are no scientific data on TTS in sharks. However, because sharks are considered hearing non-specialists and assuming they have similar hearing sensitivities as bony fish discussed previously, the potential for TTS to cause substantial deleterious effects on shark stocks due to SURTASS LFA sonar transmissions is probably very small. Moreover, because sharks are considered hearing non-specialists, the Hastings et al. (1996) suggestion supported by the Smith et al. (2004a, b) study may potentially apply, indicating that RLs of 220 to 240 dB would be required to temporarily affect hearing capability in the form of TTS. However, without any additional studies on sharks this suggestion must be considered speculative, and probably very conservative.

At the same time, while it is likely that the 180-dB value is highly conservative, it must be noted that extrapolating from bony fish to sharks is difficult, especially since the ears of fish and sharks have some significant differences in terms of associated structures that might be involved in hearing, and in the structure of certain regions of the ear. In particular, the ear structure involved in shark hearing may be the *macula neglecta*, a sensory receptor that, while very large in sharks, is tiny or not present in other vertebrates (Corwin, 1981; Popper and Fay, 1997). Because the *macula neglecta* has a somewhat different mechanism of sound-induced stimulation than do the otolithic organs of fish ears (i.e., the ear organs of fish that were damaged in the Hastings et al. [1996] study), extrapolation on the effects of intense sounds must be provisional.

Due to the lack of more definitive data on shark stock distributions in the open ocean, it is not feasible to estimate the percentage of a stock that could be located in a SURTASS LFA sonar operations area at a potentially vulnerable depth, during a sound transmission. Therefore, the aforementioned is based on the assumption that the stocks are evenly distributed. Further, the five SURTASS LFA sonar operational parameters listed at the start of Subchapter 4.1 provide additional support to the conclusion that there would be minimal impact on any substantial fraction of a shark stock through TTS.

4.1.2.4 Behavioral Change (Attraction/Repulsion)

Some sharks are attracted to pulsing LF sounds. It has been proposed that such sounds mimic the thrashing of struggling fish that are potential prey for the sharks (Nelson and Gruber, 1963; Nelson and Johnson, 1972, 1976). Since the structure of SURTASS LFA sonar signals is unlike sounds made by struggling marine animals, it is highly unlikely that this sound would be attractive to sharks.

Several shark species, including the oceanic silky shark (*Carcharhinus falciformis*) and coastal lemon shark (*Negaprion brevirostris*), have been observed withdrawing from pulsed LF sounds played from an underwater speaker (Myrberg et al., 1978; Klimley and Myrberg, 1979). Lemon sharks exhibited withdrawal responses to pulsed low to mid frequency sounds (500 to 4,000 Hz) 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 ambient noise (Klimley and Myrberg, 1979). Sharks withdrew from a normally attractive pulsed sound composed of frequencies of 150 to 300 Hz at RLs $\geq$111 dB. Since the SURTASS LFA sonar does not generate "pulsed" signals, the results described here suggest that SURTASS LFA sonar is not likely to result in causing sharks to withdraw from an area that might be used for feeding of other behaviors.

Myrberg et al. (1978) reported that a silky shark withdrew 10 m (33 ft) from a speaker broadcasting a 150 to 600 Hz sound with a sudden onset and a peak SL of 154 dB. These sharks avoided a pulsed LF attractive sound when its SL 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. These results do not rule out that such sounds may have been harmful to them after habituation; the tests were not designed to examine that point (Myrberg, pers. comm., 1999). Klimley (unpublished data) also noted the increase in tolerance of lemon sharks during successive sound playback tests. The pelagic whitetip (*Carcharhinus longimanus*) also showed a withdrawal response during limited tests (Myrberg et al., 1978).

Since the likelihood of a significant portion of any shark stock being in the vicinity of the SURTASS LFA sonar source at any one time is low, and given that the LFA signals are not "pulsed," this attraction or repulsion behavioral response is not considered an issue of concern.

4.1.2.5 Behavioral Change (Migration)

There is a body of scientific evidence that oceanic sharks make directional migrations. The most rigorous study demonstrating this phenomenon involved placing a miniature heading sensor to track scalloped hammerhead sharks (*Sphyrna lewini*) and tracking them (Klimley, 1993). The movements of these sharks between their daytime aggregations at a seamount and their nighttime feeding grounds at other surrounding seamounts were highly directional. Their paths generally coincided with magnetic ridges and valleys leading from a seamount, which may be characterized by a strong dipole field that could serve as a landmark. In addition, movements of the sharks often were along the edge of a magnetic lineation, oriented roughly in a north-south direction.

These results have led to the theory that sharks often migrate along magnetic "roads" that run north-south (coincident with magnetic lineations) and aggregate at "cities" that are seamounts and islands (with dipole fields) (Klimley, 1995).

In assessing the potential for SURTASS LFA sonar signals to affect shark migrations, it is noted that the SURTASS LFA sonar source frequency is between 100 and 500 Hz, a region of the acoustic spectrum where these species appear to be best able to hear sound. Furthermore, the LFA signal usually has no ramp-up, an acoustic property that has been shown to provoke withdrawal in an inshore species (*Negapion brevirostris*) (Klimley and Myrberg, 1979) and two pelagic species (*Carcharhinus falciformis and C. longimanus*) (Myrberg et al., 1978). These studies suggest that sharks can detect sounds with intensities below 180 dB RL. The issue is whether one or more SURTASS LFA sonar transmissions could possibly cause displacement of a shark from its migratory path, such that this activity might be disrupted to such an extent that the shark would not be able to reestablish its direction along the path.

The sharks are believed to be migrating along the edges of the magnetic lineations, where the gradients are greatest, moving back and forth across the gradient (estimated travel +/- 0.5 km [0.27 nm] either side) at an approximate speed of 1 m/sec (Klimley, pers. comm., 2000). Given that the maximum SURTASS LFA sonar signal length is 100 sec, a shark that was annoyed and moved away from the sound would travel approximately 100 m (328 ft) during that time. In the worst case, the ship would be positioned so that the shark's movement would be away from the gradient, and the shark would be at its maximum distance from the gradient at the time of the transmission. Assuming 100 m (328 ft) maximum displacement in this case, it would be likely that the shark would be able to eventually reestablish its direction along the path. Thus, the conclusion here is that it would be unlikely that significant impacts to shark migration would occur due to SURTASS LFA sonar operations in the open ocean.

4.1.2.6 Masking

Sharks use hearing to detect prey (Banner, 1972; Myrberg et al., 1972; Nelson and Johnson, 1972; Myrberg et al., 1976; Nelson and Johnson, 1976), and this detection ability may potentially be affected by masking. By way of example, Nelson and Johnson (1970) measured a lemon shark's hearing sensitivity to a 300 Hz, 130 dB SL in two different sea states (sea states 1 and 2) and two different levels of vessel traffic (light and heavy). The shark's auditory threshold was decreased by 2 dB for sea state 2 versus sea state 1, a level of difference that is probably not significant since it is certainly within the variation of the hearing ability of the animal. The difference caused by light versus heavy vessel traffic was 18 dB (measured in sea state 1). This represented differences in masking ranges (distance from animal that a sound or sounds would be masked) (due to sea state alone) of 45 m (148 ft) for sea state 2 versus 1; and 110 m (360 ft) for heavy versus light boat/ship traffic. Thus, it can be concluded that the masking range for sharks can be elevated by sea state and vessel traffic.

As in bony fish, masking effects would be most significant for sharks with critical bandwidths at the same frequencies as the SURTASS LFA sonar, assuming that masking mechanisms in sharks are similar to that in mammals. However, at an estimated 7.5 percent duty cycle and an average 60-second transmission window, any masking would probably be temporary since the intermittent nature of the signal reduces the potential impact. Long-term effects of masking sounds on hearing and potential injury to shark hearing by intense sounds have not been studied. In summary, masking effects are not expected to be significant because the SURTASS LFA sonar bandwidth is very limited (approximately 30 Hz), signals do not remain at a single frequency for more than ten seconds, and the system is usually off over 90 percent of the time.

4.1.2.7 Conclusions

Some sharks in the SURTASS LFA sonar operations area could possibly be affected by LF sounds, but only if they were very close to the sound source. However, a negligible portion of any shark stock would be exposed to levels at or above 180 dB RL on an annual basis due to the small size of the LFA mitigation zone (180-dB sound field) relative to the open ocean areas inhabited by shark stocks.

Despite the ability of sharks to detect LF sound and the possibility of affecting sharks that are migrating or aggregating at seamounts/islands, the potential for the SURTASS LFA sonar to affect shark stocks would not be significant.

4.2 Potential Impacts on Sea Turtle Stocks

There are very few studies of the potential effects of underwater sound on sea turtles, and most of these examined the effects of sounds of much longer duration than the SURTASS LFA sonar signals. This section will provide summaries of the recent research and update the analysis of the potential effects of the alternatives based on the following SURTASS LFA sonar operational parameters:

- Small number of SURTASS LFA sonar systems to be deployed;
- Geographic restrictions imposed on system employment;
- Narrow bandwidth of SURTASS LFA sonar active signal (approximately 30 Hz);
- Slowly moving ship, coupled with low system duty cycle mean fish and sea turtles would spend less time in the LFA mitigation zone (180-dB sound field); further, with a ship moving in two dimensions and animals moving in three dimensions, the potential for animals being in the sonar transmit beam during the estimated 7.5 percent of the time the sonar is actually transmitting is very low; and
- Small size of the LFA mitigation zone (180-dB sound field) relative to open ocean areas.

Due to the lack of more definitive data on sea turtle stock distributions in the open ocean, it is not feasible to estimate the percentage of a stock that could be located in a SURTASS LFA sonar operations area at a potentially vulnerable depth, during a sound transmission.

4.2.1 Injury

Very little is known about sea turtle hearing and what may cause injury to it. However, the New England Aquarium acoustic data collection discussion below supports the premise that, using a 180-dB injury threshold, a sea turtle would have to be within the LFA mitigation zone when the sonar was transmitting to be at risk of injury, including permanent loss of hearing (i.e., PTS). The five SURTASS LFA sonar operational parameters listed above also apply to this conclusion.

4.2.2 Permanent Loss of Hearing

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).

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: 20μPa). At 70 Hz, it was about 70 dB (re: 20μPa) 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[10] (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.

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 at the New England Aquarium. 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.

Given the lack of scientific data on permanent threshold shift (PTS) in sea turtles caused by LF sound and the conclusion stated in Subchapter 4.2.1 above, the potential for SURTASS LFA sonar to cause PTS in sea turtles must be considered to be negligible. Moreover, the majority of sea turtle species inhabit the earth's oceanic temperate zones, where sound propagation is predominantly characterized by downward refraction (higher transmission loss, shorter range), rather than ducting (lower transmission loss, longer range) which is usually found in cold-water regimes. Hence, transmission ranges within the principal water-column habitat for most sea turtles—the near-surface region—are relatively shorter in temperate water regimes versus ranges in colder-water regimes, equating to smaller zones of influence. Further, the five SURTASS LFA sonar operational parameters listed above further support this conclusion.

4.2.3 Temporary Loss of Hearing

As with PTS, there are no published scientific data on temporary threshold shift (TTS) in sea turtles caused by LF sound. As there are no new data that contradict any of the assumptions or

[10] 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.

conclusions regarding Subchapter 4.1.2 (Sea Turtles) in the FOEIS/EIS, its contents are incorporated by reference herein. Further, the five SURTASS LFA sonar operational parameters listed above further support the conclusion that the potential for SURTASS LFA sonar to cause TTS in sea turtles must be considered to be negligible.

4.2.4 Behavioral Change

Tagging studies have shown that sea turtles can travel many kilometers per day in the open ocean (Keinath, 1993). They make extensive migrations and movements, either for foraging opportunities or to breed. Their migration tracks may extend to thousands of kilometers (Mortimer and Carr, 1987; Bowen et al., 1995; Eckert, 1998, 1999).

This issue relates to the behavior of sea turtle stocks near a high intensity sound source, beyond effects on the animals' ears themselves. A change in behavior that causes prolonged displacement of animals from the site of their normal activities could be considered a deleterious effect. Displacement can occur in two dimensions: vertical and horizontal. For example, a turtle could move to the surface, where anthropogenic low frequency sound would be weaker, possibly exposing it to a higher degree of predation. As for horizontal displacement, this is probably of greatest importance for non-pelagic sea turtle species (green, olive ridley, hawksbill, Kemp's ridley), for which displacement from preferred benthic habitats could be construed as more serious.

Behavioral responses to human activity have only been investigated for two species of sea turtles: green and loggerhead (O'Hara and Wilcox, 1990; McCauley et al., 2000). Both studies reported behavior changes of sea turtles in response to seismic air guns. O'Hara and Wilcox (1990) reported avoidance behaviors by loggerhead sea turtles in response to air guns with sound levels (RL) of 175-176 dB. McCauley et al. (2000) reported noticeable increases in swimming behavior for both green and loggerhead turtles at RLs of 166 dB. At 175 dB RL both green and loggerhead turtles displayed increasingly erratic behavior (McCauley et al., 2000). However, it is important to note that air guns have an impulsive signal with a large bandwidth, high energy, and a short duration. Therefore, air gun signals should not be directly compared with SURTASS LFA sonar, since the signal characteristics are very different, and the likelihood of effects on living tissue dissimilar as well.

If a sea turtle happened to be within proximity of a SURTASS LFA sonar operations area, it may hear the LF transmissions. Given that the majority of sea turtles encountered would probably be transiting in the open ocean from one site to another, the possibility of significant displacement would be unlikely. This is particularly due to: 1) the low number of SURTASS LFA sonars that would be deployed in the open ocean, 2) the geographic restrictions imposed on system employment, 3) the narrow bandwidth of the SURTASS LFA sonar active signal (approximately 30 Hz bandwidth), 4) the fact that the ship is always moving (coupled with low system duty cycle [estimated 7.5 percent], which means sea turtles would have less opportunity to be located in a sound field that could possibly cause a behavioral change), and 5) short at-sea mission times.

4.2.5 Masking

Masking effects may occur for sea turtle species that have critical hearing bandwidths at the same frequencies as the SURTASS LFA sonar. However, masking would probably be temporary. The geographical restrictions imposed on all SURTASS LFA sonar operations would limit the potential for masking of sea turtles in the vicinity of their nesting sites. In summary, masking effects are not expected to be severe because of the 7.5 to 20 percent duty cycle, the maximum 100-second signal duration, the fact that the ship is always moving, the limited 30 Hz sonar bandwidth, and the signals not remaining at a single frequency for more than ten seconds.

4.2.6 Conclusions

Sea turtles could be affected if they are inside the LFA mitigation zone (180-dB sound field) during a SURTASS LFA sonar transmission. Given that received levels from SURTASS LFA sonar operations would be below 180 dB (RL) within 22 km (12 nm) or greater distance of any coastlines and offshore biologically important areas, effects to a sea turtle stock could occur only if a significant portion of the stock encountered the SURTASS LFA sonar vessel in the open ocean. Further, the majority of sea turtle species inhabit the earth's oceanic temperate zones, where sound propagation is predominantly characterized by downward refraction (higher transmission loss, shorter range), rather than ducting (lower transmission loss, longer range) which is usually found in cold-water regimes. These factors, plus the low distribution and density of sea turtles at ranges from the coast greater than 22 km (12 nm) equate to a very small probability, if any, that a sea turtle could be found inside the LFA mitigation zone during a SURTASS LFA sonar transmission.

The above analysis focuses on the potential impacts to individual sea turtles. However, the issue of potential impact to sea turtle stocks must also be addressed. To quantify the potential impact on sea turtle stocks, the analysis provided in Subchapter 4.1.2.1 of the FOEIS/EIS was updated based on more current information for leatherback sea turtles in the Pacific Ocean. The leatherbacks were chosen for this analysis because they are the largest, most pelagic, and most widely distributed of any sea turtle found between 71°N and 47°S (Plotkin, 1995), inhabit the oceanic zone and are highly migratory (Morreale et al., 1996; Hughes et al., 1998), and are capable of transoceanic migrations (Eckert, 1998). They are rarely found in coastal waters and are deep, nearly continuous divers with usual dive depths around 250 m (820 ft) (Hays et al., 2004). The volume of Pacific Ocean habitat for leatherback sea turtles was calculated as 4.4 x 10^{16} m^3 by multiplying the total ocean area (National Geographic, 2005) by a leatherback turtle diving depth of 250 m (820 ft). An annual deployment (432 transmit hours per vessel) of SURTASS LFA sonar would ensonify approximately 4.2 x 10^{11} m^3 to a depth of 91 m (300 ft). This is 0.00001 of the ocean volume. The total worldwide population of leatherback sea turtles has been estimated at 20,000 to 30,000 (Plotkin, 1995). Therefore, a conservative estimate of 20,000 leatherback sea turtles was used for the Pacific basin.

