Proceedings of the Institute of Acoustics

U.S. NAVY SURVEILLANCE TOWED ARRAY SENSOR SYSTEM LOW FREQUENCY ACTIVE (SURTASS LFA)—PROTECTING THE MARINE ENVIRONMENT IN SYSTEM DEPLOYMENT

J. S. Johnson (1), C. H. Spikes (2)

(1) U.S. Space and Naval Warfare Systems Command, San Diego, CA., USA
(2) Marine Acoustics, Inc., Ballston Metro Center, 901 N. Stuart St., Arlington, Virginia, USA

1. INTRODUCTION

Passive sonar systems are becoming less and less effective in detecting modern diesel-electric and ultra-quiet nuclear submarines, particularly as the focus of worldwide naval operations shifts from the deep ocean to the relatively noisier littoral regions. Active low frequency (LF, < 1 kHz) sonars, however, under the right sound propagation conditions, can detect even the quietest underwater targets at extended ranges. High sound pressure level LF underwater sound can potentially affect the marine environment, in particular creatures such as baleen whales, that are known to vocalize in the LF range. The U.S. Navy is studying the potential environmental impacts associated with SURTASS LFA transmissions. This paper will review the Navy's efforts to address the many issues presented in this endeavor.

2. BACKGROUND

System Description

SURTASS LFA hardware consists of a vertical line array (VLA) of acoustic transducers suspended an average of 100 m beneath the host ship, which travels at a maximum of 3-4 kts. This VLA transmits waveforms (100-500 Hz) which are much longer than other active systems. Echoes reflected off targets are detected on passive towed horizontal line arrays (HLA), and processed and evaluated to identify and classify them. The Navy is considering whether to transition the system from a test and evaluation status to the fleet for operational employment. At present, there is only one SURTASS LFA system. Additional systems may be procured if a decision is made to operationally deploy the system.

Legal Requirements

In July 1996, the Navy announced its intent to prepare an environmental impact statement (EIS) in connection with its proposal to operationally deploy the SURTASS LFA system. The EIS will examine the potential effects of SURTASS LFA on the marine environment, both within and beyond the U.S. territorial sea. The EIS will thus satisfy the requirements of the National Environmental Policy Act (NEPA), which applies within areas of U.S. sovereignty, and Executive Order (E.O.) 12114, which mandates certain environmental analysis in areas beyond U.S. territory.

In addition to conducting the NEPA /E.O. 12114 analysis, the Navy must also address other requirements in connection with the SURTASS LFA system. The U.S. Endangered Species Act (ESA) protects designated endangered and threatened species of plants and animals within U.S. territory and on the high seas. Unapproved "takes" of protected

species, which can involve even relatively minor disturbance, are prohibited. The Marine Mammal Protection Act (MMPA) affords similar protection to all marine mammal species. Under the Coastal Zone Management Act (CZMA), the Navy's actions must be consistent, to the maximum extent practicable, with certain coastal zone requirements promulgated by states of the United States. In the interests of efficiency, the focused requirements of the ESA, MMPA, CZMA and certain other U.S. statutes are generally addressed concurrently in connection with the ecosystem-wide analysis that is required under NEPA and E.O. 12114.

Inherent in all of these U.S. environmental requirements is the notion that, consistent with information security requirements, federal and state regulatory agencies and the interested public may participate in federal agency decision-making that affects the environment. As described below, this has prompted the Navy to conduct extensive public outreach in the preparation of the SURTASS LFA EIS.

In developing information for the EIS, the Navy is conducting a low frequency sound scientific research program (LFS SRP), under the aegis of some of the country's preeminent marine biologists, acousticians and bioacousticians. The keystone of the SRP is the use of the Navy's SURTASS LFA system on the research vessel (R/V) *Cory Chouest* (Figure 1) as a scientific tool to collect much-needed data on the potential effects of LFS on the marine environment. The Navy is also conducting studies on the potential effects of LFS on human divers, under the auspices of the prominent U.S. Navy Submarine Medical Research Laboratory. The EIS will integrate the findings from these two research efforts, and other relevant data. The EIS should be available in draft form in 1998.

