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**DATE:** **April 20, 2010**

**TO:** **Coastal Commissioners and Interested Parties**

**FROM:** **Peter M. Douglas, Executive Director**
**Alison Dettmer, Deputy Director**
**Mark Delaplaine, Manager, Energy, Ocean Resources and Federal Consistency Division**

**RE:** **Background Report for Presentation to the Commission by NOAA and its Collaborating Researchers of Proposed Five-Year Research Effort (2010-2015) Studying the Effects of Mid-frequency Underwater Noise on Marine Mammals**

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[**Staff Note**: This research proposal will be presented at the May 2010 Commission meeting, as an informational item only. The proposal will subsequently be scheduled for a future Commission meeting as a public hearing and voting item, in the context of a to-be-submitted NOAA consistency determination.]

**Background:**

The National Oceanic and Atmospheric Administration (NOAA) Office of Science and Technology is collaborating with academic, private sector, and civilian military scientists in a 5-Year, underwater acoustic research effort, proposed for the Southern California Bight (primarily within the U.S. Navy's existing Southern California (SOCAL) Range Complex)(Exhibits 1-2). The research is largely being funded by the U.S. Navy. The first phase of the research, referred to as SOCAL-10, is currently scheduled to commence in Summer/Fall 2010. The research is also being reviewed by NOAA itself, through a Scientific Research Permit application (under the Marine Mammal Protection Act (MMPA)) to NOAA/NMFS's Office of Protected Resources (NOAA/ NMFS File No. 14534: "Behavioral Response Studies of Marine Mammals in the Pacific Ocean Using Controlled Sound Exposure: Research Applications to Support Conservation Management.")[1] (See link to NOAA file in footnote below.)

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[1] https://apps.nmfs.noaa.gov/preview/applicationpreview.cfm?RecType=Project&RecordID=14534&ProjectID=14534&AppBack=../search/search.cfm&view=110000000110100#Contacts

**Researchers:**

The SOCAL-10 research team consists of primary investigator Brandon Southall and co-investigators: Lisa Balance, Jay Barlow, Ian Boyd, John Calambokidis, Ching-Sang Chiu, Daniel Costa, Angela D'Amico, Ari Friedlaender, John Hildebrand, David William Johnston, David Moretti, Douglas Nowacek, Greg Schorr, and Peter Tyack.

**Purpose and Objectives:**

The research proposal has been designed to better understand basic diving and vocal behavior in a variety of marine mammal species, to expand our ability to monitor marine mammal presence and/or density using passive listening sensors, and to study their reactions to a variety of controlled underwater sounds, in order to determine the effects on targeted marine mammals of acoustic exposures of mid-frequency (MF) sonar sounds. The research is intended to build on recent controlled exposure experiments conducted (by many of the same researchers) in the Bahamas in 2007-08 (called a "Behavioral Response Study" or (BRS)) and in the Mediterranean in 2009. The proposed research would include essentially the same experimental procedures and protocols to obtain important data while ensuring the safety of exposed animals, but over a larger potential area and time period, as well as including a much greater number of species.

While the primary focus will be on responses of animals to simulated military sonar signals, NOAA's MMPA scientific research permit application states that the results will have implications for assessing potential impacts of other kinds of industrial sounds as well. Also, data obtained on vocal characteristics will contribute to a number of ongoing efforts to detect and track marine mammals. Specifically, the permit application states:

> *Stated broadly, the research to be conducted under this permit with provide empirical measurements of behavior in marine mammals and behavioral changes as a function of sound exposure so that sound producers and regulatory agencies can better understand, minimize, and manage noise impacts on protected species.*

The research will address both basic and applied research questions having direct implications for increasing the understanding and effective conservation management of marine mammals. Some of the objectives will build on previous research, and others will provide completely new measurements for target species in areas of great scientific uncertainty. Hypotheses to be tested include: (a) that species differences in vocal behavior can increasingly be used to identify presence and possibly abundance of these species; and (b) that marine mammal behavior will change in a variety of ways based on characteristics and contexts of sound exposure.

NOAA notes that alternative means exist for addressing such issues, including *opportunistic* observations around on-going exercises involving sound sources. However, NOAA believes that while these opportunistic observations are important (and ongoing in several places with support from both the U.S. Navy and/or NOAA, including the area proposed for this research), they *will remain limited* in terms of providing specific information on individual responses. NOAA states:

> *Clearly, the opportunistic data are useful and needed, but arguably they will be most useful in conjunction with controlled exposure experiments (CEE) to provide the fine granularity of detail on individual responses (Tyack, 2004; Southall et al., 2007). CEEs are the proposed experimental approach for this study, involving the tagging of individual animals with measurements of behavioral response and other data before, during, and following directed sound exposures of different types. … Such experiments have [been] and will be conducted with specific protective protocols for ensuring the research is conducted safely and humanely, many of which are also integrated into the experimental approach proposed here (described in greater detail below).*

NOAA further states that the research goals will address the following questions:

> *- What kinds of vocal signals are produced by different species and what are their communicative functions?*
>
> *- How well can acoustic monitoring be used in detecting animal presence of an animal and, in combination with environmental data, estimating distribution and abundance?*
>
> *- How do marine mammals respond to ecologically relevant sounds from other marine mammals, such as a common predator, the killer whale (Orcinus orca)?*
>
> *- How do beaked whales and other marine mammals respond to simulated military sonar and other sounds?*
>
> *- What are the types and contexts of exposure resulting in different kinds of behavioral responses in different species?*
>
> *- Are beaked whales particularly sensitive species (Southall et al., 2007), as recent observations seem to indicate (Cox et al., 2006; Boyd et al., 2007; Boyd, 2008)? Are other species particularly behaviorally sensitive to sound exposure?*
>
> *- Can behavioral responses identified be related to risk factors for significant disruption of behavior or injury?*

NOAA states these will be addressed within the context of three overarching objectives, consisting of:

> *Objective 1. Identify the types and characteristics of vocal signals produced by different marine mammal species and identify their communicative functions.*

*Objective 2. How marine mammals respond to the sounds of a common predator, the killer whale (Orcinus orca).*[2]

*Objective 3. How do marine mammals respond to sonar and other sounds? What are the types and contexts of exposure resulting in different kinds of behavioral responses in different species? Can these responses be related to risk factors for more severe behavioral responses and/or injury? Are there particularly sensitive and generally tolerant marine mammal species with regard to acoustic exposure?*