Even though the leatherback distribution in the Pacific is patchy and the data on their whereabouts are sparse, SURTASS LFA sonar operations would cover enough ocean area that it is assumed that the number of animals potentially impacted would average out. The default assumption for pelagic animals is to assume even distribution for population estimates; thus, an even distribution of leatherbacks throughout the ocean volume is used here. Given this, the possible number of times a leatherback sea turtle may be in the vicinity of a SURTASS LFA sonar vessel would be less than 0.2 animals per year per vessel (20,000 animals x 0.00001 ocean volume = 0.2). Therefore, the potential for SURTASS LFA sonar operations to impact leatherback sea turtle stocks is negligible, even when up to four systems are considered.

In the unlikely event that SURTASS LFA sonar operations coincide with a sea turtle "hot spot," the narrow bandwidth of the SURTASS LFA sonar active signal (approximately 30 Hz bandwidth), the fact that the ship is always moving (coupled with low system duty cycle [estimated 7.5 percent], which means sea turtles would have less opportunity to be located in the LFA mitigation zone during a transmission), and the monitoring mitigation incorporated into the alternatives (visual and active acoustic [HF] monitoring) would minimize the probability of impacts on animals in the vicinity .

4.3 Potential Impacts on Marine Mammal Stocks

The types of potential effects on marine mammals from SURTASS LFA sonar operations can be broken down into non-auditory injury, permanent loss of hearing, temporary loss of hearing, behavioral change, and masking. The analyses of these potential impacts were presented in the SURTASS LFA sonar FOEIS/EIS. Updated literature reviews and research results indicate that there are no new data that contradict any of the assumptions or conclusions in the FOEIS/EIS; thus, its findings regarding potential impacts on marine mammals remain valid and are incorporated by reference herein.

4.3.1 Non-Auditory Injury

There are several potential areas for non-auditory injury to marine mammals from SURTASS LFA sonar transmissions. These include direct acoustic impact on tissue, indirect acoustic impact on tissue surrounding a structure, and acoustically mediated bubble growth within tissues from supersaturated dissolved nitrogen gas.

Tissue Damage

In response to the resonance issue raised by letters and comments to NMFS's Proposed Rule, Cudahy and Ellison (2002) analyzed the potential for injury related to resonance from SURTASS LFA sonar signals. Their analysis did not support the claim that resonance from SURTASS LFA sonar will cause injury. Physical injury due to resonance will not occur unless it will increase stress on tissue to the point of damage. Therefore, the issue is not whether resonance occurs in air/gas cavities, but whether tissue damage occurs. Cudahy and Ellison (2002) indicate that the potential for *in vivo* tissue damage to marine mammals from exposure to underwater low frequency sound will occur at a damage threshold on the order of 180 to 190 dB RL or higher. These include: 1) transluminal (hydraulic) damage to tissues at intensities on the order of 190 dB RL or greater; 2) vascular damage thresholds from cavitation at intensities in the 240-dB RL regime; 3) tissue shear damage at intensities on the order of 190 dB RL or greater; and 4) tissue damage in air-filled spaces at intensities above 180 dB RL.

In a workshop held April 24 and 25, 2002, an international group of 32 scientists with backgrounds in acoustics met at NMFS Headquarters in Silver Spring, Maryland, to consider the question of acoustic resonance and its possible role in tissue damage in marine mammals. The group concluded that it is not likely that acoustic resonance in air spaces plays a primary role in tissue damage in marine mammals exposed to intense acoustic sources. Tissue displacements are too small to cause damage, and the resonant frequencies of marine mammal air spaces are too low to be excited by most sounds produced by humans. Resonance of non-air containing tissues was not ruled out. While tissue trauma from resonance in air spaces seems highly unlikely, the group agreed that resonance in non-air-containing tissues cannot be considered negated until certain experiments are performed (NOAA/NMFS, 2002).

In summary, the best available scientific information shows that, while resonance can occur in marine animals, this resonance does not necessarily cause injury, and any such injury is not expected to occur below a sound pressure level of 180 dB RL. Because the Draft and FOEIS/EISs used 180 dB RL as the criterion for the determination for the potential for injury to marine life and for the implementation of geographic and monitoring mitigation measures, any non-auditory physiological impacts associated with resonance were accounted for. The 145-dB RL restriction for known recreational and commercial dive sites will provide an additional level of protection to marine animals in these areas.

Additionally, it has been claimed that air space resonance impacts can cause damage to the lungs and large sinus cavities of cetaceans, that low frequency sound could induce panic and subsequent problems with equalization, and that low frequency sound could cause bubble growth in blood vessels. With regard to the specific impacts to lungs and sinus cavities, there is abundant anatomical evidence that marine mammals have evolved and adapted to dramatic fluctuations in pressure during long, deep dives that seem to exceed their aerobic capacities (Williams et al., in *Science*, 2000; ENN, 2000). For example, marine mammal lungs are reinforced with more extensive connective tissues than their terrestrial relatives. These extensive connective tissues, combined with the probable collapse of the alveoli at the depths at which significant SURTASS LFA sonar signals can be heard, make it very unlikely that significant lung resonance effects could be realized. The panic response concern is addressed in Subchapter 4.4.3 (Marine Mammal Strandings) below.

Acoustically Mediated Bubble Growth

Presently, there is controversy among researchers on whether or not marine mammals can suffer from a form of decompression sickness. It is theorized that this may be caused by diving and then surfacing too quickly, forcing nitrogen bubbles to form in the bloodstream and tissues. In 2002, NMFS held "The Workshop on Acoustic Resonance as a Source of Tissue Trauma in Cetaceans," focusing on the March 2000 Bahamas strandings. The purpose of the workshop was to present any evidence for the possible mechanisms by which mid-frequency active sonar could lead to strandings of beaked whales. The November 2002 report on this workshop discussed needed research on acoustically mediated bubble growth and listed the major issues surrounding the hypothesis (NOAA/NMFS, 2002). The issues listed included:

- Using trained animals to test the theory of bubble growth;

- Studying the tissues damaged by bubble growth/decompression sickness and comparing this with the injuries in beaked whales already studied;
- Obtaining needed information on the rise of acoustic waves in enhancing bubble nucleation and activation in tissues that are supersaturated to upwards of 300 percent;
- Devising methods to acquire, preserve, and test tissue samples from stranded animals so that the presence of bubbles in tissues can be investigated; and
- If beaked whales are shown to have bubble growth from any cause, then determining the lowest sound pressure level at which bubble growth can be triggered, and which sonars have transmission characteristics most likely to trigger this bubble growth.

Jepson et al. (including Fernandez) (2003) (P. D. Jepson is from the School of Geography and the Environment, University of Oxford, UK) published a brief communication in *Nature* magazine on gas-bubble lesions found in stranded cetaceans (Canary Islands stranding, 2002, see Subchapter 4.4.3.1). They presented findings of acute and chronic tissue damage in stranded cetaceans that they believe resulted from the formation of *in vivo* (in the living body) gas bubbles, and stated that the animals showed severe, diffuse vascular congestion and marked, disseminated microvascular hemorrhages associated with widespread fat emboli in vital organs, particularly the liver. They also stated that the lesions were consistent with acute trauma due to *in vivo* bubble formation that results from rapid decompression, which occurs in decompression sickness. A response to this article was posted in *Nature* by Piantadosi and Thalmann (2004) of the Duke University Medical Center and Divers Alert Network (DAN) stating that whales do not develop sufficient gas supersaturation in the tissues on ascent to cause extensive bubble formation in the liver. The gas that would be available for supersaturation is located in the lungs at the onset of each held breath. According to Piantadosi and Thalmann (2004), during descent the thorax is compressed and the residual gas volume in the compliant lungs is forced**,** by Boyle's law contraction and alveolar collapse, into non-respiratory conducting airways, where it is sequestered from circulation. They explain that not enough gas is taken up to produce bubbles, except possibly during multiple rapid dives to depths approaching the lung's closing volume. Fernandez et al. (including Jepson) (2004) stated in their own brief communication that they did not present their findings as conclusive evidence of decompression sickness. All communications agree, though, that further investigation is needed, including an analysis of the composition of the gas in the bubbles (Jepson et al., 2003; Piantadosi and Thalmann, 2004; Fernandez et al., 2004).

Scientists from the Woods Hole Oceanographic Institution (WHOI) have documented bone lesions in the rib and chevron bones of sperm whales, which may have been caused by tissue damage from nitrogen bubbles (Moore and Early, 2004). They studied 16 partial or complete skeletons that died up to 111 years ago from both the Atlantic and Pacific Oceans. Studying the skeletons, they noted a series of changes in bones attached to the backbone, mainly the rib bones, and other small bones in the tail region. The changes are patches where the bone died due to an obstructed blood supply to the joint surfaces of the bone. One theory suggests that the lesions were caused by a decompression-like sickness (Dawicki, 2004).

The issue of bubble growth via rectified diffusion was evaluated in the FOEIS/EIS, Record of Decision and Final Rule. Crum and Mao (1996) stated that RL would have to exceed 190 dB in order for there to be the possibility of significant bubble growth via rectified diffusion (one form of the growth of gas bubbles in liquids) due to supersaturation of gases in the blood.

4.3.2 Permanent Loss of Hearing

Hearing Threshold

The hearing of marine mammals varies based on individuals, absolute threshold of the species, masking, localization, frequency discrimination, and the motivation to be sensitive to a sound (Richardson et al., 1995). Younger animals typically have better hearing sensitivity than older animals and hearing sensitivity also varies by species. The absolute threshold is the level of sound that is barely audible when significant ambient noise is absent, which also varies based on the frequency of the sound. Background noise may mask the sounds that a marine mammal detects; masking can come from both natural and man-made noises (Richardson et al., 1995).

The hearing mechanism for marine mammals is similar to that of terrestrial mammals. It is comprised of an outer ear, a fluid-filled inner ear with a frequency-tuned membrane interacting with sensory cells, and an air-filled middle ear, which provides a connection between the outer ear and inner ear (Nedwell et al., 2004).

Odontocetes

Behavioral audiograms have been conducted for 11 species of toothed whales, including oceanic dolphins, river dolphins, porpoises, and monodonts (narwhals and belugas). Odontocetes have a broad acoustic range, with recent hearing thresholds measured between 75 Hz and about 180 kHz (Richardson et al., 1995; Finneran et al., 2002). According to one study, the best hearing for the beluga whale seems to be between 40 and 100 kHz (Johnson et al., 1989); however, their hearing at low frequencies seems poor (Richardson et al., 1995). A 2001 audiogram study on bottlenose dolphins showed that the male dolphin’s hearing was the best between 20 and 40 kHz while the female dolphin’s best hearing was between 20 and 120 kHz (Nedwell et al., 2004). Most small to medium-sized odontocetes seem to have good hearing in high frequencies, extending up to 150 kHz in some individuals (Richardson et al., 1995). Audiograms from killer whales have shown that they have upper frequency limits near 120 kHz (Richardson et al., 1995). A study in 1999 examined the hearing ability of killer whales between 1 and 100 kHz, which showed that behaviorally, the killer whales reacted between 4 and 100 kHz (Szymanski et al., 1999).

Pinnipeds

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). 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. 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 low frequency sound in the water, as sea lions have a higher hearing threshold (116 to 119 dB RL) at frequencies of 100 Hz. Harbor seals are approximately 20 dB more sensitive to signals at 100 Hz compared to California sea lions and thus are more likely to hear low frequency anthropogenic noise. Elephant seals are the most sensitive to low frequency sound underwater with a hearing threshold of around 90 dB RL at 100 Hz. Elephant seals also are deep divers, which may expose them to higher sound levels in the deep sound channel. 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.

In a 2002 study, the California sea lion was most sensitive between approximately 2.5 and 10 kHz (Kastak and Schusterman, 2002). Other otariid species (eared seals) 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 (true seals), 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).

Other sound experiments have shown some pinniped sensitivity to low frequency sound. Ringed, harbor, and harp seal audiograms show that they can hear frequencies as low as 1 kHz, with the harp seal responding to stimuli as low as 760 Hz. Hearing thresholds of ringed, harbor and harp seals are relatively flat from 1 to 50 kHz with thresholds between 65 and 85 dB RL (Møhl, 1968; Terhune and Ronald, 1972, 1975; Terhune, 1991).

Mysticetes

There have been no psycho-acoustical or electrophysiological studies reported on baleen whales. However, some species react behaviorally to certain calls and anthropogenic sounds. Most reactions to anthropogenic sounds were below 1 kHz. Fin whales have responded to calls from the same species at 20 Hz. Observed reactions have been seen with gray, humpback, and bowhead whales from air gun pulses and underwater playbacks of recorded anthropogenic sounds. The dominant frequencies were in the 50 to 500 Hz range (Richardson et al., 1995). All mysticetes produce low frequency sounds, although no direct measurements of auditory (hearing) thresholds have been made (Clark, 1983, 1990; Richardson et al., 1995; Edds-Walton, 1997; Tyack, 2000; Evans and Raga, 2001). Based on a study of the morphology of cetacean auditory mechanisms, Ketten (1994) hypothesized that mysticete hearing is in the low to infrasonic (sound frequencies too low to be audible to humans, generally below 20 Hz) range. It is generally believed that baleen whales have frequencies of best hearing where their calls have the greatest energy—below 1,000 Hz (Dahlheim and Ljungblad, 1990; Frankel et al., 1995; Ketten, 2000).

Summary

The updated literature reviews and research results noted above indicate that there are no new data that contradict any of the assumptions or conclusions in the FOEIS/EIS; thus, its findings regarding the potential for permanent loss of hearing from SURTASS LFA sonar operations remains valid. That is, that the potential impact on any stock of marine mammals from injury (such as permanent loss of hearing) is considered negligible.

4.3.3 Temporary Loss of Hearing

In addition to the possibility of causing permanent injury to hearing, sound may cause temporary threshold shift (TTS), a temporary and reversible loss of hearing that may last for minutes to hours. TTS is quite common in humans and often occurs after being exposed to loud music, such as at a rock concert. The precise physiological mechanism for TTS is not understood. It may result from fatigue of the sensory hair cells as a result of their being over-stimulated or from some small damage to the cells, which is repaired over time. The duration of TTS depends on a variety of factors including intensity and duration of the stimulus, and recovery can take minutes, hours, or even days. Therefore, animals suffering from TTS over longer time periods, such as hours or days, may be considered to have a change in a biologically significant behavior, as they could be prevented from detecting sounds that are biologically relevant, including communication sounds, sounds of prey, or sounds of predators.

There have been no substantial changes to the knowledge or understanding for the potential effects of LF sound to cause temporary loss of hearing in marine mammals. The information in the FOEIS/EIS Subchapters 1.4.2 and 4.2.7, taken in the context of temporary loss of hearing (i.e., TTS), remains valid, and the contents are incorporated by reference herein.

4.3.4 Behavioral Change

Biologically Significant Behavior

The primary potential deleterious effect from SURTASS LFA sonar is change in a biologically significant behavior. An activity is biologically significant when it affects an animal's ability to grow, survive, and reproduce (NRC, 2005).

The Low Frequency Sound Scientific Research Program (LFS SRP) field research in 1997-98 provided important results on and insights into the types of responses of whales to SURTASS LFA sonar signals and how those responses scaled relative to RL and context. The results of the LFS SRP confirmed that some portion of the whales exposed to the SURTASS LFA sonar responded behaviorally by changing their vocal activity, moving away from the source vessel, or both., but the responses were short-lived (Clark et al., 2001)

In a 1998 SURTASS LFA sonar playback experiment, migrating gray whales avoided exposure to LFA signals (source levels of 170 and 178 dB) when the source was placed within their migration corridor. Responses were similar for the 170-dB SL LFA stimuli and for the 170-dB SL one-third octave band-limited noise with timing and frequency band similar to the LFA stimulus. However, during the SURTASS LFA sonar playback experiments, in all cases, whales resumed their normal activities within tens of minutes after the initial exposure to the LFA signal (Clark et al., 2001). Essentially, the whales made minor course changes to go around the source. When the source was relocated outside of the migration corridor, but with SL increased so as to reproduce the same sound field inside the corridor, the whales continued their migration unabated. This result stresses the importance of context in interpreting animals' responses to underwater sounds.

Prey fish within the 180-dB sound field of the SURTASS LFA sonar source could potentially be affected, which would suggest that this could presumably affect the foraging potential for some localized marine mammals to some extent. However, recent results from low frequency sonar exposure studies conducted on trout and channel catfish indicated that the impact from low frequency sonar is likely to be minimal, if not negligible; and certainly there is no potential for any measurable fish stock mortalities from SURTASS LFA sonar operations (see Subchapter 4.1.1). Therefore, marine mammal foraging will not be affected.