3. CHALLENGES IN PREPARING THE EIS

Public Perception

Underwater acoustics is a relatively foreign subject for the general public who, for the most part, are only familiar with hearing sounds in air, through human ears. Marine animals can detect sound in the water by hearing them but also by other means. Given this, and the fact that sounds behave differently in water than in air, comparisons between marine animal and human perception of underwater sound is extraordinarily complex, and generally beyond the ken of most laymen. Nonetheless, most people interested in the potential effects of LFS on the marine environment naturally attempt such comparison and, in so doing, form a subjective impression of the sound that the SURTASS LFA source would make. What is extremely difficult to explain and portray to the public is how sound intensity changes logarithmically. In spite of using understandable terminology such as 10 dB = ten-fold increase; 20 dB = 100-fold increase; and 30 dB = 1000-fold increase, they still find it difficult to comprehend that at only 30 meters away from the source, the sound has decreased 1000-fold. Add to this the fact that the decibel value for sound in water is 61.5 dB higher than for an airborne sound with equivalent power levels, and you can see how the public can become confused. Waltner [1] notes that the fundamental scientific error of direct comparisons of air-standard and water-standard decibel figures has spawned much controversy, even though the scales are as different as the Fahrenheit and Celsius temperature scales. Failure to apply the 61.5 dB correction factor corresponds to a million-fold difference in assumed power levels.