**Research Efforts:**

The research will include gathering baseline data, animal tagging, tracking, observing, exposure to playback sounds, active and passive acoustic monitoring, and tissue sampling. NOAA further describes the research as follows:

*Research described in this permit is designed to measure baseline (normal) behavior in marine mammals, including but not limited to acoustic and diving behavior, as well as changes in their behavior as a function of exposure to different sounds. Consequently, there are different elements to the study to measure behavior before, during, and after controlled exposures to different sounds. Specialized, inter-disciplinary teams of scientists are required to conduct the various project functions, including: locating and identifying target species and individuals suitable for tagging; attaching and tracking acoustic tags on individual marine mammals; safely conducting playback experiments with established mitigation measures; monitoring and tracking focal individuals (and those exposed incidentally, as possible). The procedures identified here are very similar to and consistent with those used in the Bahamas BRS efforts (see Boyd et al., 2007; Boyd, 2008; Southall et al., 2007) and also work planned for this summer on the NATO research vessel Alliance in the western Mediterranean Sea by Tyack, Southall, D'Amico and others.*

NOAA selected the Navy SOCAL Range in part due the potential for combining monitoring efforts with Navy passive acoustic monitoring already in place on the Range. NOAA states:

*One of the primary reasons for selecting the initial research area for this program is the presence of significant real-time PAM capabilities available through our collaboration with the U.S. Navy. The combined listening capabilities available on the SCORE range and the proven identification and localization of marine mammals using these sensors will be one of the principal tools used in locating target species and in monitoring real-time responses of animals during controlled exposures. This will be very similar to the use of bottom-mounted, real-*

[2] Note: SOCAL 2010, first phase, research will not include any killer whale sound experiments.

*time sensors at the AUTEC range in the Bahamas during the 2007-2008 BRS studies in the Tongue of the Ocean. Additionally, where necessary and possible, we propose to deploy hydrophone arrays or sonobuoys from either the WTV or the PBV or both to track vocalizations of marine mammals in the study area. Passive acoustic monitoring of the click sounds of odontocetes can also be used to estimate range to the animal (e.g., Tiemann et al., 2006).*

The research will include use of both passive and active acoustics. NOAA describes the proposed use of active acoustics as follows:

*Active acoustics for controlled exposure experiments*

*Controlled exposure experiments for this project will be conducted primarily in summer and Fall in the waters off Southern California within the U.S. Navy's Southern California (SOCAL) Range Complex, and primarily near the vicinity of San Clemente Island (SCI).*

*The sound source for the SOCAL-10 project has been designed for this project to be relatively easy to deploy from a small to mid-size vessel while allowing moderate levels of sound to be presented to test subjects at ranges of several kilometers. The sound source has the following specifications:*

- *Vertical line array of active transducers for projecting mid-frequency, short-duration sounds (see below);*
- *16 transducers driven by individual power amplifiers;*
- *Time-delayed inputs effectively steer the output beam to desired elevation angle;*
- *Estimated maximum source level of >215 dB re 1 mPa @1m within mid-frequency band (2-6 KHz)*
- *Deployable to at least 100 m (cable is 125m);*
- *Two-person, hand-deployable, lightweight configuration for rapid response;*
- *25-50 lb. ballast weight – dry weight of array and ballast is ~125 lb.;*
- *Simple 120VAC, 10A ship power requirements;*
- *All components shock-mounted in rugged, shipping-ready rack (30x48")*
- *Source controlled from remote laptop computer by a single operator;*

- *A calibrated hydrophone will be used to validate source performance and can be used to provide a degree of passive acoustic monitoring when the ship is stationary. Both the output signal and the receive signal from the hydrophone will be recorded along with an IRIG time signal derived from a GPS satellite. This will allow precise signal reconstruction after the exposure studies.*

*The synthetic mid-frequency waveforms (sonar-like or pseudorandom noise) would be 0.5-5 seconds in length, transmitted every 20 -60 seconds with a ramp up from 160 dB to the maximum source level planned for transmitting. In the protocol for animals that are clicking while diving (including beaked whales), the maximum source level will depend upon when in the sequence the whale stops vocalizing or is observed to respond, since the protocol calls for ceasing transmissions once it is verified that the whale has responded in a significant, identifiable manner, or, if no response is observed, to continue transmitting at the maximum source level for a pre-determined period of time before ceasing transmission.*

*When animals are observed nearer the surface, the playback will be stopped if a strong aversive behavioral response is observed by visual observers or the passive acoustic monitors. Examples of behaviors that would trigger a precautionary shutdown of the experiments include: directed, high speed or other abnormal swimming behavior (at surface), especially toward shore; unusual and abnormal surface/subsurface behavior involving apparent disorientation and confusion or dramatic changes in group cohesion.*

*Previous BRS efforts (Boyd et al., 2007; Boyd, 2008) have terminated exposures following an identified change of vocalization in deep-diving beaked whales and have only conducted CEEs with animals at depth. While that will be the protocol for beaked whales initially in the SOCAL BRS project, but subsequent exposures may include maintaining exposures slightly longer and/or exposing individuals during surfacing intervals if there are no additional contra-indicators and conditions are favorable to enable visual detection. CEEs will be conducted for other species both at the surface and during dives with monitoring using both visual and PAM methods.*

*Active acoustics for prey mapping*[3]

*An additional aspiration of the SOCAL BRS program will include gathering environmental data in parallel with detections of marine mammals for input into models to predict the distribution of different species. Most such models have had data limited to bathymetry and surface waters which creates a data gap for species that feed at depth. We propose to use scientific Simrad EY500 split-beam*

[3] Note: SOCAL 2010, first phase, also will not include this active acoustic effort.