Eight weekly aerial surveys of humpback whales were flown north of the Hawaiian Island of Kauai each year when the North Pacific Acoustic Laboratory (NPAL) source was not transmitting in 2001 and when it was transmitting in 2002 and 2003 during the peak residency period of humpback whales (February through March) (Mobley, 2005). The goal of the NPAL program was to extend the earlier thermometry findings of the Acoustic Thermometry of Ocean Climate (ATOC) experiment over a longer time to determine ocean-basin scale trends in temperature. The results of these surveys suggest that exposure to the NPAL source during the two years sampled with the source on, did not change the numbers of whales north of Kauai. It did not produce any noticeable distributional changes as measured by distance from the source and from shore, nor did it produce any noticeable changes in the depths of sighting locations. These results contrast somewhat with the results from the ATOC and MMRP studies, which found a slight change in distribution and behavior, although no change in abundance (Frankel and Clark, 2000; 2002). After four years of exposure to the ATOC/NPAL transmissions, the humpback whales continue to return to their wintering grounds near Kauai and show little changes in their normal pattern of distribution (Mobley, 2005).

4.3.5 Masking

There have been no substantial changes to the knowledge or understanding for the potential effects of LF sound on masking with regard to marine mammals. The information in Subchapter 4.2.7.7 of the FOEIS/EIS remains valid, and the contents are incorporated by reference herein. Two papers have been published fairly recently on low frequency masking in three pinniped species (northern elephant seal, harbor seal, California sea lion) that focused specifically on comparative amphibious capabilities, and revealed some LF characteristics of masking that bear on cochlear mechanics (Southall, et al., 2000; Southall et al., 2003). The former paper used behavioral techniques to determine underwater masked hearing thresholds for the three test animals. The latter paper reported on direct measurements of critical bandwidth at low frequencies and basically concluded that results are directly relevant to underwater masking because both arise from common cochlear processes in either media (air or water). Results indicate that LF signals can be masked by LF noise. However, combined data suggest that LF critical masking ratios are relatively low in both media for pinnipeds (as in much of the other marine mammal data), which would suggest less potential for masking at low frequencies.

4.3.6 Conclusions

The potential effects from SURTASS LFA sonar operations on any stock of marine mammals from injury (non-auditory or permanent loss of hearing) are considered negligible, and the potential effects on the stock of any marine mammal from temporary loss of hearing or behavioral change (significant change in a biologically important behavior) are considered minimal. Any auditory masking in marine mammals due to SURTASS LFA sonar signal transmissions is not expected to be severe and would be temporary.

4.4 Analysis of SURTASS LFA Sonar Operations under Current MMPA Rule

As a requirement of the regulations for the taking of marine mammals incidental to Navy operations of Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar, 50 CFR 216 Subpart Q (67 *Federal Register* [FR] 46785-89), the Navy must provide annual reports with an unclassified summary of the classified quarterly reports of SURTASS LFA operations onboard the USNS IMPECCABLE (T-AGOS 23) and R/V *Cory Chouest* in accordance with the requirements of the Letters of Authorization (LOAs) issued by the United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), and the National Marine Fisheries Service (NMFS). The primary purpose of this annual report is to provide NMFS with unclassified SURTASS LFA sonar operations information to assist them in their evaluation of future Navy LOA applications. As of May 2005, three annual reports have been submitted to NMFS (DON, 2003a; 2004a; 2005a). Table 4.4-1 summarizes these operations by LOA.

4.4.1 Risk Assessment Approach

The SEIS was developed based on the analyses in the SURTASS LFA sonar FOEIS/EIS (DON, 2001), the Applications for Letters of Authorization (DON, 2002; 2003b; 2004b; 2005b), updated literature reviews, and additional underwater acoustical modeling. The analytical process is summarized below. The FOEIS/EIS provided detailed risk assessments of potential impacts to marine mammals covering the major ocean regions of the world: North and South Pacific Oceans, Indian Ocean, North and South Atlantic Oceans, and the Mediterranean Sea.

The 31 acoustic modeling sites are shown in Figure 4.2-1 and Table 4.2-1 of the FOEIS/EIS. Marine mammal data were developed from the most recent NMFS stock assessment reports at the time and pertinent multinational scientific literature containing marine mammal distribution, abundance and/or density datasets. The locations were selected to represent reasonable sites for each of the three major underwater sound propagation regimes where SURTASS LFA sonar could be employed.

Table 4.4-1. Summary of SURTASS LFA sonar operations.

	Mission Number	Site[1]	Season	Length of Mission (days)	Active Transmission Time (hours)	Mitigation Protocol Suspensions/ delays
LOA 1						
R/V *Cory Chouest*	1	2	Winter	1.6	3.8	0
R/V *Cory Chouest*	2	2	Winter	5.9	14.4	0
R/V *Cory Chouest*	3	2	Spring	0.7	1.6	0
R/V *Cory Chouest*	4	4	Spring	13.2	31.7	0
R/V *Cory Chouest*	5	4	Summer	2.7	6.5	0
R/V *Cory Chouest*	6	4	Summer	1.7	4.1	2
R/V *Cory Chouest*	7	4	Summer	8.4	20.1	1
LOA 2						
R/V *Cory Chouest*	1	3	Fall	7.3	17.4	
R/V *Cory Chouest*	2	3	Winter	17.0	40.7	2
R/V *Cory Chouest*	3	3	Winter	4.9	11.7	1
R/V *Cory Chouest*	4	3	Spring	3.6	8.7	2
R/V *Cory Chouest*	5	3	Spring	13.4	32.2	2
USNS IMPECCABLE	1	2	Spring	8.2	19.7	1
USNS IMPECCABLE	2	1	Spring	3.5	8.4	2
USNS IMPECCABLE	3	1	Spring	9.0	21.5	2
USNS IMPECCABLE	4	2	Summer	3.1	7.4	0
USNS IMPECCABLE	5	3	Summer	2.5	6.0	0
LOA No. 3						
USNS IMPECCABLE	1	2	Winter	7.5	18.1	0
USNS IMPECCABLE	2	2	Winter	1.9	4.6	1

[1]See Figure 4.4-2

Acoustic analysis included underwater sound transmission via the following propagation paths:

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

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

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

These sites represent the upper bound of impacts (both in terms of possible acoustic propagation conditions, and in terms of marine mammal population and density) that can be expected from operation of the SURTASS LFA sonar system. Thus, if SURTASS LFA sonar operations were conducted in an area that was not acoustically modeled in the FOEIS/EIS, the potential effects would most likely be less than those obtained from the most similar site in the analyses presented here.

Effectively, the conservative assumptions of the FOEIS/EIS are still valid. Moreover, there are no new data that contradict any of the assumptions or conclusions made in Subchapter 4.2 (Potential Impacts on Marine Mammals) of the FOEIS/EIS. Thus, it is not necessary to reanalyze the potential acoustic impacts in the Supplemental EIS. Under the MMPA Rule, the Navy must apply for annual LOAs. In these applications, the Navy projects where it intends to operate for the period of the next annual LOAs and provides NMFS with reasonable and realistic risk estimates for marine mammal stocks in the proposed areas of operation. The LOA application analytical process is described below with the actual sensitivity/risk analysis performed for the fourth-year LOA application provided as a sample case study. It utilizes a conservative approach by integrating mission planning needs and a cautious assessment of the limited data available on specific marine mammal populations, and seasonal habitat and activity. Because of the incorporation of conservative assumptions, it is likely that the aggregate effect of such assumptions was an overestimation of risk—a prudent approach for environmental conservation when there are data gaps and other sources of uncertainty. This approach for estimating risk to marine mammal stocks was not intended to forecast the expected outcome from SURTASS LFA sonar operations but, rather, to determine reasonable upper bounds. If this type of practical analysis presented an outcome that was acceptable, then the activity would clearly satisfy the regulatory requirement to assess environmental risk. The total annual risk for each stock of marine mammal species was estimated by summing a particular species' risk estimates within that stock, across mission areas. Each stock, for a given species, was then examined. Based on this approach, the highest total annual estimated risk (upper bound) for any marine mammal species' stock was provided in the fourth year application for LOAs (DON, 2005b).

Figure (4.4-1) provides a flowchart that depicts the sensitivity/risk process. The left side of the flowchart illustrates the process that is initially carried out for all potential mission areas, which starts with the Navy's antisubmarine warfare (ASW) requirements to be met by SURTASS LFA sonar. Based on this information, mission areas are proposed by the CNO and fleet commands. Thereupon, available published data are collected, collated, reduced and analyzed with respect to marine mammal populations and stocks, marine mammal habitat and seasonal activities, and marine mammal behavioral activities. Where data are unavailable, best scientific estimates are made by highly-qualified marine biologists, based on known data for like species and/or geographic areas, and known marine mammal seasonal activity.

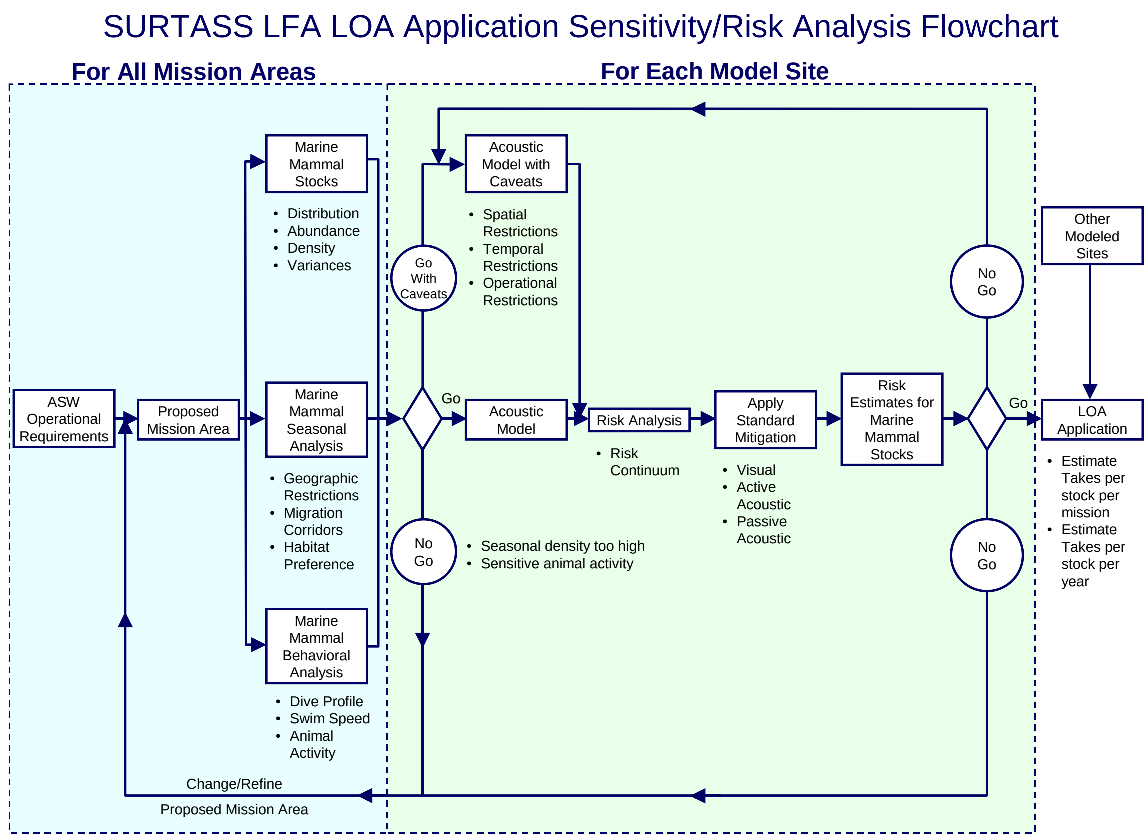


Figure 4.4-1. SURTASS LFA sonar LOA application sensitivity/risk analysis flowchart.

The right side of the flowchart portrays the process that is applied to mission sites 1 through 9 (see Figure 4.4-2) individually. The individual generic steps of this process are summarized as follows:

- Based on results from the initial process for all potential mission areas, there are three possible alternatives, which are indicated in the flow chart. If, for one or more of the proposed mission areas, seasonal densities prove to be high and/or sensitive animal activities are expected there, those mission areas are changed and/or refined and the process is re-initiated, as shown in the flow chart.
- The other two alternatives are: 1) standard acoustic modeling is performed, or 2) acoustic modeling with caveats (e.g., spatial, temporal or operational restrictions) is performed.
- After acoustic modeling, risk analysis is undertaken, using the risk continuum.
- Standard mitigation is applied.
- Risk estimates for marine mammal stocks are calculated.
- Based on these estimates, the next decision point is reached. Again, there are three possible alternatives, two of which are: 1) more acoustic modeling with changed or refined caveats is performed and the "each model site" process is re-initiated, or 2) the proposed mission area is changed or refined and the entire process is re-initiated.

- The other alternative is to move to the next step and input the risk estimates for marine mammal stocks to the LOA application, which are also combined with the estimates derived from the same process for all other modeled mission areas/sites to derive the risk estimates for marine mammal stocks for the entire LOA period of applicability (one year).

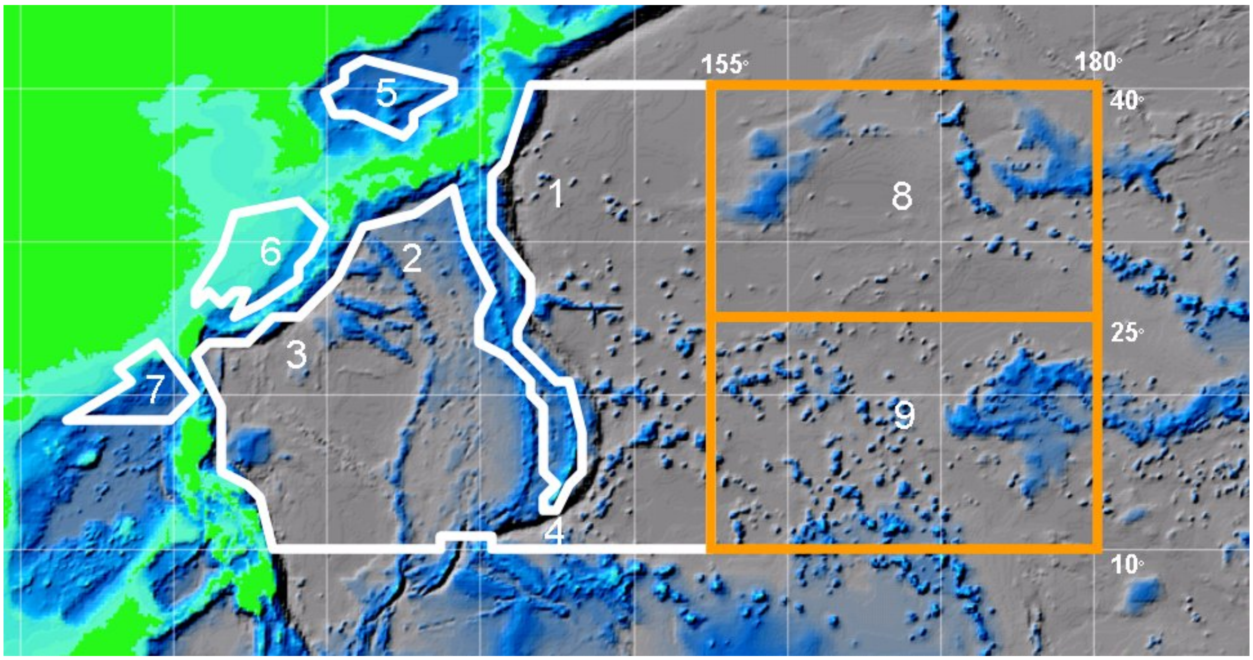


Figure 4.4-2. SURTASS LFA sonar western Pacific operational areas.

4.4.2 Risk Assessment Case Study

The same analytical methodology utilized in the application for the current LOAs (DON, 2005b) was utilized to provide reasonable and realistic estimates of the potential effects to marine mammal stocks specific to the potential mission areas as presented in the application. It is not feasible to analyze all potential mission areas throughout the oceanic regions pertinent to this SEIS (Atlantic, Mediterranean, Pacific, and Indian), for all species' stocks for all seasons. In the case study, sites and seasons are based on reasonable and realistic choices for SURTASS sonar operations proposed in the LOA application. The CNO's mission for SURTASS sonar operations to be conducted under the requested LOAs is to train the Navy crews manning the vessels and to test and operate the SURTASS LFA sonar systems in as many and varied at-sea environments as possible. The Navy has determined that the SURTASS LFA sonar testing and training operations that are the subject of NMFS's July 16, 2002, Final Rule constitute a military readiness activity as that term is defined in Public Law 107-314 (16 U.S.C. § 703 note) because those activities constitute "training and operations of the Armed Forces that relate to combat" and constitute "adequate and realistic testing of military equipment, vehicles, weapons and sensors for proper operation and suitability for combat use."

Information on how the density and stock/abundance estimates are derived for the selected mission sites are given in the LOA applications. These data are derived from current, available published source documentation, and provide general area information for each mission area with species-specific information on the animals that could potentially occur in that area, including estimates for their stock/abundance and density.