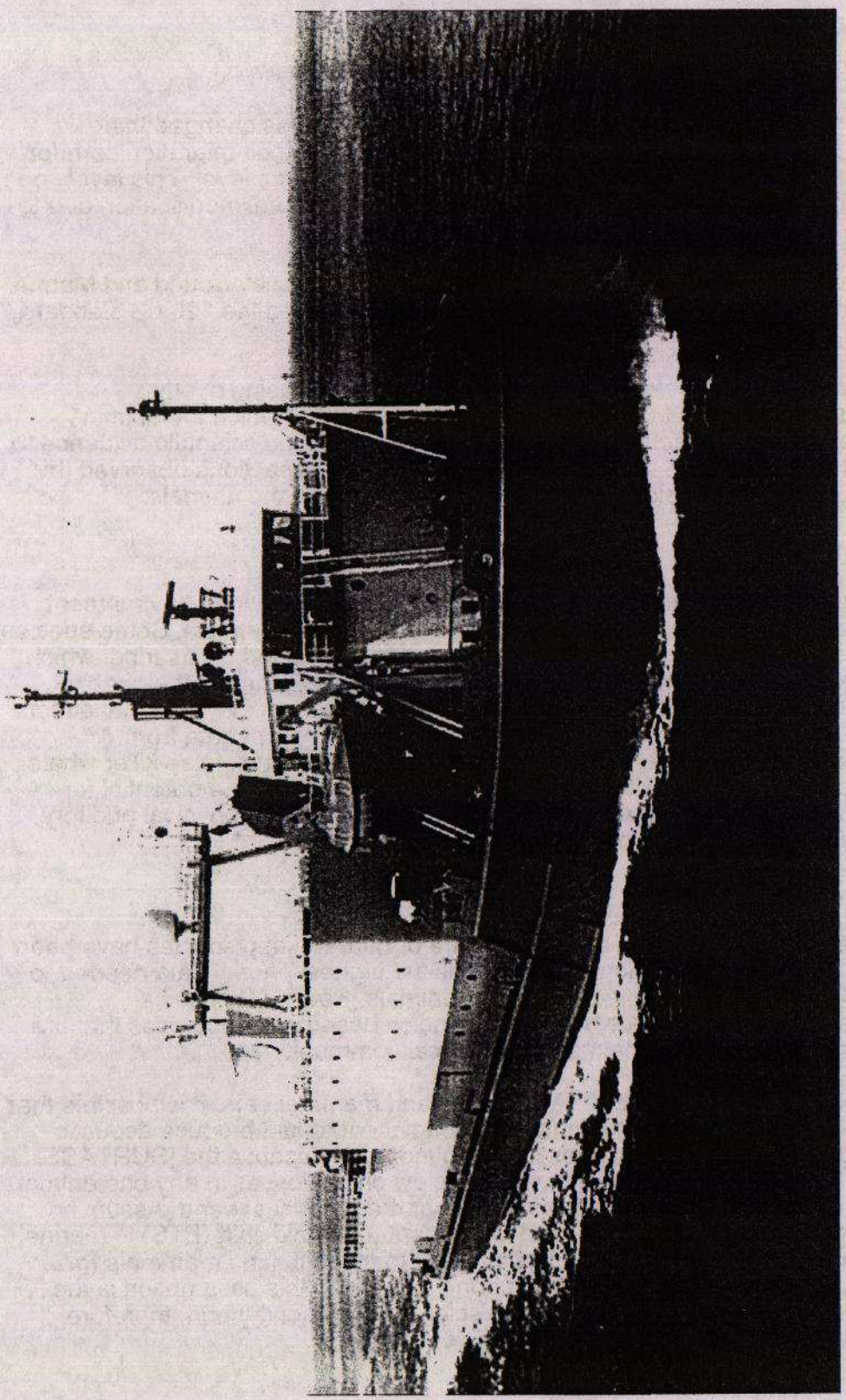

Figure 1. R/V *Cory Chouest*

In a 1983 test, Malme et al. [2] observed that 50% of the gray whales changed their migration track around a stationary vessel located in the middle of their migration corridor when a LFS source over the side transmitted sound at 120 dB source level. This level soon became the benchmark that environmental groups used for behavioral modification due to underwater LFS.

In 1994, the National Research Council in its report on "Low Frequency Sound and Marine Mammals—Current Knowledge and Research Needs" [3] questioned the 120 dB standard, stating:

> ...the data from which the 120 dB criterion was derived are being overly extrapolated. It is possible that this level is simply the one at which the animals detected the presence of sound. If this is true, then there is no scientific evidence to indicate that the relatively minor and short-term behavioral reactions observed [by Malme et al.] indicate any significant or long-term effects on the animals.

Species Potentially Affected

High underwater sound levels can potentially cause impacts on the marine environment, either by affecting animals' hearing or by causing other physiological effects. Some species of marine mammals, particularly mysticetes, are believed to have good LF hearing, which suggests that active sonar systems in the LF band could potentially impact their habitat. However, it is particularly difficult to study large whales in the wild, so that potential effects must be inferred in most cases from available data. Conversely, recent data from underwater audiometric measurements with smaller cetaceans (dolphin, false killer whale, beluga whale) indicate minimal sensitivity to LF sound. In most cases, the potential for affecting marine animals can be broken down into three categories: 1) physical auditory effects; 2) masking effects; and 3) cumulative effects.

Lack of Threshold Data

LF auditory thresholds of baleen whales and other rare or hard-to-keep species have been identified time and again by marine bioacousticians as the highest priority data needed to realistically assess the potential for effects on these animals. Ketten [4] poses a methodology for estimating large whale hearing thresholds based on hypotheses that are becoming increasingly accepted by the marine biological community:

> Given the similarities of whale and seal ears to land mammal ears, it is possible that a relatively intense sound source (immediately adjacent) could produce acoustic trauma in some—but not all—species in the sound field. Because the [SURTASS LFA] signal has a narrow frequency band with slow onset, losses in any one animal are likely to be restricted to frequencies in or near the broadcast band. Assuming that temporary threshold shift (TTS) and permanent threshold shift (PTS) in marine mammals occur at intensity-duration limits similar to those in land mammals (given the lack of measured TTS/PTS data for marine mammals, this assumption is the starting point generally agreed upon by the scientific community) and, therefore,

that such noise trauma requires a signal greater than 80-100 dB over hearing threshold, this means that only those species capable of detecting signals below 1 kHz would need to have a hearing sensitivity below the range of 60-80 dB to be adversely affected by 160 dB signals, even with repeated exposures.