*echosounder systems with sources operating at one of three frequencies (38 kHz, 70 kHz, and/or 120 kHz) to map prey for marine mammals at depth. The transducers for this echosounder have a 7 degree beam and a maximum continuous input of 30-40 W with maximum instantaneous pulse output of 1-4 kWatts. The source level for the 38 kHz ES38DD, which is the one listed with a maximum power of 4 kWatts (vs 1 kWatt for the other two) is listed as 183 dB re 1µPa per V, but the spec sheet does not indicate how many volts can drive it. The maximum instantaneous power is 4 kWatts with a 40% electroacoustic efficiency. This would suggest that the ES38DD has a maximum acoustic output of .4 x 4000 = 1600 Watts. If 1 acoustic watt corresponds to a source level of 170 dB re 1 microPa at 1 m, then the maximum source level would be 202 dB re 1 microPa (170 dB+ 10 log(1600) = 170 + 34 = 202 dB source level). The duration of pulses is typically < 1 msec to allow discrimination of small targets. These echosounders are the type routinely used for fisheries surveys by NMFS and other agencies and researchers. This echosounder has such a narrow beam and such brief pulse durations that their use in surveys is not typically regulated under this kind of permit. By NMFS' current criteria (see NMFS, 2005), the zone of potential injury would be a narrow cone extending 10m below the ship. The risk of encountering this is small compared to the risk of colliding with the actual ship. By the criteria of NMFS (2005a), the zone of potential harassment would be a narrow cone extending 100m below the ship. The odds of animals encountering this are very small, and the animal would only have to swim 10m to move out of the beam at this maximum range of 100m. Their operating frequencies are well above the expected upper limit of hearing of baleen whales (see Southall et al. 2007) and sea turtles (Ridgway et al., 1969). It is possible that sperm whales could hear 38 kHz, but there is no evidence for short pulses at this frequency affecting sperm whales. Watkins and Tyack (1991) attached transponders that produced 7 msec pings at 36 kHz at a level of 180 dB re 1 µPa to sperm whales with no sign of reaction to these pulses which were much longer and higher in level than expected for the echosounder signals.*

Finally, as described previously, the research is intended to be integrated with and expand on recent research efforts. NOAA describes these relationships as follows:

*Other Exploratory Research Associated with Key Objectives*

*Several authors (e.g., Tyack et al.,2004; Southall et al., 2007) have argued that opportunistic and controlled experimental studies of effects of sound on marine mammals are complementary and are often much stronger in combination. There has been growing interest in the development of tagging and passive acoustic monitoring techniques to monitor the effects of sound-producing activities over the full duration of the activity. There has been increasing recent and ongoing research in these areas and increasing integration among teams working in different areas (including related to the recent BRS project in the Bahamas and monitoring on the AUTEC range using solely the listening sensors during real*

*military sonar training exercises). The experimental effort described here is intended to similarly contribute to an integrated opportunistic and experimental approach to measuring the behavioral responses of marine mammals in an area where active military sonar is fairly common. For instance, there have been and are ongoing Navy efforts on the SCORE range in southern California to monitor the presence of marine mammals before, during, and after real military training exercises involving the use of mid-frequency sonar (Moretti et al., 2008)). Additionally, researchers from Cascadia have deployed satellite tags ahead of real exercises to track individual movements on a broad scale before, during, and after these operations (J. Calambokidis, pers. comm). These other associated projects will contribute to and be informed by the experimental CEE approach proposed here; many of the same researchers are involved in each of these projects, which will be closely coordinated and cross-pollinated in terms of personnel, results, interpretation, and subsequent modification of experimental approaches.*

*Additionally, while several specific hypotheses and applied objectives have been specified, much of this research involves topics where so little is known that there are frequent unanticipated discoveries. During the last five years of permitted research by some of the co-investigators included here, the following are some of the unanticipated discoveries:*

*• Dive behavior and risk of decompression in Cuvier's beaked whales (Zimmer and Tyack, 2008).*

*• Characteristics and beampattern of echolocation clicks produced by sperm whales (Zimmer et al., 2005a), Cuvier's beaked whale (Zimmer et al., 2005b) and Blainville's beaked whale (Johnson et al., 2006).*

*• How beaked whales use their echolocation to forage (Johnson et al., 2004; Madsen et al., 2005).*

*• Beaked and sperm whales can detect echoes from the seafloor and surface for orientation (Zimmer et al., 2005a; Madsen et al., 2005).*

*• How sperm whales use coda vocalizations to communicate in different phases of the dive cycle (Watwood et al., submitted).*

*There are several related exploratory research directions related to primary focus of this research program over the next five years. For instance, when more than one animal is tagged simultaneously within a group, it becomes possible to measure the distance between the pairs of tagged animals by timing how long the sound takes to travel from a tagged vocalizing whale to the tagged receiving whale. When more animals are tagged within a group, this may allows one to locate the calls even of animals that are not tagged; this is an exploratory*

> *research area for which we plan simultaneously to tag several animals within one group, as possible and appropriate. Also, the WHOI group is working on a smaller version of the tag that will be suitable for attachment to smaller delphinids which produce a more diverse array of communication signals than sperm and beaked whales. The basic questions to be answered include: what is the effective range of communication, what are the contexts in which animals signal and how do receivers respond, and what are the functions of the calls. While animals will be taken for the research objectives described above, the research is likely to also provide unanticipated results leading to scientific publications on other topics. Finally, new-generation DTAGs are being designed for attachment and recording durations of 2-5 days and include a GPS sensor so that the location of the tagged individuals can be recorded without a ship having to follow the animal continuously. This is expected to enable longer term studies and will involve some changes in experimental methodology, including studying the responses of animals to human activities lasting for up to several days, and for controlled exposure designs that investigate effects of repeated exposures. This question of how the responses of marine mammals change over repeated exposure has been described as a "critical subject for future research" by Southall et al. (2007), and has been identified as a high-priority research objective for U.S. federal agencies involved in this issue (Southall et al., 2009).*

This last reference is to a recent interagency task force report entitled: *"Addressing the Effects of Human-Generated Sound on Marine Life: An Integrated Research Plan for U.S. federal agencies. Interagency Task Force on Anthropogenic Sound and the Marine Environment of the Joint Subcommittee on Ocean Science and Technology. Washington, DC."* (Southall, B., Berkson, J., Bowen, D., Brake, R., Eckman, J., Field, J., Gisiner, R., Gregerson, S., Lang, W., Lewandoski, J., Wilson, J., and Winokur, R. 2009.) The executive summary of that report is attached as Exhibit 3.

Additional details about the research proposal (including a Draft Environmental Assessment) can be found at NOAA/NMFS's Office of Protected Resources website for the pending NOAA Scientific Research Permit application (see footnote 1, p. 1, above).