Tables 4.4-1 through 4.4-9 provide a set of annual estimates of potential effects to marine mammal stocks for a single ship conducting a single mission at each of the nine mission sites (see Figure 4.4-2) with the operating profile provided in Table 2-2, for the season specified. Nine possible mission sites are analyzed, although the expected annual operating profile would be for six active missions, as per Table 2-2. The values in the tables support the conclusion that estimates of potential effects to marine mammal stocks are below the criteria delineated by NMFS in its current Final Rule. Furthermore, “small numbers” and “specified geographical region” are no longer requirements under the MMPA as amended by the National Defense Authorization Act of Fiscal Year 2004 (NDAA, FY04).

Table 4.4-2. Estimates of percentage of marine mammal stocks potentially affected for Mission Site 1, Summer Season.

East of Japan					
Mission Site 1	**Animal**	**# Animals in Area**	**# Animals Stock**	**% Affected <180 dB**	**% Affected (w/mit) ≥ 180 dB**
	Blue whale	60	9250	0.10	0.00
	Fin whale	60	9250	0.10	0.00
	Sei whale	180	37000	0.07	0.00
	Bryde's whale	180	22000	0.12	0.00
	Minke whale	1080	25000	0.69	0.00
	N. Pacific right whale	3	922	0.05	0.00
	Sperm whale	300	102112	0.04	0.00
	Kogia	930	350553	0.04	0.00
	Baird's beaked whale	870	8000	1.52	0.00
	Cuvier's beaked whale	1620	90725	0.25	0.00
	Ginkgo-toothed beaked whale	150	22799	0.09	0.00
	Hubbs' beaked whale	150	22799	0.09	0.00
	False killer whale	1080	16668	1.15	0.00
	Pygmy killer whale	630	30214	0.37	0.00
	Short-finned pilot whale	3840	53608	1.20	0.00
	Risso's dolphin	2910	83289	0.72	0.00
	Common dolphin	22830	3286163	0.14	0.00
	Bottlenose dolphin	5130	168791	0.62	0.00
	Spinner dolphin	150	1015059	0.00	0.00
	Pantropical spotted dolphin	7770	438064	0.35	0.00
	Striped dolphin	3330	570038	0.11	0.00
	Rough-toothed dolphin	1770	145729	0.24	0.00
	Fraser's dolphin	1200	220789	0.11	0.00
	Pacific white-sided dolphin	2460	67769	0.71	0.00

Table 4.4-3. Estimates of percentage of marine mammal stocks potentially affected for Mission Site 2, Winter Season.

North Philippine Sea					
Mission Site 2	**Animal**	**# Animals in Area**	**# Animals Stock**	**% Affected <180 dB**	**% Affected (w/mit) ≥ 180 dB**
	Bryde's whale	180	22000	0.11	0.00
	Minke whale	1080	25000	0.56	0.00
	N. Pacific right whale	3	922	0.04	0.00
	Sperm whale	300	102112	0.04	0.00
	Kogia	930	350553	0.03	0.00
	Cuvier's beaked whale	1620	90725	0.23	0.00
	Blainville's beaked whale	150	8032	0.24	0.00
	Ginkgo-toothed beaked whale	150	22799	0.09	0.00
	Killer whale	120	12256	0.14	0.00
	False killer whale	870	16668	0.73	0.00
	Pygmy killer whale	630	30214	0.29	0.00
	Melon-headed whale	360	36770	0.14	0.00
	Short-finned pilot whale	4590	53608	1.20	0.00
	Risso's dolphin	3180	83289	0.64	0.00
	Common dolphin	16860	3286163	0.08	0.00
	Bottlenosed dolphin	4380	168791	0.44	0.00
	Spinner dolphin	150	1015059	0.00	0.00
	Pantropical spotted dolphin	4110	438064	0.14	0.00
	Striped dolphin	9870	570038	0.26	0.00
	Rough-toothed dolphin	1770	145729	0.18	0.00
	Fraser’s dolphin	1200	220789	0.08	0.00
	Pacific white-sided dolphin	3570	67769	0.79	0.00

Table 4.4-4. Estimates of percentage of marine mammal stocks potentially affected for Mission Site 3, Fall Season.

West Philippine Sea					
Mission Site 3	**Animal**	**# Animals in Area**	**# Animals Stock**	**% Affected <180 dB**	**% Affected (w/mit) ≥ 180 dB**
	Fin whale	60	9250	0.36	0.00
	Bryde's whale	180	22000	0.45	0.00
	Minke whale	540	25000	1.14	0.00
	Humpback whale (winter only)	0	394	0.00	0.00
	Sperm whale	300	102112	0.12	0.00
	Kogia	510	350553	0.06	0.00
	Cuvier's beaked whale	90	90725	0.03	0.00
	Blainville's beaked whale	150	8032	0.84	0.00
	Ginkgo-toothed beaked whale	150	22799	0.30	0.00
	False killer whale	870	16668	2.79	0.00
	Pygmy killer whale	630	30241	1.11	0.00
	Melon-headed whale	4290	36770	6.21	0.00
	Short-finned pilot whale	2280	53608	2.25	0.00
	Risso's dolphin	3180	83289	2.34	0.00
	Common dolphin	16860	3286163	0.30	0.00
	Bottlenose dolphin	4380	168791	1.59	0.00
	Spinner dolphin	150	1015059	0.00	0.00
	Pantropical spotted dolphin	4110	438064	0.54	0.00
	Striped dolphin	4920	570038	0.51	0.00
	Rough-toothed dolphin	1770	145729	0.72	0.00
	Fraser's dolphin	1200	220789	0.33	0.00
	Pacific white-sided dolphin	7350	67769	6.39	0.00

Table 4.4-5. Estimates of percentage of marine mammal stocks potentially affected for Mission Site 4, Spring and Summer Seasons.

Guam					
Mission Site 4	**Animal**	**# Animals in Area**	**# Animals Stock**	**% Affected <180 dB**	**% Affetced (w/mit) ≥ 180 dB**
	Blue whale	60	9250	0.21	0.00
	Fin whale	60	9250	0.21	0.00
	Bryde's whale	270	22000	0.45	0.00
	Minke whale	60	25000	0.09	0.00
	Humpback whale (winter only)	0	4005	0.00	0.00
	Sperm whale	300	102112	0.09	0.00
	Kogia	510	350553	0.03	0.00
	Cuvier's beaked whale	1620	90725	0.56	0.00
	Blainville's beaked whale	390	8032	1.50	0.00
	False killer whale	630	35132	1.68	0.00
	Melon-headed whale	2790	36770	3.39	0.00
	Short-finned pilot whale	600	53608	0.51	0.00
	Risso's dolphin	210	83289	0.15	0.00
	Bottlenose dolphin	750	168791	0.27	0.00
	Spinner dolphin	3000	1015059	0.15	0.00
	Pantropical spotted dolphin	31410	438064	3.81	0.00
	Striped dolphin	18060	570038	1.68	0.00
	Rough-toothed dolphin	1740	145729	0.63	0.00

Table 4.4-6. Estimates of percentage of marine mammal stocks potentially affected for Mission Site 5, Fall Season.

Sea of Japan					
Mission Site 5	**Animal**	**# Animals in Area**	**# Animals Stock**	**% Affected <180 dB**	**% Affected (w/mit) ≥ 180 dB**
	Fin whale	270	9250	0.98	0.00
	Bryde's whale	30	22000	0.04	0.00
	Minke whale	120	25000	0.16	0.00
	Minke J stock	48	893	1.80	0.00
	Gray whale	3	100	1.00	0.00
	N. Pacific right whale	3	922	0.15	0.00
	Sperm whale	240	102112	0.06	0.00
	Stejneger's beaked whale	420	8000	1.56	0.00
	Baird's beaked whale	90	8000	0.34	0.00
	Cuvier's beaked whale	1290	90725	0.42	0.00
	Ginkgo-toothed beaked whale	150	22799	0.20	0.00
	False killer whale	810	9777	3.24	0.00
	Melon-headed whale	3	36770	0.00	0.00
	Short-finned pilot whale	420	53608	0.30	0.00
	Risso's dolphin	2190	83289	1.18	0.00
	Common dolphin	25800	3286163	0.32	0.00
	Bottlenose dolphin	270	105138	0.12	0.00
	Spinner dolphin	3	1015059	0.00	0.00
	Pantropical spotted dolphin	4110	219032	0.78	0.00
	Pacific white-sided dolphin	900	67769	0.54	0.00
	Dall's porpoise	15600	76720	8.36	0.00

Table 4.4-7. Estimates of percentage of marine mammal stocks potentially affected for Mission Site Site 6, Summer Season.

East China Sea					
Mission Site 6	**Animal**	**# Animals in Area**	**# Animals Stock**	**% Affected <180 dB**	**% Affected (w/mit) ≥ 180 dB**
	Fin whale	60	500	1.90	0.00
	Bryde's whale	180	22000	0.13	0.00
	Minke whale	1080	25000	0.69	0.00
	Minke J stock	432	893	7.68	0.00
	Gray whale (winter only)	3	100	0.48	0.00
	N. Pacific right whale	3	922	0.05	0.00
	Sperm whale	300	102112	0.04	0.00
	Kogia	510	350553	0.02	0.00
	Cuvier's beaked whale	1560	90725	0.22	0.00
	Blainville's beaked whale	270	8032	0.44	0.00
	Ginkgo-toothed beaked whale	150	22799	0.09	0.00
	False killer whale	540	9777	0.72	0.00
	Pygmy killer whale	90	30214	0.04	0.00
	Melon-headed whale	630	36770	0.26	0.00
	Short-finned pilot whale	1080	53608	0.30	0.00
	Risso's dolphin	3180	83289	0.68	0.00
	Common dolphin	13830	3286163	0.06	0.00
	Bottlenose dolphin	4380	105138	0.74	0.00
	Spinner dolphin	330	1015059	0.01	0.00
	Pantropical spotted dolphin	4122	219032	0.32	0.00
	Striped dolphin	4920	570038	0.14	0.00
	Rough-toothed dolphin	510	145729	0.20	0.00
	Fraser’s dolphin	1200	220789	0.09	0.00
	Pacific white-sided dolphin	840	67769	0.21	0.00

Table 4.4-8. Estimates of percentage of marine mammal stocks potentially affected for Mission Site Site 7, Fall Season.

South China Sea					
Mission Site 7	**Animal**	**# Animals in Area**	**# Animals Stock**	**% Affected <180 dB**	**% Affected (w/mit) ≥ 180 dB**
	Fin whale	60	9250	0.09	0.00
	Bryde's whale	180	22000	0.65	0.00
	Minke whale	120	25000	0.07	0.00
	Gray whale (winter only)	0	100	0.00	0.00
	Sperm whale	300	102112	0.03	0.00
	Kogia	510	350553	0.01	0.00
	Cuvier's beaked whale	90	90725	0.01	0.00
	Blainville's beaked whale	150	8032	0.17	0.00
	Ginkgo-toothed beaked whale	150	22799	0.07	0.00
	False killer whale	540	9777	0.82	0.00
	Pygmy killer whale	630	30214	0.31	0.00
	Melon-headed whale	2610	36770	1.06	0.00
	Short-finned pilot whale	2289	53608	0.64	0.00
	Risso's dolphin	3180	83289	0.75	0.00
	Common dolphin	13830	3286163	0.07	0.00
	Bottlenose dolphin	4380	105138	0.82	0.00
	Spinner dolphin	330	1015059	0.01	0.00
	Pantropical spotted dolphin	4122	219032	0.33	0.00
	Striped dolphin	4929	570038	0.15	0.00
	Rough-toothed dolphin	1200	145729	0.15	0.00
	Fraser's dolphin	1200	220789	0.10	0.00

Table 4.4-9. Estimates of percentage of marine mammal stocks potentially affected for Mission Site Site 8, Summer Season.

Offshore North of 25-40ºN					
Mission Site 8	**Animal**	**# Animals in Area**	**# Animals Stock**	**% Affected <180 dB**	**% Affected (w/mit) ≥ 180 dB**
	Blue whale	90	9250	0.30	0.00
	Fin whale	30	9250	0.10	0.00
	Sei whale	3	37000	0.00	0.00
	Bryde's whale	9	22000	0.02	0.00
	Minke whale	90	25000	0.12	0.00
	Sperm whale	90	102112	0.02	0.00
	Kogia	1470	350553	0.12	0.00
	Baird's beaked whale	30	8000	0.10	0.00
	Cuvier's beaked whale	510	90725	0.16	0.00
	Mesoplodon spp	150	22799	0.18	0.00
	False killer whale	1080	16668	2.30	0.00
	Pygmy killer whale	3	30214	0.00	0.00
	Melon-headed whale	3	36770	0.00	0.00
	Short-finned pilot whale	15	53608	0.00	0.00
	Risso's dolphin	300	83289	0.14	0.00
	Common dolphin	25890	3286163	0.30	0.00
	Bottlenose dolphin	150	168791	0.04	0.00
	Spinner dolphin	3	1015059	0.00	0.00
	Pantropical spotted dolphin	5430	438064	0.48	0.00
	Striped dolphin	15000	570038	1.04	0.00
	Rough-toothed dolphin	3	145729	0.61	0.00
	Pacific white-sided dolphin	1440	67769	1.23	0.00

Table 4.4-10. Estimates of percentage of marine mammal stocks potentially affected for Mission Site 9, Summer Season.

Offshore South of 10-25ºN					
Mission Site 9	**Animal**	**# Animals in Area**	**# Animals Stock**	**% Affected <180 dB**	**% Affected (w/mit) ≥ 180 dB**
	Bryde's whale	9	22000	0.02	0.00
	Sperm whale	105	102112	0.02	0.00
	Kogia	270	350553	0.02	0.00
	Cuvier's beaked whale	510	90725	0.16	0.00
	False killer whale	630	16668	1.34	0.00
	Short-finned pilot whale	270	53608	0.16	0.00
	Risso's dolphin	780	83289	0.38	0.00
	Common dolphin	25890	3286163	0.30	0.00
	Bottlenose dolphin	210	168791	0.06	0.00
	Spinner dolphin	2670	1015059	0.10	0.00
	Pantropical spotted dolphin	24060	438064	2.16	0.00
	Striped dolphin	3300	570038	0.22	0.00
	Rough-toothed dolphin	360	145729	0.10	0.00

4.4.3 Marine Mammal Strandings

4.4.3.1 Cetacean Stranding Events

Marine mammal strandings are not a rare occurrence. The Cetacean Stranding Database (www.strandings.net) registers that over a hundred strandings occurred worldwide in the year 2004. However, mass strandings, particularly multi-species mass strandings, are relatively rare. Acoustic systems are becoming increasingly implicated with marine mammal strandings. Many theories exist as to why noise may be a factor in marine mammal strandings. It is theorized that they become disoriented, or that the noise forces them to surface too quickly which may cause symptoms similar to decompression sickness, or that they are physically injured by the sound pressure.

A review of historical data (mostly anecdotal) maintained by the Marine Mammal Program in the National Museum of Natural History, Smithsonian Institution reports 49 beaked whale mass stranding events between 1838 and 1999. The largest beaked whale mass stranding occurred in the 1870s in New Zealand when 28 Gray's beaked whales (*Mesoplodon grayi*) stranded. Blainsville's beaked whale (*Mesoplodon densirostris*) strandings are rare, and records show that they were involved in one mass stranding in 1989 in the Canary Islands. Cuvier's beaked whales (*Ziphius cavirostris*) are the most frequently reported beaked whale to strand, with at least 19 stranding events from 1804 through 2000 (DOC and DON, 2001; Smithsonian Institution, 2000). By the nature of the data, much of the information on strandings over the years is anecdotal, which has been condensed in various reports, and some of the data have been altered or possibly misquoted.

Strandings within the western Pacific region have been compiled from various, mostly uncorroborated, public sources. Uncertainties exist in many cases as to exact location, and species identification, due to the anecdotal nature of these reports. The paucity of independent scientific verification of strandings in this region can partly be explained by regional language differences between conservation programs and publications, cultural preferences, and some inherent media restrictions. The best source of stranding information for Japan, the Marine Mammal Standing Database from the Natural History Museum of Tokyo, currently has only made data publicly available through 2001.

Strandings related to natural causes

There are many known causes for strandings. Stranded marine mammals may be ill. They could have a disease or parasites, or pollution could cause illness. They may follow prey and get too close to shore or they could follow a sick member of the pod and strand. Climatic cycles may also change the ecological composition of species in a region, bringing in new species, which could lead to more strandings of the new species. Strandings can also be caused by animal disorientation with respect to geomagnetic fields when they are used as a source of directional information.