Ketten's findings do not appear to be inconsistent with the interim guidelines adopted by NMFS, and used in recent EAs, that mysticetes could possibly experience discomfort or a temporary elevation of their hearing threshold at frequencies below 1 kHz if exposed to sound levels above 160 dB. Based on Ketten's findings, to suffer TTS, a marine mammal must:

- Be capable of hearing signals below 1 kHz and have hearing sensitivity in the range of 60-80 dB for frequencies below 1 kHz (assuming that TTS would occur for received levels greater than 80-100 dB above absolute threshold, as for humans listening in air).
- Be located within the sound field greater than 160 dB, choose not to depart or be unable to move to an area of lower sound intensity; and/or be subjected to repeated exposures. In this regard, it is assumed that if an animal detected the sound, it could depart the area of high intensity sound (above 160 dB). All marine mammals have adequate swim speed to accomplish this: 3 knots or greater.

Probably the best opportunity for measuring hearing thresholds in large whales will occur from strandings of the animals. A baby gray whale was rescued from a Los Angeles, California beach in January, 1997 and taken to Sea World in San Diego. The SPAWAR Systems Center San Diego, formerly Naval Command Control and Ocean Surveillance Center, has a NMFS permit to conduct hearing experiments on live stranded whales and has been attempting to develop a viable protocol to take advantage of this rare opportunity.

Interaction with Regulatory Agencies

Research on the effects of LFS on protected species often involves minor "taking" of such species, and thus requires an ESA or MMPA authorization. The regulatory agency, in addition to considering the importance of the proposed research and the effect on the species, will also be sensitive to public perceptions concerning the proposed research. Merely addressing the scientific need for certain research in the permit application, without regard for public perception, may not be enough to win approval. It behooves the permit applicant to stay in the review and approval process loop. In some cases, in-person briefings to the appropriate regulatory agency staff members are useful, so that they fully understand the nature of the activity proposed, why the applicant believes there will be no impact on marine animals, and how the importance of the research can be most effectively conveyed to the public.
Other difficulties include the fact that existing federal and state regulations do not clearly establish permissible sound levels to which protected species may be exposed. Given this reality, and the relatively little consensus as to the potential effects of LFS on

marine species, each permit application necessarily involves an element of give and take negotiation in which the applicant, the regulator, and the interested public attempt to balance a host of potentially competing interests.

Worldwide Problem

The question of LFS impacts on the marine environment is by no means strictly a military issue. Every man-made sound source present in the oceans, including high energy seismic sound (HESS) used in oil exploration, commercial shipping, and pleasure craft (including jet skis), contributes to the ambient noise level, and could thus be affected by regulatory actions addressing ocean noise.

At a recent HESS workshop held in June, 1997, the expert panel prioritized the marine mammal species that need to be considered when scheduling seismic surveys, based on two factors: 1) the sensitivity of the marine mammal to sounds from air guns; 2) the level of endangerment of the marine mammal. Priority marine mammals are: blue, humpback, fin and gray whales. Second priority marine mammals are sperm whale, elephant seal, and other mysticetes. Third priority are other odontocetes and other pinnipeds.

Time and Money

The environmental processes, both federal and state require a significant expenditure of time and money. However, this commitment helps to ensure that the ultimate decision on important issues reflects consideration of all relevant data and points of view, in keeping with the democratic tradition of the U.S.