**Attachments**

Exhibit 1 Southern California Research Area, Navy SOCAL Area, and Shipping Lanes
Exhibit 2 Underwater Topography in Area
Exhibit 3 Executive Summary, Interagency Integrated Research Plan
Exhibit 4 Acronyms

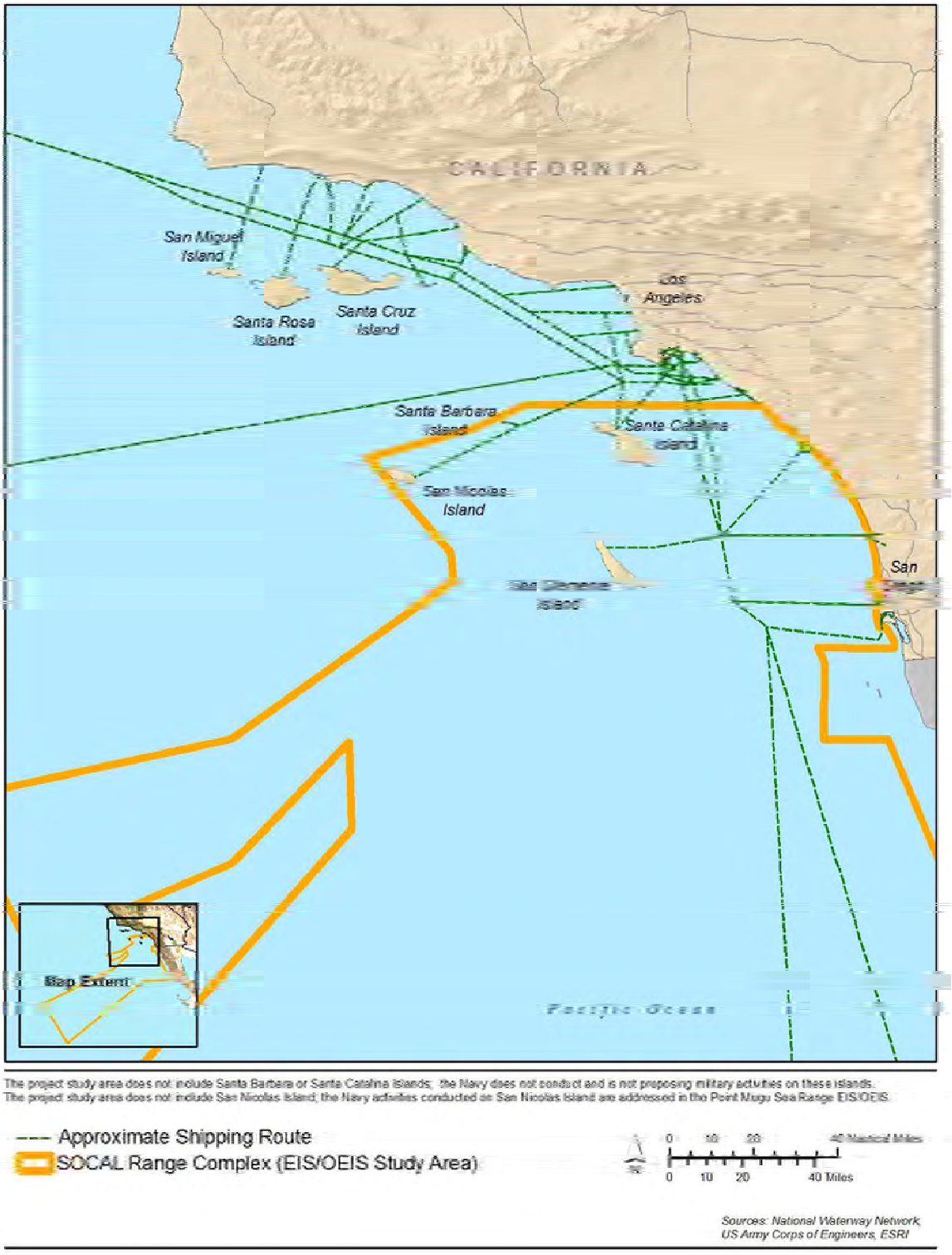


Figure 3-1: SOCAL Range Complex Shipping Routes (DON, 2008)