Between March 10 and April 13, 2004, 107 bottlenose dolphins stranded dead along the Florida Panhandle. In addition to the dolphins, many fish and invertebrates were also found dead. An "Interim Report on the Bottlenose Dolphin (*Tursiops turncatus*) Unusual Mortality Event Along the Panhandle of Florida, March-April 2004" has been released by the National Oceanic and Atmospheric Administration and the Florida Fish and Wildlife Conservation Commission (NOAA and USFWS, 2004). The interim report outlines the initial findings and the ongoing analyses of the investigation on the unusual mortality event. The analyses conducted found brevetoxins, naturally occurring neurotoxins produced by *Karenia brevis*, the Florida red tide, at high levels in the stomach contents of all dolphins examined to the date of the publication of the Interim Report. The concentrations of the brevetoxins in the subsamples of the stomach contents were greater than or equal to those observed in previous marine mammal mortality events associated with Florida red tides in the Gulf of Mexico. Military exercises were being conducted off the coast of the Florida Panhandle in March 2004, but were a significant distance from the stranded animals. From the examination of 22 dolphins, no physical evidence of blast or acoustic trauma was found, and based on the stomach contents of the stranded animals, brevetoxins are believed to have caused this unusual mortality event.

On November 28, 2004, 73 long-finned pilot whales and 25 bottlenose dolphins stranded on a beach on King Island in Tasmania. On November 29, 2004, 53 long-finned pilot whales stranded at Maria in Tasmania and 55 long-finned pilot whales stranded on the Coramandle

Peninsula in New Zealand (WDCS, 2004a). Statements were made in newspapers that strandings are fairly frequent in Tasmania, the Bass Strait, and in New Zealand during that time of year (ECBC, 2004). The Whale and Dolphin Conservation Society (WDCS) of Australia released a statement that Tasmanian researchers reported on research in July 2004 at the Australian Marine Science Association's conference linking a series of whale stranding in southern Australia to climatic cycles (WDCS, 2004b). Some scientists believe that the cyclical winds were pushing sub-Antarctic cold, nutrient-rich waters closer to the surface which may have led the whales and dolphins to strand in November (ECBC, 2004).

MacLeod et al. (2005) investigated whether recent oceanic climate change had been significant enough to alter the local cetacean community off northwest Scotland and what it could mean for the conservation of the cetaceans. Since 1981, there has been an increase in temperature of local waters of 0.2 to 0.4ºC per decade. Based on this study, the authors suggest that the warming of local waters has led to changes in the cetacean community, increasing the occurrence of warm-water species, the common dolphin (*Delphinis delphis*), and the addition of new warm-water species, the striped dolphin (*Stenella coeruleoalba*). There has also been a decline in occurrence of a cold-water species, such as the white-beaked dolphin (*Lagenorhynchus albirostris*). This change in the cetacean community has led to a decline of strandings of white-beaked dolphins and an increase in common and striped dolphin strandings (MacLeod et al., 2005).

Strandings potentially related to anthropogenic sound

As stated above, there have been recent stranding events that have been publicly reported and which may, or may not, have been attributed to anthropogenic sound. Several of these are discussed below. SURTASS LFA sonar has not been implicated in any of these events and, in fact, there is no record of it ever being implicated in any stranding event since LFA prototype systems were first operated in the late 1980s.

In May 1996, 12 or 13 Cuvier's beaked whales stranded on the Greek coast. Seven of the whales were examined, all of them adolescents with fresh food in their stomachs. They were tested for viruses with negative results, but there was no investigation of their inner ears. NATO was conducting Shallow Water Acoustic Classification exercises, using low- and mid-frequency sonar, in the Kyparissiakos Gulf in the area of the strandings. The frequencies of the sources were between 450 and 3,300 Hz. Since the inner ears were not examined, though, an acoustic link could not be established or eliminated (NATO, 1998).

From 15 to 17 March 2000, 17 cetaceans stranded in the Bahamian islands of Grand Bahama, Abaco, and smaller surrounding islands. Four species were involved, including Cuvier's beaked whales, Blainville's beaked whales, minke whales (*Balaenoptera acutorostrata*), and spotted dolphins (*Stenella ssp.)*. Seven animals died and ten animals were returned to the water alive. According to the June 2003 Beaked Whale Necropsy Findings by Darlene R. Ketten, Ph.D., there was no evidence of near-field blast damage (Ketten, 2003). However, there were deposits of blood within some of the inner ear chambers, and, in one animal, the blood trail could be traced to a hemorrhage in a region of the fluid spaces around the brain and the animal also had clotting on the dorsal surfaces of both lateral ventricles of the brain. The necropsy findings suggest pressure-related trauma in the stranded beaked whales. The pattern of the hemorrhaging suggested that the animals were alive at the time of injury. There was also hemorrhaging in the "acoustic" fats of the jaws. The level of hemorrhaging was consistent with acoustic trauma, but did not necessarily indicate permanent hearing loss or mortality. It could have been caused by other factors. In addition, the animals that were returned to sea did not re-strand, which is consistent with non-permanent trauma (Ketten, 2003). The Department of Commerce and the Department of the Navy (DOC and DON) published a Joint Interim Report on the Bahamas Marine Mammal Stranding (DOC and DON, 2001). This Report concluded:

> "A combination of specific physical oceanographic features, bathymetry, presence of beaked whales, and specific sound sources were present. Six of the whales and one dolphin (unassociated) died after stranding on beaches. Ten whales returned to the sea alive. The four dead whales from which specimen samples could be collected showed signs of inner ear damage and one showed signs of brain tissue damage. While the precise causal mechanisms of tissue damage are unknown, all evidence points to acoustic or impulse trauma. Review of passive acoustic data ruled out volcanic eruptions, landslides, other seismic events, and explosive blasts, leaving mid-range tactical Navy sonars operating in the area as the most plausible source of the acoustic or impulse trauma. This sound source was active in a complex environment that, as noted above, included the presence of a surface duct, unusual underwater bathymetry, constricted channel with limited egress, intensive use of multiple active sonar units over an extended period of time, and the presence of beaked whales that appear to be sensitive to the frequencies produced by these sonars. The investigation team concludes that the cause of this stranding event was the confluence of the Navy tactical mid-range frequency sonar and the contributory factors noted above acting together." (DOC and DON, 2001)

On September 24, 2002, 14 animals of multiple species of beaked whales stranded in the Canary Islands of Spain. This event coincided with a Spanish-led Navy maneuver in nearby waters. Five animals were found dead, three were found alive, but later died, and six animals were returned to the sea. On September 25, two dead beaked whales appeared, and on September 26, two more dead beaked whales appeared. Specimens from September 24 underwent a necropsy by members of the Veterinary University of Las Palmas as well as the Society for the Study of Cetaceans of the Canaries Archipelago (Martin et al., 2004). Efforts to study the whale specimens from this incident continue and a report has not yet been published.

4.4.3.2 Pinniped Stranding Events

There are many causes for pinniped strandings, such as disease, climatic conditions, injuries and domoic acid[11]. One study focused on the causes of live strandings of California sea lions along

[11] Domoic acid is produced by a neurotoxic phytoplankton by the name of *Pseudo-nitzschia australis*, which occurs naturally in California's waters. When there is a significant algal bloom, which has happened every spring for the last several years, an abundant amount of the poisonous domoic acid is produced. The toxin then amasses within the bodies of the sardines and anchovies that feed on the poisonous phytoplankton. The acid accumulates as it climbs the food chain into progressively larger animals like the sea lions and dolphins. As the toxin is absorbed into the body, it affects the neural pathways of sea mammals and inhibits the neurochemical processes of those it afflicts.

the central California coast from 1991 to 2000 (Greig et al., 2005). Diseases may reflect environmental changes such as pollution, a shift in prey, and global warming. Natural environmental changes, such as storm surges and El Niňo events have been correlated to the number of pinniped strandings. However, detection rate is also dependent upon human effort, better public awareness, and the accessibility to stranded animals. Data collection from strandings are opportunistic and can vary based on season, weather conditions, and the number of people on the beach. According to this study, malnutrition was the most common reason for pinniped strandings (32 percent); followed by leptospirosis (a bacterial disease that affects humans and animals) (27 percent); trauma (e.g., gunshot wounds, entanglement, shark bites, propeller wounds) (18 percent); domoic acid intoxication (9 percent); and cancer (3 percent). In past surveys conducted by The Marine Mammal Center from 1975 to 1990, the major causes of strandings were malnutrition, renal disease, and pneumonia. In the 1991 to 2000 study, the causes of the strandings were determined from clinical experimentations, hematology and serum biochemistry parameters, radiographs, gross necropsy, histopathologic examination of tissues, fecal sedimentation for parasites, bacterial culture, and biotoxin assays. The results of this study showed that the annual number of live California sea lion strandings along the central California coast increased since 1975. Furthermore, a greater number of strandings occurred during the El Niňo events of 1983/1984, 1991/1992, and 1997/1998 (Greig et al., 2005).

4.4.3.3 Conclusion

Although much of the public currently have the impression that military sonar usage is a principal cause of marine mammal strandings, the facts that are available indicate otherwise. The biological mechanisms for these effects must be determined through scientific research, while recognizing that there is an ongoing issue with public perception of the cause that must be dealt with. The important point here is that there is no record of SURTASS LFA sonar ever being implicated in any stranding event since LFA prototype systems were first operated in the late 1980s. Moreover, the system acoustic characteristics differ between LF and MF sonars: the former use frequencies generally below 1,000 Hz, with relatively long signals (pulses) on the order of 60 sec; while the latter use frequencies greater than 1,000 Hz, with relatively short signals on the order of 1 sec.

4.4.4 Multiple Systems Analysis

Given that there are no new data that contradict any of the assumptions or conclusions presented in Subchapter 4.2.7.4 of the FOEIS/EIS, its contents are incorporated by reference herein. In summary, simply adding the potential impacts from each of the sources conservatively bounds the effect of multiple systems being employed in proximity.

4.5 Socioeconomics

This subchapter addresses the potential impact to commercial and recreational fisheries, other recreational activities, and research and exploration activities, that could result from implementation of the alternatives under consideration.

4.5.1 Commercial and Recreational Fisheries

SURTASS LFA sonar operations are presently geographically restricted such that SURTASS LFA sonar RLs are less than 180 dB RL at 22 km (12 nm) from coastlines and at the boundaries of offshore biologically important areas during biologically important seasons. The highest fisheries productivity is generally within these same regions. In addition, based on the low frequency sonar controlled exposure experiments on fish (Subchapter 4.1.1), SURTASS LFA sonar operations will not affect fish populations and, therefore, will not affect commercial and recreational fishing.

4.5.2 Other Recreational Activities

There are no new data that contradict any of the assumptions or conclusions regarding Subchapter 4.3.2 (Other Recreational Activities) in the FOEIS/EIS regarding swimming, snorkeling and diving; hence, its contents are incorporated by reference herein.

Wolfson (1977) stated that whale watching along the North America west coast gray whale migration route was not well-regulated and that activity, in combination with commercial fishing and vessel operations, may cause gray whales to migrate further offshore. Bursk (1989) reported that gray whales often changed speed and deviated from their course in the presence of whale watching boats.

SURTASS LFA sonar operations are restricted to less than 180 dB RL within 22 km (12 nm) of coastlines and offshore biologically important areas during biologically important seasons, and will not exceed 145 dB RL for known recreational and commercial dive sites. One reason for the geographic restrictions imposed on SURTASS LFA sonar operations is because these areas can have concentrations of marine mammals (which may be prime whale watching locations). There are no significant impacts to whale watching activities as a result of the employment of SURTASS LFA sonar primarily because the operations avoid prime whale watching areas. In addition, the 145-dB RL restriction for commercial and recreational dive sites would help protect whales and the whale watching industry. Moreover, given that whale watching continues to grow in popularity and as an industry, it can be logically construed that SURTASS LFA sonar operations have not had any impact on the whale watching industry.

4.5.3 Research and Exploration Activities

It is not believed that SURTASS LFA sonar operations will affect research submersibles, nor is it expected that SURTASS LFA sonar operations will affect seafloor cable-laying. SURTASS LFA sonar could potentially affect oceanographic research activities and oil and gas exploration, as they use equipment such as air guns, hydrophones, and ocean-bottom seismometers. If in the vicinity of a research or exploration activity, SURTASS LFA sonar could possibly interfere with or saturate the hydrophones of these other operations. Research activities and oil and gas exploration, though, could also potentially interfere with SURTASS LFA sonar operations. For these reasons, SURTASS LFA sonar operations are not expected to be close enough to these activities to impact them to any measurable degree.

4.6 Potential Cumulative Impacts

Cumulative impacts, which can result from individually minor, but collectively significant, actions taking place over time and space, have been defined by the Council on Environmental Quality (CEQ) in 40 CFR 1508.7 as:

> Impacts on the environment which result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions.

Two areas were evaluated to compare the incremental impacts of SURTASS LFA sonar operations with "past, present, and reasonably foreseeable future actions." These include:

- Comparison to anthropogenic oceanic noise levels; and
- Comparison of injury and lethal takes from anthropogenic causes.

4.6.1 Cumulative Impacts from Anthropogenic Oceanic Noise

A potential cumulative impact issue associated with SURTASS LFA sonar operations is the addition of underwater sound to oceanic ambient noise levels, which in turn could have impacts on marine animals. Anthropogenic sources of ambient noise that are most likely to have contributed to increases in ambient noise levels are commercial shipping, offshore oil and gas exploration and drilling, and naval and other use of sonar (ICES, 2005).

The potential impact that up to four SURTASS LFA sonars may have on the overall oceanic ambient noise level should be viewed in the following contexts:

- Recent changes to ambient sound levels in the world's oceans;
- Operational parameters of the SURTASS LFA sonar system, including proposed mitigation; and
- The contribution of SURTASS LFA sonar to oceanic noise levels relative to other human-generated sources of oceanic noise.

4.6.1.1 Recent Changes in Oceanic Noise Levels

Ambient noise is defined as "Environmental background noise not of direct interest during a measurement or observation; may be from sources near and far, distributed and discrete, but excludes sounds produced by measurement equipment, such as cable flutter…It is generally unwanted sound—sound that clutters and masks other sounds of interest (Richardson et al., 1995). Thus, any potential for cumulative impact should be put into the context of recent changes to ambient sound levels in the world's oceans. Research and statements made regarding recent changes in oceanic noise levels before 2001 can be found in the SURTASS LFA sonar FOEIS/EIS, Subchapter 4.4.1.

Andrew et al. (2002) compared ocean ambient sound from the 1960s with the 1990s for a receiver off the California coast. The data showed an increase in ambient noise of approximately 10 dB in the frequency range of 20 to 80 Hz and 200 and 300 Hz, and about 3 dB at 100 Hz over a 33-year period. A possible explanation for the rise in ambient noise is the increase in shipping noise.

4.6.1.2 Commercial Shipping

The Final Report of the NOAA International Symposium on "Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology" stated that the worldwide commercial fleet has grown from approximately 30,000 vessels in 1950 to over 85,000 vessels in 1998 (NRC, 2003, Southall, 2005). Between 1950 and 1998, the U.S. flagged fleet declined from approximately 25,000 to less than 15,000 and currently represents only a small portion of the world fleet. Foreign waterborne trade in the U.S. has increased from 718 to 1,164 million gross metric tons from 1981 to 2001. From 1985 to 1999, world seaborne trade doubled to 5 billion tons and currently includes 90 percent of the total world trade, with container shipping movements representing the largest volume of seaborne trade. It is unknown how international shipping volumes and densities will continue to grow. However, current statistics support the prediction that the international shipping fleet will continue to grow at the current rate or at greater rates in the future. Shipping densities in specific areas and trends in routing and vessel design are as, or more, significant than the total number of vessels. Densities along existing coastal routes are expected to increase both domestically and internationally. New routes are also expected to develop as new ports are opened and existing ports are expanded. Vessel propulsion systems are also advancing toward faster ships operating in higher sea states for lower operating costs; and container ships are expected to become larger along certain routes (Southall, 2005).

4.6.1.3 Vessel Noise Sources

Boats and ships produce sound due to propeller cavitation (or propeller singing) as well as other machinery. Propeller singing has a frequency between 100 and 1,000 Hz (Richardson et al., 1995). Noise from propulsion machinery enters the water through the hull of the ship. Propulsion machinery sources include rotating shafts, gear reduction transmissions, reciprocating parts, gear teeth, fluid flow turbulence, and mechanical friction. Other sources of noise include pumps, non-propulsion engines, generators, ventilators, compressors, flow noise from water dragging on the hull, and bubbles breaking in the wake. Medium and large vessels generate frequencies up to approximately 50 Hz, primarily from propeller blade rate and secondarily from the engine cylinder firing rates and shaft rotation (Richardson et al., 1995). Propeller cavitation and flow noise can produce frequencies as high as 100 kHz but generally peak energy occurs between 50 and 150 Hz; and auxiliary machinery (pumps and compressors) may produce frequencies up to several kilohertz (Richardson et al., 1995). Moreover, most (83 percent) of the acoustic field surrounding large vessels is the result of propeller cavitation (Southall, 2005). Larger ships generally are diesel-powered and have two propellers, which are larger and slower rotating. These propellers typically have four blades, which turn at a rate of approximately 160 rpm and have a frequency of 10 to 11 Hz (Richardson et al., 1995). It is generally believed that acoustic source levels are not a function of speed for modern diesel vessels across most of their common operations (Heitmeyer et al., 2004). Supply ships often have bow thrusters to help maneuver the ship. A bow thruster may create a harmonic tone with a high fundamental frequency, depending on the rotation rate of the thrusters. One study found nine harmonics, extending up to 1,064 Hz. In another study, the noise increased by 11 dB when the bow thrusters began operating.