4. THE LFA ENVIRONMENTAL PROCESS--FROM INCEPTION TO TODAY

Initial at-sea tests of the LFA system, during the developmental years of the early 1990's, were carried out after test-specific environmental analyses were conducted under E.O. 12114. In late 1995 and early 1996, extensive discussions took place among the staffs of the Assistant Secretary of the Navy (Installations & Environment), the Chief of Naval Operations, the General Counsel of the Navy, the Space and Naval Warfare Systems Command (SPAWAR), the Office of Naval Research (ONR), various fleet commands, NMFS, and selected public environmental organizations, to identify environmental requirements associated with potential operational employment of the LFA system. It was agreed that the best course of action was to prepare a global EIS. The Navy's notice of intent to prepare the SURTASS LFA EIS was published in the Federal Register in July, 1996. Thereupon, public scoping meetings, to identify issues to be addressed in the EIS, were held in Norfolk, Virginia; San Diego, California; and Honolulu, Hawaii.

U.S. NAVY SURTASS - LFA PROTECTING THE MARINE ENVIRONMENT IN SYSTEM DEPLOYMENT

5. APPROACH

Outreach Efforts

In conjunction with preparation of the EIS, the Navy embarked on an extensive program of outreach to regulatory agencies and interested environmental interest groups. In addition to the public scoping meetings, in January 1997 the Navy held a public information briefing in Washington, D.C. As a result of that meeting, the Navy invited regulatory agencies and environmental interest groups to identify data gaps pertinent to LFS, and to make recommendations on how best to acquire the needed data. The LFS Scientific Research Program was the result. In May and October, 1997, the Navy held meetings on Phases I and II of the program, respectively. This is in addition to the public hearings for Phases I and II of the LFS SRP (see below) held by the California Coastal Commission in August and December, 1997. Thus, the Navy is aggressively seeking involvement federal and state governmental organizations that deal with environmental matters, the marine legal community, other academic and industrial marine science and technology activities, and a number of environmental interest groups, including:

- Natural Resources Defense Council
- Whale Conservation Institute
- Humane Society of the U.S.
- Cetacean Society International
- Friends of the Sea Otter
- League for Coastal Protection

Low Frequency Sound Scientific Research Program (LFS SRP)

In February, 1997, the CNO convened the SURTASS LFA Scientific Working Group Meeting #1, entitled "Potential Effects of LFS on the Marine Environment—Data Needs and Research Solutions." The purpose of the meeting was to provide a forum for scientific discourse among Navy and non-governmental organizations to address the underlying scientific issues needed to develop environmental compliance requirements for SURTASS LFA. The Navy used this meeting to initiate the search for scientific information in support of its ongoing development of a comprehensive EIS for employment of SURTASS LFA. The specific objectives of this meeting were:

- Identify scientific data gaps regarding auditory, other physiological and behavioral effects of LFS on all marine species potentially affected.
- With respect to knowledge gaps identified, delineate scientific research protocol that could be performed to fill the gaps.

The product of the meeting was a detailed listing of recommended research with high relevance to LFS environmental compliance issues. The topics were divided into general research that would not rely on using the SURTASS LFA system, and SURTASS-LFA related research. From the working group's recommendations the LFS SRP has been developed, which has the primary objective of assessing the potential effects of LFS on the behavior of marine mammals.

Specific goals are to assess the potential effects of LFS signals on the behavior,

vocalization and movement of total mysticete species within the areas of observation in the northeast Pacific Ocean. Three research phases have been planned:

- Phase I: Blue and fin whale behavioral response measurements; in the Southern California Bight, west of San Nicolas Island; during September-October, 1997.
- Phase II: Gray whale behavioral response measurements; off central California coast; during January, 1998.
- Phase III: Humpback and sperm whale behavioral response measurements; off the northwest coast of the Big Island, Hawaii; during February-April, 1998.