**Exhibit 1**

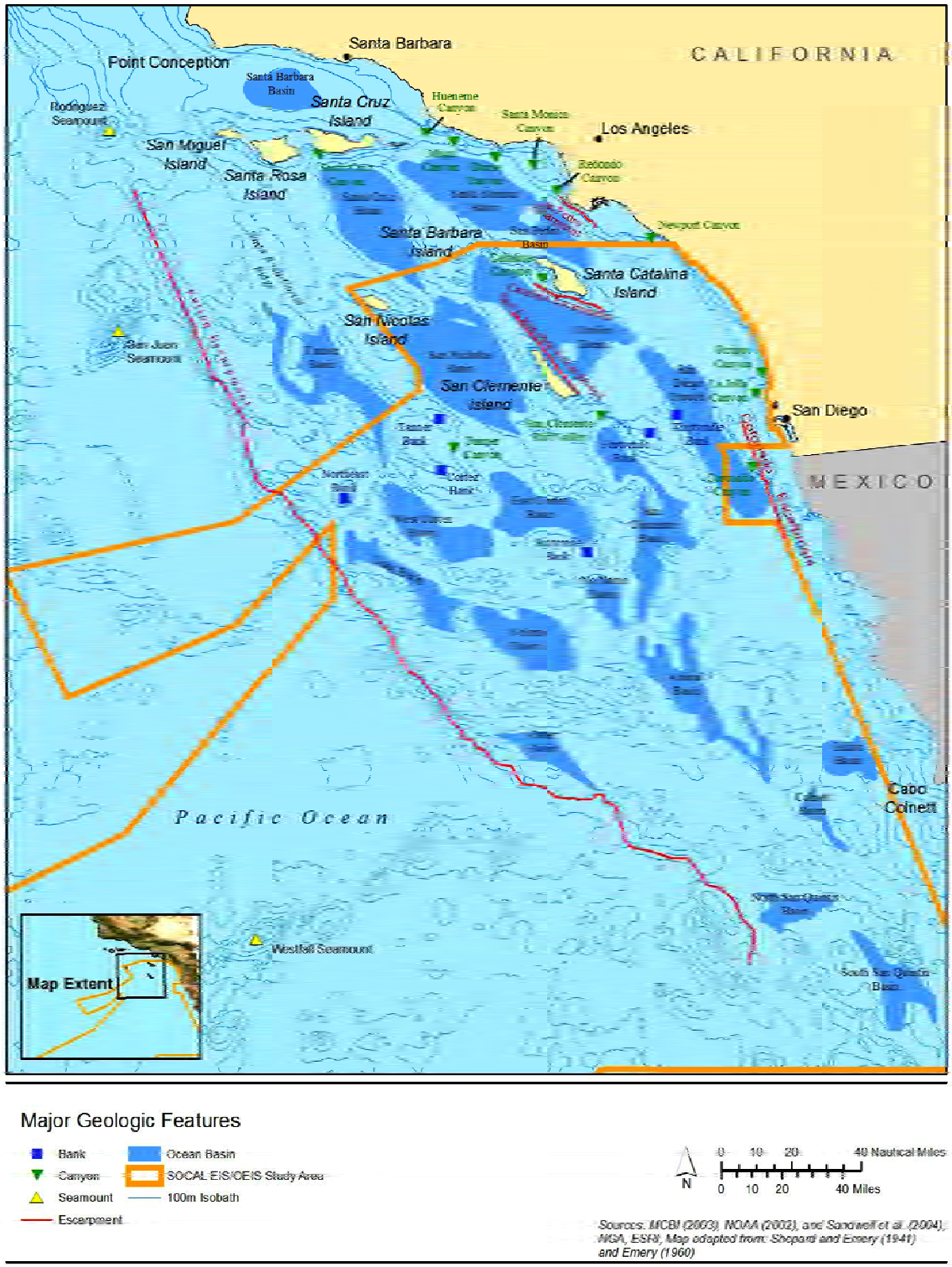


Figure 3-3: Major Geologic Features in the NE portion of the SOCAL Range Complex. (DON, 2008)

**Exhibit 2**




# "Addressing the Effects of Human-Generated Sound on Marine Life:
## *An Integrated Research Plan for U.S. Federal Agencies"*

**A Report of the Joint Subcommittee on Ocean Science & Technology (JSOST)**

**~ INTERAGENCY TASK FORCE ON ANTHROPOGENIC SOUND AND THE MARINE ENVIRONMENT ~**

**Contributing Federal Agencies** (in alphabetical order):

Marine Mammal Commission (MMC)
Minerals Management Service (MMS)
National Oceanic and Atmospheric Administration (NOAA)
National Science Foundation (NSF)
U.S. Army Corps of Engineers (ACE)
U.S. Coast Guard (USCG)
U.S. Department of Defense, U.S. Navy (USN)
U.S. Department of Energy (DOE)
U.S. Department of State (DOS)
U.S. Fish and Wildlife Service (FWS)

**Exhibit 3**

This document should be cited as follows:

Southall, B., Berkson, J., Bowen, D., Brake, R., Eckman, J., Field, J., Gisiner, R., Gregerson, S., Lang, W., Lewandoski, J., Wilson, J., and Winokur, R. 2009. Addressing the Effects of Human-Generated Sound on Marine Life: An Integrated Research Plan for U.S. federal agencies. Interagency Task Force on Anthropogenic Sound and the Marine Environment of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

## Acknowledgements

We appreciate and acknowledge the many scientists and managers from participating federal agencies that contributed to this report

**Cover page photo credits** (from left to right)
(1) Sperm whale beginning a dive in Mississippi Canyon Block 127 in the Gulf on the 2002 S-tag cruise (photo credit: Christoph Richter, Texas A&M University-Galveston).

(2) Acoustic and behavioral monitoring tag being applied to a pilot whale in Hawai'i by Duke University researcher Doug Nowacek; NOAA's research vessel Oscar Elton Sette is visible in the background (photo credit: NOAA/NMFS Pacific Islands Fisheries Science Center).

(3) Harbor seal participating in behavioral hearing experiments in a specialized anechoic testing chamber at Long Marine Laboratory, University of California, Santa Cruz, CA (photo credit: Brandon Southall, NOAA).

(4) Harbor porpoise (photo credit: Ari Friedlaender, Duke University)

Council on Environmental Quality
Office of Science and Technology Policy
Executive Office of the President
January 13, 2009

Dear partners and friends in the ocean and coastal community:

We are pleased to present this report, ***Addressing the Effects of Human-Generated Sound on Marine Life: An Integrated Research Plan for U.S. Federal Agencies***. This report was developed in response to an Interagency Committee on Ocean Science and Resource Management Integration request for a focused, coordinated Federal science and technology plan from the National Science and Technology Council's Joint Subcommittee on Ocean Science and Technology (JSOST). The JSOST's Interagency Task Force on Anthropogenic Sound and the Marine Environment prepared this report.

Whether and how human-generated sounds in the ocean affect marine life has become an issue of increasing awareness, within scientific and regulatory circles as well as among the general public. Many activities vital to our society, including the actions of many Federal agencies, introduce sound into the marine environment. Consequently, there is much interest and effort involved in understanding associated environmental impacts and, where appropriate and practical, developing ways of minimizing them. A number of Federal agencies are actively engaged in advancing the science and technologies needed to address these challenging issues.

This report provides an explicit interagency roadmap for the next decade to focus and prioritize research efforts addressing this issue. It summarizes collective research efforts by Federal agencies in several key areas and includes a number of specific and prioritized research recommendations regarding future efforts, with particular emphasis on interagency collaboration. Finally, it summarizes some general coordinating actions and means of increasing the transparency and public recognition of ongoing interagency efforts in this field. The findings indicate that many of the challenging scientific, regulatory, and legal issues regarding underwater sound can be addressed with focused, prioritized, and sustained effort coordinated among the Federal agencies. We hope it will be useful to a broad range of interested parties.

Sincerely,

James L. Connaughton
Chair, Committee on Ocean Policy
Chair, Council on Environmental Quality

John H. Marburger III
Director
Office of Science and Technology Policy

# Joint Subcommittee on Ocean Science and Technology (JSOST)

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Dr. Richard Spinrad, DOC/NOAA, Co-Chair
Dr. Dan Walker, OSTP, Co-Chair

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## *Report Overview and Summary*

The issue of anthropogenic sound[1] and its possible impacts on the marine environment has created unique challenges for virtually all federal agencies conducting, supporting, or assessing operations in the marine environment. These agencies are charged with regulating, supporting, and/or performing activities in the marine environment vital to our nation's health, economy, and security across a wide scope of sectors. Sound (both intentionally produced as a tool or as a by-product of other activities) is an integral part of the activities of these agencies and of many critical human activities, including vessel operation and navigation, offshore minerals exploration, national defense, and scientific research. Federal agencies are challenged with achieving their mission goals in conducting and/or regulating these critical activities while meeting their mandated responsibilities as environmental stewards for the nation. Continuing to develop a scientific basis for determining potential impacts and the appropriate response is an urgent requirement for federal agencies, if they are to continue to achieve their primary missions for our nation in an environmentally safe manner.