Small boats with large outboard engines produce SLs of 175 dB, at frequencies up to several hundred Hertz (Richardson et al., 1995). A study was conducted on the effects of boat noise from whale-watching vessels on the interaction of humpback whales (Au and Green, 2000). Two boats were inflatables with outboard engines. Two were larger coastal boats with twin inboard diesel engines, and the fifth boat was a small water plane area twin hull (SWATH) ship. The study concluded that it is unlikely that the levels of sounds produced by the boats in the study would have any serious effect on the auditory system of humpback whales.

Another study was conducted on the effects of boat noise from whale-watching vessels on pods of killer whales. The average number of whale-watching vessels around the whales has increased approximately fivefold from 1990 to 2000. This study found no significant difference in the duration of primary calls as a function of the presence and absence of boats during 1977 to 1981 and 1989 to 1992, but there was a significant increase in call duration for all three pods studied in the presence of boats from 2001 to 2003 (Foot et al., 2004).

A study was also conducted on the effects of watercraft noise on the acoustic behavior of bottlenose dolphins in Florida (Buckstaff, 2004). The study focused on short-term changes in whistle frequency range, duration, and rate of production. The frequency range and duration of signature whistles did not significantly change due to approaching vessels. However, dolphins whistled more often at the onset of approaching vessels compared to during and after vessel approaches. The whistle rate also increased more at the onset of a vessel approach than when there were no vessels present.

4.6.1.4 Oil and Gas Industry

According to the NRC (2003), the oil and gas industry has five categories of activities which create sound: seismic surveys, drilling, offshore structure emplacement, offshore structure removal, and production and related activities. Seismic surveys are conducted using air guns, sparker sources, sleeve guns, innovative new impulsive sources and sometimes explosives, and are routinely conducted in offshore exploration and production operations in order to define subsurface geological structure. The resultant seismic data are necessary for determining drilling location and currently seismic surveys are the only method to accurately find hydrocarbon reserves. Since the reserves are deep in the earth, the low frequency band (5 to 20 Hz) is of greatest value for seismic surveys, because lower frequency signals are able to travel farther into the seafloor with less attenuation.

Air gun firing rate is dependent on the distance from the array to the substrate. The typical inter-shot time is 9-14 sec, but for very deep water surveys, inter-shot times are as high as 42 sec. Air gun acoustic signals are typically measured in peak-to-peak pressures. Peak levels from the air guns are generally higher than continuous sound levels from any other ship or industrial noise. Broadband SLs of 248 to 255 dB from zero-to-peak are typical for a full-scale array. The most powerful arrays have source levels as high as 259 dB, zero-to-peak with air gun volumes of 130 L (7,900 in^3). Smaller arrays have SLs of 235 to 246 dB, zero-to-peak. For deeper-water surveys, most emitted energy is around 10 to 120 Hz. However, some pulses contain energy up to 1,000 Hz (Richardson et al., 1995), and higher.

Vibroseis is a method of seismic profiling on shore-fast ice. The ice is vibrated with hydraulically-driven pads mounted beneath a line of trucks. Veibrosis generally has frequency levels from 10 to 70 Hz with harmonics reaching to about 1.5 kHz. Vibroseis signals are transient but not impulsive. The sweeps each last five to 20 seconds and there are 10 sweeps before the trucks move 70 to 100 m (230 to 328 ft) to the next station (Richardson et al., 1995).

Drill ship activities are one of the noisiest at-sea operations because the hull of the ship is a good transmitter of all the ship's internal noises. Also, the ships use thrusters to stay in the same location rather than anchoring. Auxiliary noise is produced during drilling activities, such as helicopter and supply boat noises. Offshore drilling structure emplacement creates some localized noise for brief periods of time, and emplacement activities can last for a few weeks and occur worldwide. Additional noise is created during other oil production activities, such as borehole logging, cementing, pumping, and pile driving. Although sound pressure levels for some of these activities have not yet been calculated, others have (e.g., pile-driving). More activities are occurring in deep water in the Gulf of Mexico and offshore west Africa areas.

These oil and gas industry activities occur year-round (not individual surveys, but collectively) and are usually operational 24 hours per day and 7 days per week, as compared to the limited and intermittent SURTASS LFA sonar transmissions.

4.6.1.5 Military and Commercial Sonar

Active sonar was probably the first wide-scale, intentional use of anthropogenic noise within the oceans. The outbreak of WWI in 1914 was the impetus for the development of a number of military applications of sonar (Urick, 1983); and by 1918, both Britain and the U.S had built active sonar systems. The years of peace following WWI saw a steady, though extremely slow, advance in applying underwater sound to practical needs. By 1935 several adequate sonar systems had been developed, and by 1938 with the imminence of WWII, quantity production of sonar sets started in the U.S. (Urick, 1983). The NRC (2003) notes that there are both military and commercial sonars: military sonars are used for target detection, localization, and classification; and commercial sonars are typically higher in frequency and lower in power and are used for depth sounding, fish finding, and detecting obstacles in the water. Commercial sonar use is expected to continue to increase, although it is not believed that the acoustic characteristics will change.

4.6.1.6 SURTASS LFA Sonar Compared with other Human-Generated Sources of Oceanic Noise

The most widespread potential impact of anthropogenic noise is masking and decrease in distances that underwater sound can be heard by a marine mammal. These effects have the potential to cause a long-term decrease in a marine mammal's efficiency at foraging, navigating or communicating (ICES, 2005).

Broadband low-frequency shipping noise is more likely to affect marine mammals than narrowband, low duty cycle SURTASS LFA sonar. Moreover, SURTASS LFA sonar bandwidth is limited (approximately 30 Hz), the average maximum pulse length is 60 sec, signals do not remain at a single frequency for more than 10 sec, and during an operation the system is off 80 to 92.5 percent of the time. Most mysticete vocalizations are in the low frequency band below 1 kHz. No direct auditory measurements have been made for any mysticete, but it is generally believed that their frequency band of best hearing is below 1,000 Hz, where their calls have the greatest energy (Clark, 1990; Edds-Walton, 2000; Ketten, 2000). However, with a maximum duty cycle of 20 percent, any masking from SURTASS LFA sonar would be temporary.

Odontocetes have a broad acoustic range and hearing thresholds measure between 400 Hz and 100 kHz (Richardson, et al., 1995; Finneran et al., 2002). It is believed that odontocetes communicate above 1,000 Hz and echolocate above 20 kHz (Würsig and Richardson, 2002). There is a possibility for upward masking of high-frequency noises by low frequency noises. However, with the maximum duty cycle of 20 percent, masking would be temporary. For these reasons, any masking effects from SURTASS LFA sonar are expected to be negligible and extremely unlikely.

In a recently released report entitled "Ad-Hoc Group on the Impact of Sonar on Cetaceans," the International Council for the Exploration of the Sea (ICES, 2005) concluded, "It appears that sonar is not a major current threat to marine mammal populations generally, nor will it ever be likely to form a major part of ocean noise." They went on to state that shipping accounts for more than 75 percent of all human sound in the oceans, that sonar amounts to no more than 10 percent or so and shipping noise is projected to increase, where sonar is not (ICES, 2005).

4.6.2 Cumulative Impacts due to Injury and Lethal Takes

The second area for potential cumulative effects to marine mammal populations is through injury and lethal takes. In order to evaluate the effects of SURTASS LFA sonar operations, it is necessary to place it in perspective with other anthropogenic sound sources that have impacts on marine mammals and other marine resources.

Bycatch

Bycatch is the industry term for the inadvertent capture of non-target species in fishing gear. Besides cetaceans and other marine mammals, sea turtles, seabirds and non-commercial fish species also are regularly caught and killed unintentionally as bycatch. World Wildlife Fund convened a summit of the world's leading cetacean experts in January 2002 in Annapolis, MD, which was attended by 25 scientists from six continents. The group reached consensus that the single biggest threat facing cetaceans worldwide is death as bycatch in fishing gear. More whales dolphins and porpoises die every year by getting entangled in fishing gear than from any other cause. Researchers at Duke University and the University of St. Andrews in Scotland estimate a global annual average of nearly 308,000 deaths per year—or nearly 1,000 per day (CBRC, 2005). Fishing gear that poses the biggest danger to cetaceans includes: gillnets, set nets, trammel nets, seines, trawling nets and longlines. Because of their low cost and widespread use, gillnets are responsible for a very high proportion of global cetacean bycatch.

Baird et al. (2002) performed a study on gray whale mortality incidental to commercial fishing operations in British Colombia, Canada waters, and derived the estimate of between 2 and 2.4 gray whales killed incidentally in British Colombian commercial fisheries each year.

Ship Strikes

Marine mammals are often injured or killed from ship strikes throughout the world. Jensen and Silber (2003) used the best available data to report the known large-whale ship strikes through 2002. Their report shows that ship strikes have been reported in the waters of Antarctica, Australia, Brazil, Canada, the Canary Islands, France, Japan, Mexico, New Zealand, Panama, Peru, Puerto Rico, and South Africa. However, it is likely that many ship strikes go undetected or unreported each year. For that reason, the number of ship strikes is possibly significantly greater than those reported. There have been 292 reported ship strikes since 1885, with 11 species confirmed to be victims of ship strikes. Of the recorded 292 ship strikes, 48 were known to result in injury and 198 were fatal. In many injury cases, however, the fate of the whale is unknown. The impact to the whale was unknown in 39 reports and 7 incidents report that there appeared to be no sign of injury to the whale (Jensen and Silber, 2003). Ship strikes are generally not an issue for SURTASS LFA sonar vessels because of their slow operational speed (3 to 5 knots) and transit speed (10 to 12 knots).

International Whaling Commission-Authorized Whale Takes

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 2001, Denmark was authorized to kill 176 whales, St. Vincent killed two whales, Russia killed 113 whales, and the United States killed 75 whales. In 2002, Canada killed one whale, Denmark killed 162 whales, Russia killed 134 whales, and the United States killed 50 whales.

Three countries presently issue scientific research permits to themselves to capture and kill whales on an annual basis. In 2001, Norway killed over 500 minke whales under its scientific research permit. Japan, under its self-issued scientific research permit, is authorized to annually kill 400 minke whales around the Antarctic and 100 minke whales in the waters around Japan

(IWC, 1998). Since 2003, Iceland's scientific research permit allows harvesting of 38 minke whales annually.

Conclusion

Based on extensive evaluation in both this document and the FOEIS/EIS, the operation of SURTASS LFA sonar with monitoring and mitigation will result in no lethal takes. This is supported by the fact that SURTASS LFA sonar has been operating since 2003 in the northwestern Pacific Ocean with no reported Level A (MMPA) harassment takes or strandings associated with its operations. Moreover, there has been no new information or data that contradict the FOEIS/EIS finding that the potential effect from SURTASS LFA sonar operations on any stock of marine mammals from injury (non-auditory or permanent loss of hearing) is considered negligible.

4.6.3 Summary of Cumulative Impacts

Two areas were evaluated to compare the incremental impacts of the operations of up to four SURTASS LFA sonars with "past, present, and reasonably foreseeable future actions." These included:

- Comparison to anthropogenic oceanic noise levels; and
- Comparison of injury and lethal takes from anthropogenic causes.

Given the information provided in this Subchapter 4.6, the potential for cumulative impacts from the operations of up to four SURTASS LFA sonars is considered to be extremely small and has been addressed by limitations proposed for employment of the system (i.e., geographical restrictions and monitoring mitigation). The geographic restriction imposed by the 145-dB RL exposure criterion for known commercial and recreational dive sites supports the conclusion that SURTASS LFA sonar contributions to oceanic ambient noise are small and incremental. That is, the 145-dB RL restriction further limits (in addition to the 180-dB RL geographic restriction) the accumulation of anthropogenic sound in coastal areas. Even if considered in combination with other underwater sounds, such as commercial shipping, other operational, research, and exploration activities (e.g., acoustic thermometry, hydrocarbon exploration and production), recreational water activities, and naturally-occurring sounds (e.g., storms, lightning strikes, subsea earthquakes, underwater volcanoes, whale vocalizations, etc.), the SURTASS LFA sonar systems do not add appreciably to the underwater sounds that fish, sea turtle and marine mammal stocks are exposed to. Moreover, SURTASS LFA sonar will cause no lethal takes of marine mammals.

4.7 Evaluation of Alternatives

NEPA requires federal agencies to prepare an EIS that discusses the environmental effects of a reasonable range of alternatives (including the No Action Alternative). Reasonable alternatives are those that will accomplish the purpose and meet the need of the proposed action, and those that are practical and feasible from a technical and economic standpoint. In the FOEIS/EIS, alternatives included the No Action Alternative, Alternative 1 (employment with geographic restrictions and monitoring mitigation), and Alternative 2 (unrestricted operation). Alternative 1 was the Navy's preferred alternative in the FOEIS/EIS.

The FOEIS/EIS also considered alternatives to LFA, such as other passive acoustic and non-acoustic technologies, as discussed in FOEIS/EIS Subchapters 1.1.2, 1.1.3, and 1.2.1; Table 1-1; and Responses to Comments (RTCs) 1-1.3, 1-2.1, 1-2.2, and 1-2.3. These were also addressed in the NMFS Final Rule and the ROD (67 FR 48152). These alternatives were eliminated from detailed study in the FOEIS/EIS in accordance with CEQ Regulation §1502.14 (a). These acoustic and non-acoustic detection methods included radar, laser, magnetic, infrared, electronic, electric, hydrodynamic, and biological technologies, and high- or mid-frequency sonar. It was concluded in the FOEIS/EIS that these technologies did not meet the purpose and need of the proposed action to provide Naval forces with reliable long-range detection and, thus, did not provide adequate reaction time to counter potential threats. Furthermore, they were not considered to be practical and/or feasible for technical and economic reasons.

The Court found that, "Defendants' alternatives analysis is arbitrary and capricious" and that, "…defendants' second alternative, full deployment with no mitigation or monitoring, is a phantom option. Moreover, plaintiffs have demonstrated that defendants should have considered training in areas that present a reduced risk of harm to marine life and the marine environment when practicable…" The SEIS alternative analysis herein addresses these findings. In particular, the latter Court finding is addressed in Subchapter 2.5.2.1.

This subchapter provides an analysis of the proposed alternatives for the employment of SURTASS LFA sonar, as summarized in Table 4.7-1. In addition to the No Action Alternative, four alternatives were analyzed to satisfy the Court's findings and to determine the potential effects of changes to the proposed action. These alternatives incorporate coastline standoff restrictions of 22 and 46 km (12 and 25 nm), seasonal variations, additional offshore biologically important areas (OBIAs), and the possibility of employing shutdown procedures for schools of fish. These alternatives include:

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

Table 4.7-1. SURTASS LFA sonar system alternatives matrix.

Proposed Restrictions/ Monitoring	No Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Dive Sites (RL)	145 dB	145 dB	145 dB dB	145 dB dB	145 dB dB
Coastline Restrictions (RL)	NA	<180 dB at 12 nm	<180 dB at 12 nm	<180 dB at 25 nm	<180 dB at 25 nm
Seasonal Variations	NA	Yes	Yes	Yes	Yes
Original OBIAs	NA	Yes	Yes	Yes [1]	Yes[1]
Additional OBIAs	NA	No	Yes	No	Yes
Shutdown procedures for fish schools	NA	No	No	No	Yes
Visual Monitoring	NA	Yes	Yes	Yes	Yes
Passive Acoustic Monitoring	NA	Yes	Yes	Yes	Yes
Active Acoustic Monitoring	NA	Yes	Yes	Yes	Yes
Reporting	NA	Yes	Yes	Yes	Yes

Note 1: Only those OBIAs, or a portion thereof, which are outside of 46 km (25 nm) are analyzed in Alternatives 3 and 4.

4.7.1 No Action Alternative

Under the No Action Alternative, the SURTASS LFA sonar system would not be deployed. The No Action Alternative would fail to meet the U.S. need for improved capability in detecting quieter and harder-to-find foreign submarines at long range. Thus, U.S. forces would not have adequate time to react to, and defend against, potential submarine threats while maintaining a safe distance from a submarine's effective weapons range. The effects of the No Action Alternative are those effects, going forward, that can be expected if the proposed project is not implemented. Given that the primary detection method for quiet diesel submarines, particularly in the littorals, would still be active sonar, shorter-range tactical sonars would need to compensate for the loss of long-range detection capability afforded by SURTASS LFA sonar. Any attempt to achieve a near-comparable level of security for U.S. and allied ships and the personnel who man them, would require a greater number of tactical sonars (deployed from ships and aircraft). In some cases, this greater number could be somewhat reduced by having the tactical sonar ships and aircraft spend more time at sea (i.e., above standard deployment schedule). However, in all cases the number of ships/aircraft and sonars would be greater than the number of SURTASS LFA sonars required. This, in turn could lead to increased underwater noise, both spatially and temporally, albeit in a different frequency regime (i.e., MF vice LF), so that relevant impacts on marine species could be different. In addition, there would be an increase in fuel consumption and expenditure of energy resources associated with additional ships or increased time at sea, most likely accompanied by an increase of petroleum by-product pollution, and solid and liquid wastes. Thus, there would be environmental impacts resulting from implementation of this alternative.