Controlled exposures of whales to LFS from the SURTASS LFA source is preceded by baseline visual and acoustic observations. Data collection is usually augmented by a second research vessel collecting visual, passive acoustic, and measured received sound level data. When feasible, fixed undersea hydrophone arrays and autonomous acoustic arrays (called "pop-ups") collect simultaneous data for post-test correlation and examination of any association of vocalizations and sound stimuli. In addition, an aerial survey platform can collect information on abundance, distribution and behavioral response; and a smaller vessel with high frequency sonar may be used to periodically map the distribution of the whales' primary prey species in the area. The LFS SRP employs applicable mitigation measures during all scientific operations (see below).

Human Diver Studies

Because the LFA system may be operated in coastal areas where there exists potential for human diver exposure to some level of LFS, the EIS will address the potential effects of LFS on recreational divers. The Navy Submarine Medical Research Laboratory is coordinating various Navy and academic institution research efforts, some of which involve in-water testing of human subjects. These studies were planned with the assistance of the Divers Alert Network (DAN), the Professional Association of Diving Instructors (PADI), and some of the nation's leading experts in diving physiology. Manned in-water testing commenced in October of this year in San Diego, California. Subjects were selected using the DAN demographic data base and health screening protocols. The objective was to select subjects who most closely mirrored the general civilian population.

The physiological testing includes three separate phases to test subjects for detection, annoyance and anxiety. The detection phase tests heart rate, startle response, and respiration rate, using five signals at six different frequencies (below 500 Hz), and six different sound pressure levels. Annoyance (or aversion) testing involves similar protocols and signal combinations. Anxiety (or arousal) testing uses the most aversive signals broadcast "blind" to naïve divers.

The other study target areas include concussive effects, lung vibration, active tissue, vestibular effects, and dive computers. The objective is to determine, through prediction, a damage risk threshold (DRT) for each area studied. (Tests on human subjects will not involve testing up to the DRT level.) These data will in turn be used to develop the LFA mitigation measures that will be presented in the forthcoming EIS.

U.S. NAVY SURTASS - LFA PROTECTING THE MARINE ENVIRONMENT IN SYSTEM DEPLOYMENT

6. ENVIRONMENTAL IMPACT STATEMENT

Information from the LFS SRP, the diver studies and other research will be synthesized into the draft EIS, scheduled for public release in the summer of 1998. The development of the EIS itself will entail the following essential scientific and data integration procedures:

- Define objectives for EIS sections (scope of discussions, level of detail, etc.).
- Identify data needs (availability of data, etc.) and acoustic modeling requirements.
- Collect information and scientific data (library searches, Internet queries, interviews and personal communications).
- Collate, process and analyze all data.
- Draft EIS sections.
- Internal Navy review.
- Collate changes into Draft EIS (DEIS); internal review.
- File notice of availability of DEIS in Federal Register.

The public will be invited to submit written comments on the DEIS. The Navy may also schedule public meetings to receive comments. All comments received will be reviewed and responded to in the final EIS (FEIS). Upon review of the FEIS, the appropriate Department of the Navy decision-maker will issue a record of decision (ROD) on the FEIS.

7. MAKING THE PROCESS WORK

Lessons Learned

What has the SURTASS LFA EIS team learned from being enveloped in the process so far? The important lessons are: 1) Be sensitive to the public perception of the proposed action, and work to alleviate potential concerns; 2) Involve your lawyers early. The applicable requirements are largely legally driven, and the points of contact with stakeholder environmental agencies and interest groups are often their lawyers; 3) Be as open as possible with the public from the beginning, with the understanding that universal support for the proposal is probably not feasible; and 4) Do not lose faith. The process is often long and tortuous but sound proposals should eventually be approved. The real challenge is to keep upper level management, which ultimately pays the bills, supportive of the sometimes convoluted process.