There is considerable scientific uncertainty regarding the nature and magnitude of the actual impacts of anthropogenic sound on the marine environment, as well as the most appropriate and effective mitigation measures where effects have been demonstrated or are likely. Societal benefits from the full spectrum of sound-producing activities should be considered along with, and not overshadowed by, any potential negative impacts of those activities. The goal of federally-supported research in this area

1 Within this report, the term "sound" is used to refer to the acoustic energy radiated from a vibrating object, with no particular reference for its function or potential effect. "Sounds" include both meaningful signals and "noise" which may have either no particular impact or may have a range of adverse effects. The term "noise" is only used where adverse effects are specifically described, or when referring to specific technical distinctions such as "masking noise" and "ambient noise."

is to obtain mission-critical data that are used in a timely and effective manner to inform policy guidance, develop targeted mitigation measures, and develop and improve regulatory criteria.

How anthropogenic sound may affect marine life is a new field of study. What began as a simple concern that commercial shipping might affect the long-distance calls of whales (Payne and Webb, 1972) has now evolved into a more complex recognition that various anthropogenic acoustic sources have the potential to adversely affect marine life. Additionally, concerns regarding potential impacts are compromising human applications of sound for important scientific, commercial, and military purposes, particularly where scientific data are lacking or ambiguous. These concerns stem from both an increased understanding of the biological importance of sound to most marine vertebrates (particularly marine mammals and many fish) and a growing appreciation of the value of acoustics as a tool for ocean research, energy development, monitoring ocean health, resource management, military activities, and ship operations. How do we as a society reconcile our growing dependence on sound as a tool for studying, using, and conserving the marine environment with a similarly growing understanding of the potential for unintended adverse environmental consequences? How do we balance the potential negative environmental impacts from the incidental introduction of sound with the benefits of ocean-based commerce, national security, research, or transportation? And most important, how do we regulate these

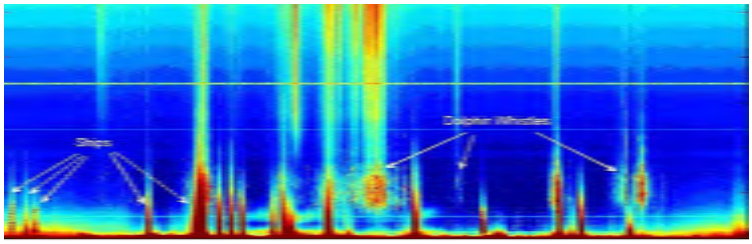

Image courtesy of Dr. John Hildebrand, Scripps Institute of Oceanography

essential human activities in the face of significant scientific uncertainty about adverse effects? Many of these fundamental questions remain to be answered and they clearly require additional scientific data to be adequately addressed.

The most immediate response by U.S. federal agencies has focused on understanding and minimizing the potential adverse effects of their activities, or activities they support or regulate. The current status of science (in terms of exactly what level and types of sound will result in a specific effect) often results in estimates of potential adverse impacts that contain a high degree of uncertainty.

Public perception of threats and scientific analyses of risks may lead to different priorities for acoustic research. There is growing concern by scientific experts in relevant disciplines, that the public and legal focus on a very narrow range of active sources and the predictable agency responses are distorting an appropriate scientific approach to assessing the broader impacts of anthropogenic noise as a global issue (see NRC, 2000; 2003; 2005; Nowacek *et al.*, 2007; Southall *et al.*, 2007). This creates a growing need for both transparency and public and stakeholder outreach as agencies respond to the increasing awareness of sound as an environmental issue.

The laudable aim of minimizing acoustic effects has produced controversy, social tension, and litigation. It has also led to precautionary restrictions, considerable additional costs and delays, not the least of which has been the paradoxical effect of hindering ocean acoustic science essential to understanding not only this issue but also other important environmental issues such as the marine aspects of climate change. These anticipatory restrictions and other precautions imposed through litigative challenges have taken place against a background of considerable uncertainty as to the

nature and extent of impacts from noise exposure. It is this gap, between what should and can be done with scientific confidence and what is currently being done with abundant precaution but demonstrable societal cost, which we seek to reduce through the coordinated federal research strategy depicted here. A summary of key overarching summary points is given below (Box 1).

**Box 1 – OVERVIEW OF KEY POINTS**

**Sound is of vital importance for most marine vertebrates.**

**Natural and human sounds can have benign (or no) to significant effects on marine life.**

**Public, media and regulatory attention has focused on known and/or potential adverse impacts of active sonar and seismic systems, but agencies must consider a wider array of sound sources.**

**Existing data needed to assess and mitigate effects are limited, leading to uncertainty in determining the necessary responses (if any).**

**Federal research has been largely focused on immediate needs specific to individual agencies.**

**However, agencies often have common science and technology needs on this issue that could be most quickly and economically met through a coordinated program of effort.**

## Purpose of Report

As the scope and nature of the issue has expanded, so has the need for increased communication and collaboration across federal agencies[2]. At present, federal agencies have already begun working to develop tools, technologies, and knowledge to provide empirical data on these difficult questions, but these have largely occurred at an agency-specific level. In response, the Interagency Committee on Ocean Science and Resource Management Integration (ICOSRMI) formed an "Interagency Task Force on Anthropogenic Sound and the Marine Environment" within the Joint Subcommittee on Ocean Science & Technology (JSOST). This Task Force was comprised of federal

2 Brief descriptions of the mandates of involved U.S. federal agencies relative to the issue of marine sound, as well as agency representatives contributing to this report are listed in Appendix 1.

agencies most directly involved in this issue with each individual agency providing a representative to participate and speak for their agency perspective. The Task Force was charged with developing a focused, coordinated science and technology plan of action among federal agencies and reporting on this plan through JSOST to ICOSMRI. Therefore, this report represents an overall, interagency (not individual agency) perspective, as determined through the interactions and deliberations of Task Force members.