4.7.2 Alternative 1

Alternative 1 is the same as Alternative 1 of the FOEIS/EIS. This alternative proposes the employment of SURTASS LFA sonar technology with geographical restrictions to include maintaining sound pressure level below 180 dB RL within 22 km (12 nm) of any coastline and within the originally designated OBIAs (see Table 2-3 of the FOEIS/EIS) that are outside of 22 km (12 nm). Restrictions for OBIAs are year-round or seasonal, as dictated by marine animal abundances. SURTASS LFA sonar sound fields will not exceed 145 dB RL within known recreational and commercial dive sites. Monitoring mitigation includes visual, passive acoustic, and active acoustic (HF/M3 sonar) to prevent injury to marine animals when employing SURTASS LFA sonar by providing methods to detect these animals within the LFA mitigation zone.

4.7.3 Alternative 2 (the preferred alternative)

Alternative 2 is the Navy's preferred alternative. It is the same as Alternative 1, but with additional OBIAs, including seasonal restrictions as listed in Table 2-4.

4.7.4 Alternative 3

Alternative 3 is the same as Alternative 1, but with a greater coastal standoff distance. This alternative proposes the employment of SURTASS LFA sonar technology with geographical restrictions to include maintaining sound pressure levels to below 180 dB RL within 46 km (25 nm) of any coastline and within designated OBIAs that are outside of 46 km (25 nm).

4.7.5 Alternative 4

Alternative 4 is the same as Alternative 1, but with additional OBIAs, extended coastal standoff distance to 46 km (25 nm), and shutdown procedures for schools of fish.

4.7.6 Analysis of Alternatives

This subchapter analyses the above alternatives. The additional criteria that are analyzed here are additional OBIAs, shutdown procedures for fish schools, and increasing the coastal standoff from 22 km (12 nm) to 46 km (25 nm).

Offshore Biologically Important Areas (OBIAs)

The Navy has addressed the Court-defined deficiency regarding additional OBIAs via inclusion in its preferred alternative, Alternative 2. The additional OBIAs presented in Table 2-4 reflect a thorough review of potential areas where SURTASS LFA sonar may be restricted from operating without significantly impacting the Navy's required ASW readiness and training evolutions.

Shutdown procedures for schools of fish

The possibility of modifying the current SURTASS LFA shutdown protocols to include schools of fish is dealt with in Subchapter 2.5.2.2. In summary, it is infeasible and impractical to apply such a mitigation procedure in the context of military readiness and training. Furthermore, recent results from fish controlled exposure experiments (CEEs) indicate that the opportunity for a fish or a school of fish to be exposed to sound pressure levels from SURTASS LFA sonar transmissions that could cause harm is negligible (see Subchapter 4.1.1.6).

Generic Analytical Methodology for Coastal Standoff Range Comparison

Increasing the coastal standoff by 24 km (13 nm) would be more significant in terms of differences in potential impacts to meeting the Navy's stated purpose and need versus potential impacts to the marine environment. Analyses in the FOEIS/EIS and this SEIS support the argument that the highest potential for impact from SURTASS LFA sonar operations is to marine mammals. Accompanying Table 4.7-2 below is a generic analytical methodology to determine the difference in potential impact to marine animals (including fish, sharks, and sea turtles, but particularly for marine mammals) between a 22 km (12 nm) and a 46 km (25 nm) coastal standoff for SURTASS LFA sonar operations.

The methodology used to assess the change in potential impacts to marine animals was designed to utilize several sets of simplified assumptions in order to determine a relative trend in these potential impacts for a variety of oceanic and biological conditions. This approach allows one to assess the trends without the extensive process of modeling all of the conditions that exist.

The first assumption is that the propagation loss from the source is spherical (i.e., 20 Log(range)) for the first 1,000 m (0.54 nm), and cylindrical (i.e., 10 Log(range)) beyond that, regardless of bathymetry or propagation mode. Generally, the spherical spreading assumption is correct and even conservative for water greater than 1,000 m (3,281 ft) deep. For shallower waters, the additional losses due to bottom interactions tend to compensate for the slight overestimation of the spreading loss. The fact that no absorption, volume scattering, or boundary losses are included in this assumption also makes it more conservative. Finally, the likelihood that a surface duct or a convergence zone could negate this propagation assumption is unlikely because if the propagation loss has been slightly underestimated for a specific case, the same conditions will apply to both coastal standoff cases (22 km [12 nm] vs. 46 km [25 nm]). This would have the effect of increasing the representative zone of influence (ZOI) annuluses[12] shown in Figure 4.7-1 and increasing the final percentages in Table 4.7-7. It should be noted that the annulus is the area within and between two ZOIs.

[12] The annulus is the horizontal one-dimensional area delineated by two concentric circles representing two different levels of RL (in dB).

Table 4.7-2. Analytical methodology for comparing potential for impacts on marine animals between 22 km (12 nm) and 46 km (25 nm) coastal standoff ranges.

Step	Action	Reference	Product/Result
1	Determine which SPE values to go forward with for comparing 22 km (12 nm) vs. 46 km (25 nm) standoff range.	FOEIS/EIS Subchap 4.2.3: Definition of Biological Risk and Determination of Risk Function. Fig 4.2-2b: Single Ping Equivalent Risk Function.	FOEIS/EIS analyses indicate 155-180 dB SEL should be addressed; 6 SELs chosen: 155-160, 160-165, 165-170, 170-175, 175-180 and >180 dB.
2	For each of the 6 SPE values determine a ZOI radius, based on average SURTASS LFA sonar operating conditions.	FOEIS/EIS Subchap. 4.2.6: Sample Model Run. Fig 4.2-3: SURTASS LFA sonar Risk Analysis Flowchart.	TL spherical to 1 km, cylindrical beyond 1 km.
3	Assume 3 coastal shelf cases where SURTASS LFA sonar operations could occur: 1. Shelf Case A 2. Shelf Case B 3. Shelf Case C	FOEIS/EIS Subchap 3.1.2.1: Geology and Bottom Topography. Table 3.1-3: Generalized Summary of Oceanic Regimes. Subchap 3.1.3.2: Shallow Water Bottom Interaction.	Shelf Case A: Within 5 nm of coast (e.g., Hawaii) Shelf Case B: Within 5-20 nm of coast (e.g., Charleston) Shelf Case C: ≥ 20 nm off coast (e.g., Jacksonville, East China Sea)
4	Assume 3 generic biology (i.e., marine mammal) types that SURTASS LFA sonar operations could affect. 1. Shelf Species: Biology Type 1 2. Shelf Break Species: Biology Type 2 3. Pelagic Species: Biology Type 3	SEIS Subchap 3.2.4: Cetaceans (Mysticetes). Table 3.2-3: Information Summary for Mysticetes. Subchap 3.2.5: Cetaceans (Odontocetes). Table 3.2-4: Information Summary for Odontocetes. Subchap 3.2.6: Pinnipeds (Sea Lions, Fur Seals, and Hair Seals). Table 3.2-5: Information Summary for Otariids. Table 3.2-6: Information Summary for Phocids.	1. Shelf species: assume species in this category have abundances/densities ≥ 2x same species' abundances/ densities at shelf break, and beyond in deep water. 2. Shelf break species: assume species in this category have abundances/ densities in vicinity of shelf break ≥ 2x that on shelf and in deep water. 3. Pelagic species: assume species in this category have abundances/densities beyond the shelf break in deep water ≥ 2x that in vicinity of shelf break.
5	For the two cases (12 vs. 25 nm coastal standoff), determine ZOI annulus areas and correct for risk areas: e.g., for 12 nm case, 180 dB annulus will be beyond 12 nm, but the lower RL ZOIs (160-175 dB) will be inside 12 nm and some will be truncated by shallow water/land.	N/A	1. Table for 12 nm coastal standoff case. 2. Table for 25 nm coastal standoff case.
6	For each shelf case and biology type, integrate corrected risk areas to provide: 1. Potential impacts to marine animals for 3 shelf cases vs. 3 biology types; for 12 nm coastal standoff case. 2. Potential impacts to marine animals for 3 shelf cases vs. 3 biology types; for 25 nm coastal standoff case.	N/A	1. Table for 12 nm coastal standoff case. 2. Table for 25 nm coastal standoff case. Note: See Subchapter 4.7.6.1 for a detailed methodology.

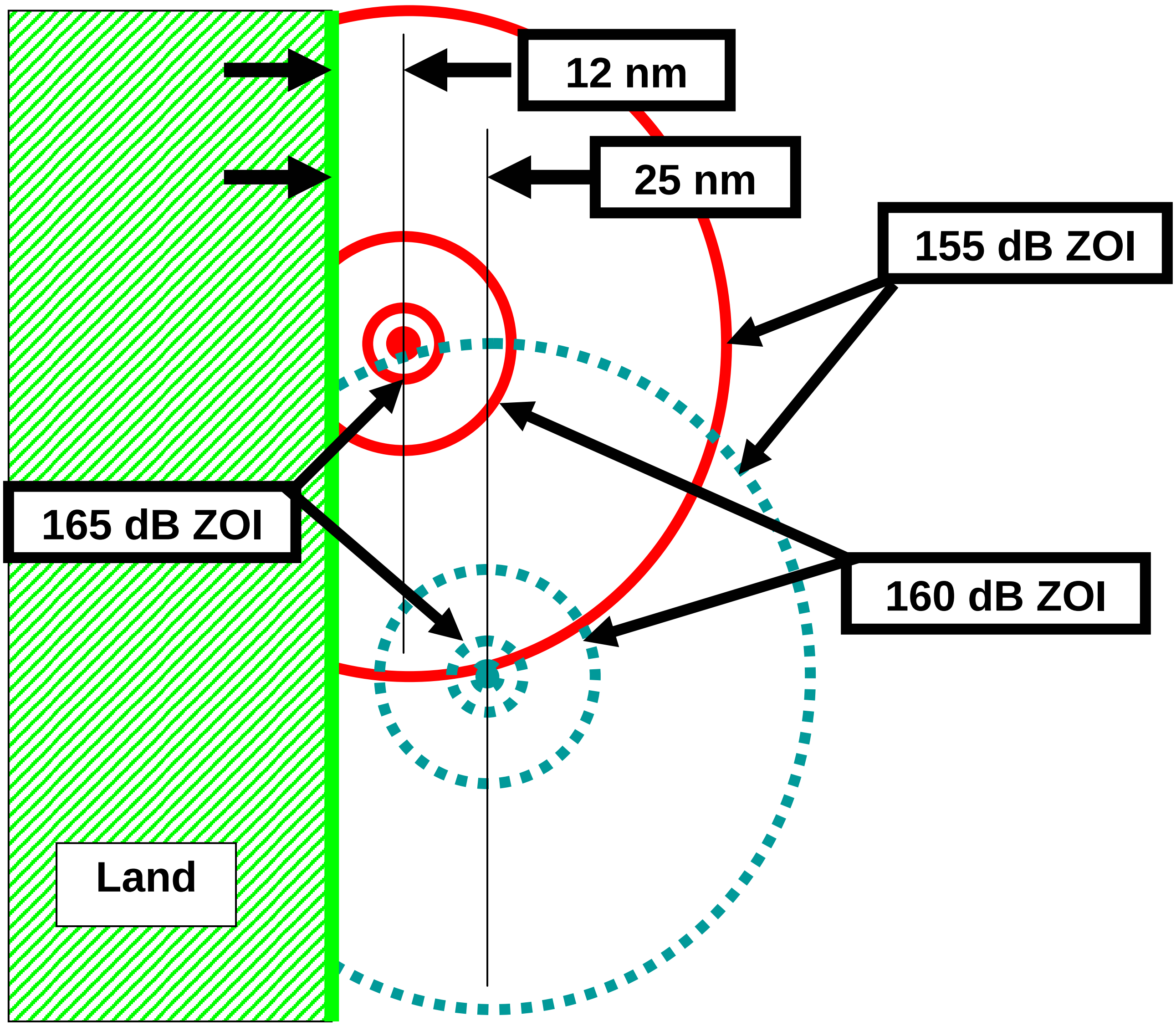


Figure 4.7-1. 12 nm (solid line) versus 25 nm (dotted line) standoff distance from the coast (dB values are SELs).

Tables 4.7-3 and 4.7-4 provide several of the descriptive quantities for each of the ZOI annuluses identified. These annuluses correspond to an approximate area in which an animal receives a single ping equivalent (SPE[13]) exposure to an underwater acoustic signal. Thus, an animal in the outer-most annulus receives an SPE between 155 and 160 dB SEL. For this annulus, the SPE Risk Function curve (FOEIS/EIS Figure 4.2-2B) is used to determine that the SPE risk runs from 0.9 (or 9.0 percent) (for an SPE of 155 dB SEL) to 0.27 (or 27.0 percent) (for an SPE of 160 dB SEL). Moreover, this annulus has been assessed an average risk of 0.18 (or 18.0 percent) (e.g., {(9+27)/2} =18), as shown in Tables 4.7-3 and 4.7-4. These tables also show the area of each annulus that is in the water. When the water area is multiplied by the average risk for that annulus the result is the "corrected risk area," which is also provided in these tables. Once the relative densities of marine animals are qualitatively established and normalized, the corrected risk areas can be multiplied by those densities to determine the "relative risk" in each annulus, and the total relative risk for each source placement (i.e., 22 km [12 nm] vs. 46 km [25 nm] coastal standoff ranges).

Table 4.7-3. ZOI annulus vs. corrected risk area for 22 km (12 nm) coastal standoff case.

ZOI Annulus (SEL)	Water Area (km^2)	Average Risk	Corrected Risk Area
> 180 dB	0.3	100.0	0.3
180-175 dB	2.8	91.5	2.6
175-170 dB	28.3	80.5	22.8
170-165 dB	282.7	61.5	173.9
165-160 dB	2601.2	38.5	1001.5
160-155 dB	17530.1	18.0	3155.4

Table 4.7-4. ZOI annulus vs. corrected risk area for 46 km (25 nm) coastal standoff case.

ZOI Annulus (SEL)	Water Area (km^2)	Average Risk	Corrected Risk Area
> 180 dB	0.3	100.0	0.3
180-175 dB	2.8	91.5	2.6
175-170 dB	28.3	80.5	22.8
170-165 dB	282.7	61.5	173.9
165-160 dB	2827.4	38.5	1088.6
160-155 dB	24033.2	18.0	4326.0

[13] SPE (single ping equivalent) is the methodology used during the acoustic modeling of potential impacts to marine animals from exposure to LF sound. This method estimates the total exposure of each individually modeled animal, which was exposed to multiple sonar pings over an extended period of time. This was accomplished by the summation of the intensities for all received pings into an equivalent exposure from one ping, which is always at a higher level than the highest individual ping received, and is expressed in SEL units (dB re 1 μPa^2-s).

To qualitatively determine relative marine animal densities, two generic quantities need to be identified and approximated. The first of these is the relative width of the continental shelf for possible cases. For this analysis, the shelf is assumed to end at the shelf break, which is defined here as the 200 m (656 ft) bathymetric curve. For simplicity, three shelf cases have been identified. They are:

- Shelf Case A, a narrow shelf; ending at the shelf break within 9.3 km (5 nm) from the coast; a nominal 5 nm shelf break is used in this analysis;
- Shelf Case B, a medium-width shelf, ending at the shelf break within 9.3-37 km (5-20 nm) from the coast; a nominal 28 km (15 nm) shelf break is used in this analysis; and
- Shelf Case C, a wide shelf, ending at the shelf break beyond 37 km (20 nm) from the coast; a nominal 148 km (80 nm) shelf break is used in this analysis.

Figure 4.7-2 graphically represents Shelf Cases A, B and C. Additionally, for simplicity, the shelf slope (i.e., the region from the shelf break to the deep abyssal plane) is assumed to be half as wide as the continental shelf.

The remaining input to qualitatively estimate relative marine animal densities for this analysis is to identify potential bathymetric-based animal behavior and assign relative animal densities for that type of behavior. For the purposes of this analysis, three generic behavior types were identified and used. They are:

- Biology type 1, a shelf species whose habitat is predominantly on the shelf, but may have a lesser density on the continental slope area;
- Biology type 2, a continental shelf break or slope species whose habitat is predominantly in proximity of the shelf break and/or on the slope, but may have a lesser density on half the continental shelf area or the deep water areas adjacent to the slope; and
- Biology type 3, a pelagic species whose habitat is predominantly in deep water, but may have a lesser density on the continental slope area.