Mitigation Sensors and Procedures

Since 1994, SURTASS LFA at-sea operations have been underwritten by appropriate environmental compliance documentation that includes mitigation procedures to minimize any potential effects on marine animals and human divers. The following list summarizes the types of mitigation techniques employed during SURTASS LFA testing:

- Visual monitoring, using Big Eye 25x pedestal-mounted binoculars.
- Passive acoustic monitoring, using the Advanced Canary/Popeye real-time whale detection and localization system, originally developed by the Cornell

University Bioacoustics Research Program. This system uses passive hydrophones in the SURTASS LFA towed receive array to detect, locate and track vocalizing mysticetes.

- Initiation of transmissions—the source is gradually increased to the operating level.
- Monitoring of sound field, performed periodically during operations with passive sonobuoy, over-the-side vertical line array (VLA), or towed horizontal line array (HLA).
- Sound Pressure Level (SPL) monitoring; modeled predictions of the SPL at potential dive sites are made, and real-time verification of predicted SPL is accomplished via acoustic model updates.
- Control of duty cycle—for most at-sea testing, average duty cycle is below 10%.
- Advance public announcement—test plan particulars are made available to the local area dive community via Internet on 3 Web sites: DAN, National Association of Underwater Instructors (NAUI), and PADI. Test details are also passed to local dive shops.

8. SUMMARY

Addressing the many environmental requirements associated with operational employment of the LFA system has broken significant new ground for the U.S. Navy. The EIS to be completed in 1998 is expected to add significantly to current knowledge of the effects of LFS on marine mammals and human divers. The lessons learned from this experience will influence the Navy's approach to comparable issues in the future, and may be a template for similar efforts by the U.S. and allied navies.

9. REFERENCES

[1] A. Waltner. 1997. The Regulation of Marine Scientific Research: The Experience of the Scripps Institution of Oceanography's Acoustic Thermometry of Ocean Climates Experiment. Prepared for the California State Bar environmental Law Section's 1997 Environmental Law Institute at Yosemite. Law Offices of Alan Waltner, 1736 Franklin St., Eight Floor, Oakland, CA 94612.

[2] Malme, C., P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird. 1984. Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior/Phase II: January 1984 Migration. BBN Rep. 5586, Rep. from Bolt Beranek and Newman, Inc., Cambridge, MA for U.S. Department of the Interior, Minerals Management Service, Anchorage, AK.

[3] National Research Council. 1994. Low-frequency Sound and Marine Mammals/-Current Knowledge and Research Needs. U.S. National Research Council, Ocean Studies Board, Committee on Low-frequency Sound and Marine Mammals (D.M. Green, H.A. DeFerrar, D. McFadden, J.S. Pearse, A.N. Popper, W.J. Richardson, S.H. Ridgway, and P.L. Tyack). National Academy Press, Washington, DC. 75 p.

[4] Ketten, D.R. 1992. The Cetacean Ear: Form, Frequency, and Evolution. Proceedings of a symposium on sensory systems of aquatic mammals, held

October 16-19, 1991, in Moscow, Russian Federation. Plenum Press, New York.

[5] Ridgway, S.H., D.A. Carder, R.S. Smith, T. Kamolnick, C.E. Schlundt, W.R. Elsberry. 1997. Behavioral Responses and Temporary Shift in Masked Hearing Threshold of Bottlenose Dolphins, *Tursiops truncatus*, to 1-second tones of 141 to 201 dB re 1µa. Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA 92152-5001. Technical Report 1751.

[6] Chief of Naval Operations. June 1997. Potential Effects of Low Frequency Sound on the Marine Environment: Data Needs and Research Solutions. Scientific Working Group Meeting #1 Summary Report.

[7] Chief of Naval Operations letter 5100, serial 875/7U658377 of June 25, 1997 (request for guidance on safe LFS operating parameters during interim use of SURTASS LFA for LFS SRP experiments).

[8] Chief Bureau of Medicine and Surgery letter 5100, Serial 21/0149 (concurrence with Chief of Naval Operations letter of 25 June 1997) of July 1, 1997.