The recommendations offered within this report provide a strategic vision for integrating, prioritizing and optimizing the science and technology efforts of U.S. federal agencies on marine anthropogenic sound over the next decade. It is based on lessons learned from inter-agency coordination on ocean science issues generally, as well as coordination on pressing research needs regarding this issue specifically. The intent is to promote and develop better scientific understanding, thereby leading to better documentation of effects, less controversy regarding risks, increased scientific certainty underlying policies and regulatory decisions, and effective mitigation efforts where impacts are known or likely. The report is also intended to improve the combined federal effort by increasing inter-agency coordination, planning, and leveraging resources, while reducing redundancy and disproportionate focus in a few areas.

The report is organized into a general overview (this section) that summarizes the key issues and recommendations of the task force, followed by a list of acronyms, five primary chapters, and three detailed appendices. Throughout the report, completed research and specific recommended research actions are given within five general subject categories: (1) Sound Sources and Acoustic Environment; (2) Baseline Biological

Information (Physiology, Distribution, and Abundance); (3) Effects of Sound (Criteria and Thresholds); (4) Monitoring and Mitigation; and (5) Outreach, Education, and Scientific Peer Review. Chapter 1 states the general issue in greater detail than this general overview and provides a sense of the limits to currently available information. Chapter 2 provides an overview of effort to date by federal agencies. Chapter 3 offers specific recommendations for future effort and sets priorities within specific action areas. Chapter 4 considers the opportunities and obstacles for inter-agency coordination. Chapter 5 draws together both general and specific recommendations for a coordinated federal science and technology response to this issue, acknowledging the pragmatic challenges that are known or expected. Appendix I provides a summary of the roles and responsibilities of the participating federal agencies on the marine sound issue; it also includes a list of the agency representatives that contributed to the preparation of this report. Subsequent appendices are more detailed versions of Chapters 2 and 3, providing additional specific information on the current federal effort (Appendix II) and prioritized recommended future federal research and development (Appendix III).

## Task Force Conclusions and Recommendations

The Task Force considered both positive and negative outcomes of anthropogenic sound in the marine environment, both through direct use of acoustics for sensing and communication, and through the noise generated as an unwanted, but often unavoidable, aspect of essential human ocean-related activities (*e.g.*, shipping, marine construction, energy exploration and production). Additionally, we note that the scientific understanding and technologies that are needed to enable the federal government to

respond appropriately will, in some cases, be the same tools and technologies required to better execute federal national security and resource management missions. The full extent of research required to address the environmental consequences of anthropogenic marine sound can seem overwhelming. However, some clear, high-priority actions exist that should be undertaken collaboratively among federal agencies for effective action on this issue, including better understanding of the actual impacts of noise, both acute and cumulative.

Of these, the Task Force has identified both specific research action areas and general coordination recommendations which are of the greatest importance to the federal government. Table 1(below) provides an ordinal ranking of these *highest* priority research action areas, their associated suggested timelines (*i.e.*, short-term vs. long-term), and those agencies most likely to have leading/direct interest and/or secondary level of involvement. Each recommended research action area in Table 1 is subjectively categorized by the overall importance and social relevance of the work ("importance") and the relative level of effort required for significant progress ("effort"): (1) High importance/moderate effort; (2) High importance/high effort; (3) Moderate importance/moderate effort; (4) Moderate importance/high effort. [note: additional details regarding the research action areas specified here are given in Chapter 3 and Appendix III].

## *Table 1* – Overview of Highest Priority Research Recommendations

| Prioritized Recommended Federal Research Action Areas | Short or Long-term? | Relative Importance and Level of Effort * | Agencies Involved (see notes below) | General Subject Area(s) (described in Chapter 2) |
|---|---|---|---|---|
| **(1) Improve ability to identify and understand biologically-significant effects of sound exposure in order to improve effectiveness and efficiency of efforts to mitigate risk.** | Ongoing and long-term | **High Importance/ High Effort** | NOAA[1]MMC[2] NSF, USN, MMS | Effects of Sound |
| **(2) Hearing, physiological, behavioral, and effects data (*e.g.*, controlled exposure studies) for key species of concern (baleen whales, beaked whales, Arctic & endangered species).** | Ongoing and long-term | **High Importance/ High Effort** | USN[1], NOAA[2], NSF, MMS, MMC | Baseline Biological Information; Effects of Sound |
| **(3) Develop new technologies (*e.g.*, acoustic monitoring) to detect, identify, locate, and track marine mammals, in order to increase the effectiveness of detection and mitigation.** | Ongoing and short-term | **High Importance/ Moderate Effort** | USN[1], NOAA[1], MMS, NSF, USCG, ACE, DOT, FWS | Sound Sources and Acoustic Environment; Mitigation and Monitoring |
| **(4) Develop and validate mitigation measures to minimize demonstrated adverse effects from anthropogenic noise**. | Short-term and long-term | **High Importance/ High Effort** | NOAA[1], MMC[2], USN, MMS, NSF, FWS, USCG, ACE | Mitigation & Monitoring; Effects of Sound |
| **(5) Support the development, standardization, and integration of online data archives of marine mammal distribution, abundance, and movement for use in assessing potential risk to marine mammals from sound-producing activities.** | Ongoing, short, and long-term | **High Importance/ Moderate Effort** | NOAA[1], USN, FWS, MMS, MMC | Baseline Biological Information |
| **(6) Long term biological and ambient noise measurements in high-priority areas (*e.g.*, Arctic, protected areas, commerce hubs).** | Ongoing and long-term | **High Importance/ High Effort** | NOAA[1] USN, MMS | Sound Sources and Acoustic Environment |
| **(7) Test/validate mitigating technologies to minimize sound output and/or explore alternatives to sound sources with adverse effects (*e.g.*, alternative sonar waveforms).** | Long-term | **High Importance/ High Effort** | USN[1], NSF[1], MMS[1], NOAA, MMC, DOE | Mitigation & Monitoring |
| **(8) Explore need for and effectiveness of time/area closures versus operational mitigation measures.** | Ongoing and long-term | **Moderate Importance/ Moderate Effort** | MMS[1], NOAA[2], MMC[2], USN, NSF | Mitigation and Monitoring |
| **(9) Develop and improve noise exposure criteria and policy guidelines based on periodic reviews of best available science to better predict and regulate potential impacts.** | Ongoing and long-term | **Moderate Importance/ Moderate Effort** | NOAA[1], FWS[1], MMC[2], USN, MMS, NSF | Effects of Sound |
| **(10) Standardize data-collection, reporting, and archive requirements of marine mammal observer programs.** | Long-term | **Moderate Importance/ Moderate Effort** | NOAA[1], FWS[1], MMS, NSF, USN, USCG, MMC | Mitigation and Monitoring |
| **(11) Expand/improve distribution, abundance and habitat data for marine species particularly susceptible to anthropogenic sound.** | Ongoing and long-term | **Moderate Importance/ High Effort** | NOAA[1], FWS[1], USN, MMC, MMS | Baseline Biological Information |