Figure 4.7-3 graphically portrays each of the normalized marine animal density regions. Note that in each case the primary location for that species type was assessed a normalized density of 1.0[14] at its primary site, where the majority of animals are expected to be (e.g., Biology type 1, shelf species, have a density of 1.0 on the shelf, etc.), 0.5 (i.e., 0.5 animal/sq km) at secondary areas and 0.0 (i.e., no animals) in all other areas, where the fewest animals are expected to be.

[14] i.e., 1.0 animal/sq km or approximately 4 animals/sq nm, which is an unrealistic animal density but the 1.0 value is optimal for subsequent mathematical calculations

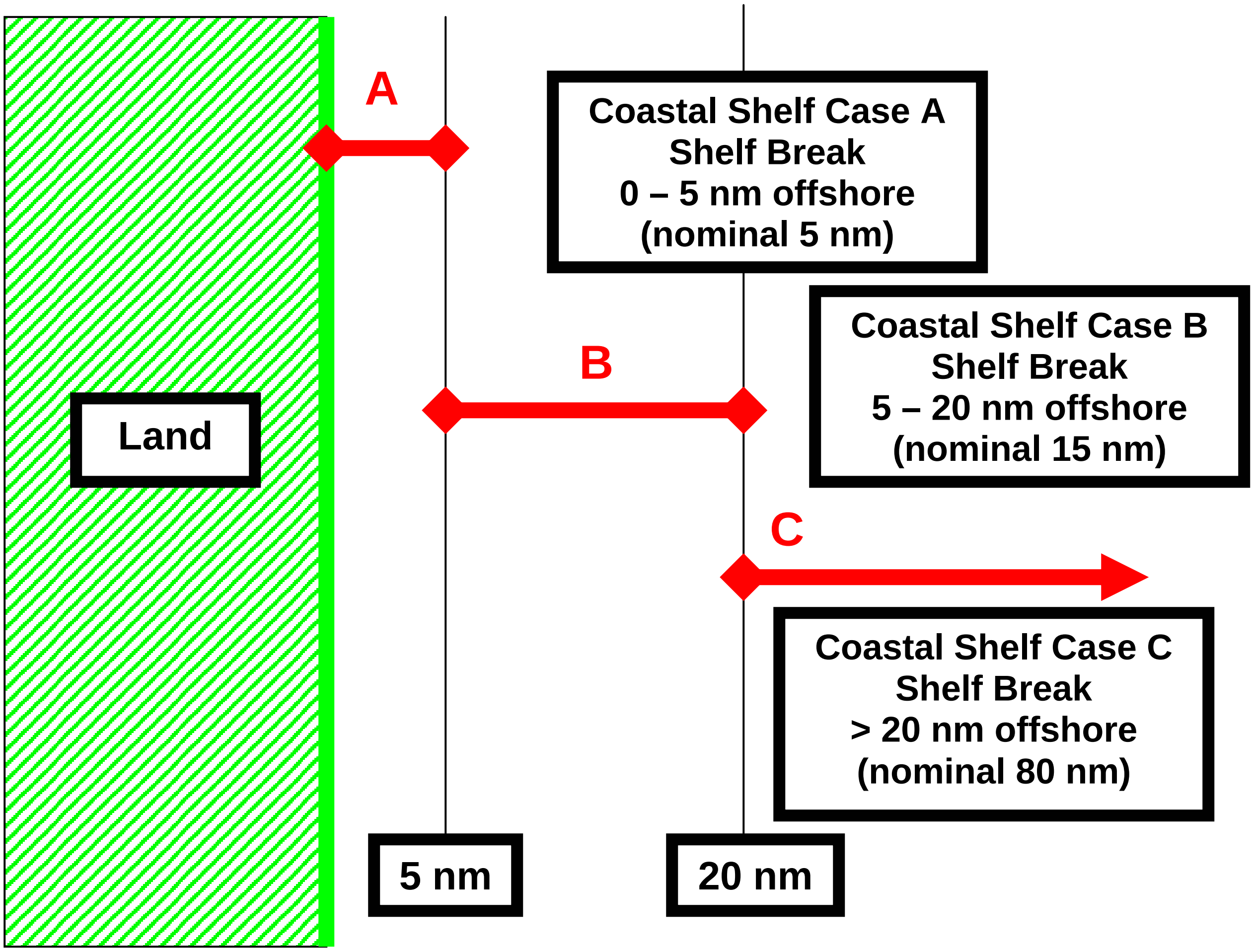


Figure 4.7-2. Coastal Shelf Cases.

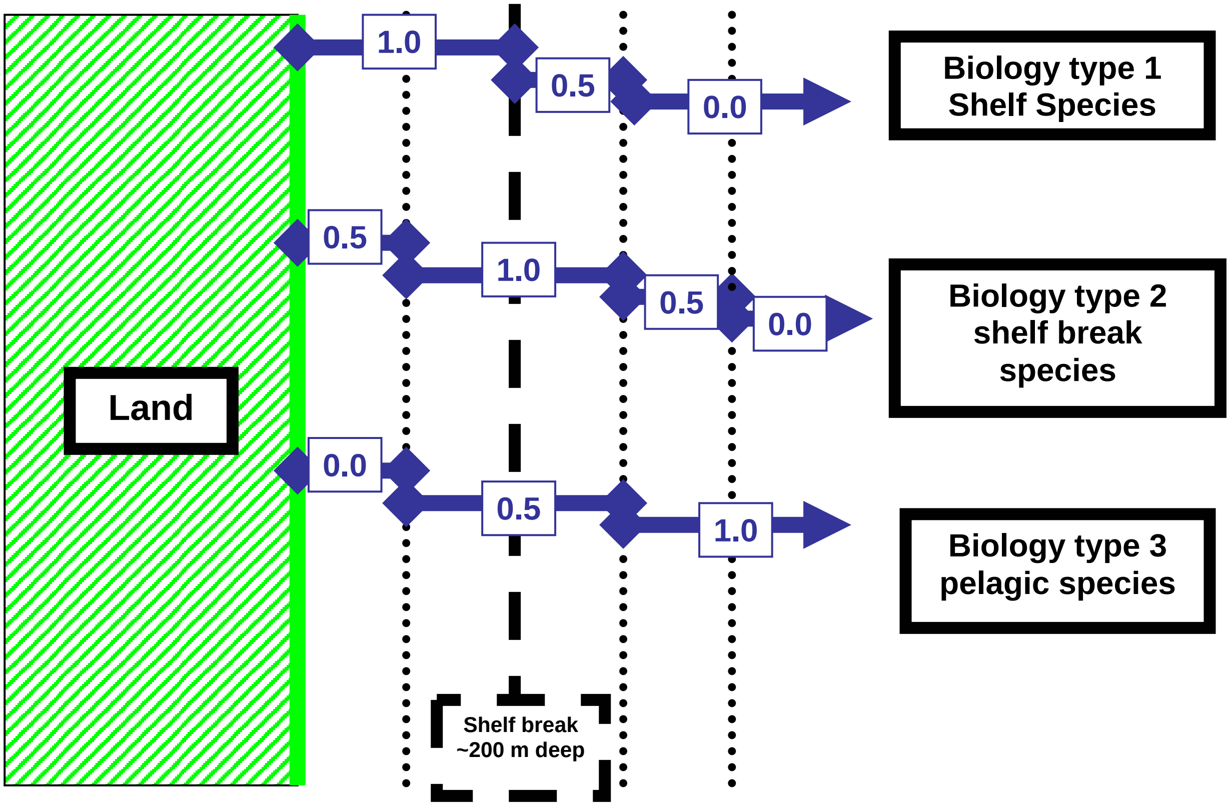


Figure 4.7-3. Normalized density regions for assumed biologic types.

For each of the nine possible combinations of shelf case vs. biology type, the normalized densities of marine animals in each of the six ZOI annuluses can now be identified for each coastal standoff range (22 km [12 nm] vs. 46 km [25 nm]):

a. The percentage of each annulus's area that overlays each normalized density region was determined and multiplied by the appropriate normalized density to get the "relative density";
b. Then for each annulus, the "corrected risk area" of each of the six annuluses (see Tables 4.7-3 and 4) was multiplied by the "relative density" to determine the "relative risk" for each of the six annuluses;
c. The six annulus values were then summed for each of the nine possible combinations of shelf case vs. biology type (see Tables 4.7-5 and 6) for each coastal standoff range option (this summation produces the large relative values in those tables); and
d. The percentage change of the 46 km (25 nm) standoff option over that of the 22 km (12 nm) standoff option is provided in Table 4.7-7.

Table 4.7-5. Total relative risk (corrected risk area multiplied by normalized densities) for 3 shelf cases and 3 biology types; for 22 km (12 nm) coastal standoff case.

		Shelf Case (shelf break range from coast)		
		Within 5 nm (A)	**Within 5-20 nm (B)**	**> 20 nm (C)**
Biology type	**Shelf Species (1)**	762	2,117	4,041
	Shelf Break Species (2)	929	2,224	2,992
	Pelagic Species (3)	3,565	2,687	631

Table 4.7-6. Total relative risk (corrected risk area multiplied by normalized densities) for 3 shelf cases and 3 biology types; for 46 km (25 nm) coastal standoff case.

		Shelf Case (shelf break range from coast)		
		Within 5 nm (A)	**Within 5-20 nm (B)**	**> 20 nm (C)**
Biology type	**Shelf Species (1)**	508	2,118	4,100
	Shelf Break Species (2)	1,146	2,618	4,390
	Pelagic Species (3)	5,165	4,075	1,461

Table 4.7-7. Percent Change in Estimated Risk for the 46 km (25 nm) coastal standoff case (Alternatives 3 and 4, Table 4.7-6) versus the 22 km (12 nm) coastal standoff case (Alternatives 1 and 2, Table 4.7-5).

		Shelf Case (shelf break range from coast)		
		Within 5 nm (A)	**Within 5-20 nm (B)**	**> 20 nm (C)**
Biology type	**Shelf Species (1)**	-33.3 percent	0.1 percent	1.5 percent
	Shelf Break Species (2)	23.4 percent	17.7 percent	46.7 percent
	Pelagic Species (3)	44.9 percent	51.7 percent	131.5 percent

Coastal Standoff Range Comparison Results

Under Alternatives 3 and 4, additional geographical restrictions would be levied on SURTASS LFA sonar operations through the increase in the coastal standoff range from 22 km (12 nm) to 46 km (25 nm). Tables 4.7-5 and 4.7-6 indicate that this change in geographical restrictions only decreases the potential impacts in one out of nine cases, while increasing the potential impacts in six out of nine cases. Thus, for example, increasing the coastal standoff range from 22 km (12 nm) to 46 km (25 nm) decreases the potential impacts to shelf species (Biology type 1) within 9.3 km (5 nm) of the coastline (Shelf Case A) by about 33 percent, but increases potential impacts for all other combinations of Shelf Case and Biology types. This is most apparent for Shelf Case C with Biology type 2, and all Shelf Cases with Biology type 3. These results are summarized in Table 4.7-7. Based on the analysis of the risk areas and the potential impacts to marine animals, increasing the coastal standoff range does decrease exposure to higher received levels for the concentrations of marine animals closest to shore (shelf species [1]); but does so at the expense of increasing exposure levels for shelf break species (2) and pelagic species (3).

4.7.7 Conclusions

The following conclusions are supported by the analyses addressing the operations of up to four SURTASS LFA sonar systems in the FOEIS/EIS, which is incorporated by reference herein; and the supplementary analyses undertaken in this SEIS, which also encompass the at-sea operations of up to four systems.

No Action Alternative

In summary, the No Action Alternative would avoid all environmental effects of employment of SURTASS LFA sonar. It does not, however, support the Navy's stated priority ASW need for long-range underwater threat detection. The implementation of this alternative would allow potentially hostile submarines to clandestinely threaten U.S. Fleet units and land-based targets. Without this long-range surveillance capability, the reaction times to enemy submarines would be greatly reduced and the effectiveness of close-in, tactical systems to neutralize threats would be seriously, if not fatally, compromised.

Alternative 1

Under Alternative 1, as was concluded in the FOEIS/EIS the potential impact on any stock of marine mammals from injury is considered to be negligible, and the effect on the stock of any marine mammal from significant change in a biologically important behavior is considered to be minimal. Any momentary behavioral responses and possible indirect impacts to marine mammals due to potential impacts on prey species are considered not to be biologically significant effects. Any auditory masking in mysticetes, odontocetes, or pinnipeds is not expected to be severe and would be temporary. Further, the potential impact on any stock of fish, sharks or sea turtles from injury is also considered to be negligible, and the effect on the stock of any fish, sharks or sea turtles from significant change in a biologically important behavior is considered to be negligible to minimal. Any auditory masking in fish, sharks or sea turtles is expected to be of minimal significance and, if occurring, would be temporary.

Alternative 2 (the preferred alternative)

Under Alternative 2, additional geographical restrictions would be levied on SURTASS LFA sonar operations through the inclusion of more OBIAs. The general summary provided in the above paragraph for Alternative 1 would also apply to this alternative. Any change to the above conclusion would be to slightly decrease the potential for impacts to marine animals from SURTASS LFA sonar operations.

Alternative 3

Under Alternative 3, additional geographical restrictions would be levied on SURTASS LFA sonar operations through the increase in the coastal standoff range from 22 km (12 nm) to 46 km (25 nm). The general summary provided in the above paragraph for Alternative 1 would also apply to this alternative. Based on the analysis of the risk areas and the potential impacts to marine animals, increasing the coastal standoff range does decrease exposure to higher received levels for the concentrations of marine animals closest to shore (shelf species [1]); but does so at the expense of increasing exposure levels for shelf break species (2) and pelagic species (3). The "Coastal Standoff Range Comparison Results" paragraph above discusses this further.

Alternative 4

Under Alternative 4, the additional geographical restrictions of both Alternative 2 (additional OBIAs) and Alternative 3 (increase in coastal standoff range from 22 km [12 nm] to 46 km [25 nm]), plus shutdown procedures for schools of fish would be combined. The general summary provided for Alternative 1 above also applies here, as do the results from Alternative 2 regarding additional OBIAs and Alternative 3 regarding the increased standoff range.

Results Summary

It is important to note that the results of the analysis of Alternative 3, as well as Alternative 4, may at first appear counter-intuitive. The analysis shows that overall there is a greater risk of potential impacts to marine animals with the increase of the coastal standoff distance from 22 km (12 nm) to 46 km (25 nm). This is due to an increase in affected area, as shown in Figure 4.7-1, with less of the ensonified annuluses overlapping land for the 46 km (25 nm) standoff distance than for the 22 km (12 nm) standoff distance. Essentially, by locating the array in waters further from land, nominally the same animal density regions are typically ensonified, but more water area is affected. This is true for all of the examined test cases, except for the shelf area closest to shore (the 5 nm-wide Shelf Case A) with a shelf species (Biology type 1). In this case, the act of moving the source further offshore lowers the received level (i.e., lowers the average risk by placing a lower risk annulus over the shelf) and therefore lowers the potential impact on the shelf where the highest animal densities are, thus lowering the overall impact. Therefore, this does decrease exposure to higher received levels for the concentrations of marine animals closest to shore (shelf species [1]); but does so at the expense of increasing exposure levels for shelf break species (2) and pelagic species (3). It should be emphasized that even though Table 4.7-8 portrays some large percent differences between the 22 km (12 nm) and 46 km (25 nm) coastal standoff ranges, no injury (MMPA Level A harassment) is expected and all potential biologically significant behavioral impacts remain minimal, if not negligible.

Table 4.7-8 provides a qualitative estimate of the ability of each alternative to meet the Navy's purpose and need. Alternative 2 (additional OBIAs) would be expected to decrease to some extent the littoral areas where SURTASS LFA sonar could operate outside of 22 km (12 nm); thus the detection of threats in the littorals and training in the littorals would remain high but may be slightly degraded compared to Alternative 1. Alternatives 3 and 4, the expansion of the coastal standoff range from 22 km (12 nm) to 46 km (25 nm), and the expansion of the coastal standoff range with the additional OBIAs would be expected to impose the greatest impact on meeting the Navy's purpose and need, and military readiness, as a much larger portion of the littorals would be restricted from the conduct of SURTASS LFA sonar operations.

Table 4.7-8. Estimate of ability to meet the Navy's Purpose and Need/Military Readiness/Training for Alternatives 1 through 4.

	Detection of threats in open ocean	Detection of threats in littorals	Training in open ocean	Training in littorals
No Action Alternative	N/A	N/A	N/A	N/A
Alternative 1	H	H	H	H
Alternative 2	H	H	H	H
Alternative 3	H	M/H	H	M/H
Alternative 4	H	M/H	H	M/H

N/A = Does not meet/not applicable
M = Medium level
L = Low level
H = High level

Given the results from the alternatives analysis presented above and Table 4.7-8, the Navy's preferred alternative is Alternative 2.

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