Notes:
[*] note shading corresponds to four relative importance/effort categories; see text for more detailed explanation
[1] denotes agencies with a leading and/or direct interest on each recommended action
[2] denotes agencies with a secondary level of involvement in each recommended action

Many of the research action areas included in these recommendations are to some extent already being investigated or acted upon by some of the participating agencies in this task force. However, our intention is to focus on those action items and research recommendations that are most likely to remain important for the U.S. federal government, now and over the coming decade. Some of these will require prioritization and action by individual agencies; others will need more concerted inter-agency collaboration.

Perhaps the most important outcome of this report, and of the Task Force generally, is the increased coordination, communication, and planning across federal agencies on this important environmental issue. In order to sustain existing collaborations and enhance further coordination, the Task Force felt it was also imperative to identify the *highest* priority coordination action items. The Task Force feels these actions are critical for the successful implementation of this strategic plan and will ultimately maximize the diverse capabilities and perspectives of the federal agencies. These highest priority coordination action items include:

- **Sustained interagency collaboration and coordination, including:**
  - High-level, inter-agency coordination among individuals with sufficient authority to make timely planning and budget recommendations within their respective agencies; and
  - Program-level, inter-agency coordination among agency subject matter experts and program managers to implement directives and provide technical advice to leadership.

- **Enhanced communication and coordination on the marine sound issue with private sector interests and with the governments of other nations to reduce duplication of effort and advance a consistent scientific response.**
- **Continued efforts to streamline research permitting involving acoustic sources.**
- **Development of a biennial forum for information transfer to report on the results of inter-agency research to various stakeholders (*e.g.*, federal and state government agencies, industry, academia, public, educators, media, and environmental groups).**

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AAM | Active Acoustic Monitoring |
| ABR | Auditory Brainstem Response |
| ADC | Analog-Digital Converter |
| ATOC | Acoustic Thermometry of Ocean Climate |
| AUTEC | U.S. Atlantic Undersea Test and Evaluation Center |
| BEQ | Bachelor Enlisted Quarters |
| BRS | Behavioral Response Study |
| CA | Close Approach |
| CDFG | California Department of Fish and Game |
| CEE | Controlled Exposure Experiment |
| CETAP | Cetacean and Turtle Assessment Program |
| CFR | Code of Federal Regulations |
| CI | Confidence of Intervals; Co-Investigator |
| CINMS | Channel Islands National Marine Sanctuary |
| CITES | Convention on International Trade in Endangered Species |
| cm | centimeter(s) |
| CV | Coefficient of Variation |
| dB | decibel(s) |
| DDT | Dichloro-diphenyl-trichloroethane |
| DOC | Department of Commerce |
| DON | Department of the Navy |
| EA | Environmental Assessment |
| EFH | Essential Fish Habitat(s) |
| EIS | Environmental Impact Statement |
| EKG | Electrocardiogram |
| ESA | Endangered Species Act |
| Et seq | Et sequencial |
| FAO | Fisheries and Agriculture Organization |
| FEIS | Final Environmental Impact Statement |
| FF | Focal Follow |
| FM | Frequency Modulated |
| FMP | Fishery Management Plan(s) |
| FOEIS | Final Overseas Environmental Impact Statement |
| FONSI | Finding of No Significant Impact |
| FR | Federal Register |
| ft | feet |
| FWS | Fish and Wildlife Service |
| Gb | Gigabyte(s) |
| GOMEX | Gulf of Mexico |
| HMS | Highly migratory species |
| hr | hour |
| Hz | Hertz |
| IACMST | Inter-Agency Committee on Marine Science and Technology (United Kingdom) |
| ICW | Intra-Coastal Waterway |
| IUCN | International Union for Conservation of Nature and Natural Resources |
| JASA | Journal of the Acoustical Society of America |
| kHz | kiloHertz |
| km | kilometer(s) |
| km/hr | kilometer(s) per hour |
| kt | knot(s): nautical mile(s) per hr |
| LF | Low Frequency |



**Exhibit 4**

| | |
|---|---|
| m | meter(s) |
| Mb | Megabyte(s) |
| MBTA | Migratory Bird Treaty Act |
| MF | Mid-Frequency |
| mi | mile(s) (statute) |
| MICA | Mesure de l'Impact des Catures Accessoires |
| min | minute(s) |
| MMA | Marine Managed Area(s) |
| MMC | Marine Mammal Commission |
| MMPA | Marine Mammal Protection Act |
| MPA | Marine Protected Areas |
| MSL | Mean Sea Level |
| NATO | National Oceanic and Atmospheric Administration |
| NEO | NOAA Executive Order |
| NEPA | National Environmental Policy Act of 1969 |
| NMFS | National Marine Fisheries Service |
| NMS | National Marine Sanctuary |
| NURC | NATO Undersea Research Centre (formerly SACLANTCEN) |
| NUWC | Naval Underwater Warfare Center |
| OEIS | Overseas Environmental Impact Statement |
| OPAREA | Operational Area |
| OPR | Office of Protected Resources |
| OV | Observation and tracking Vessel |
| Pa | Pascal |
| PAM | Passive Acoustic Monitoring |
| PB | Playback |
| PBV | Play Back Vessel |
| PCB | Poly-Chlorinated Biphenyls |
| Pers. Comm. | Personal Communication |
| ppt | parts per thousand |
| psu | Parts per thousand salinity units |
| PTS | Permanent Threshold Shift |
| RDT&E | Research, Development, Test and Evaluation |
| RL | Received Level |
| rms | root mean squared |
| SACLANTCEN | Supreme Allied Commander, Atlantic: Undersea Research Centre |
| SAG | Surface Action Group |
| SARA | Canada's Species at Risk Act |
| SCANS | Small Cetaceans in the North Sea |
| SCB | Southern California Bight |
| SCI | San Clemente Island |
| SCIUR | San Clemente Island Underwater Range |
| SCORE | Southern California Offshore Range |
| sec | Second(s) |
| SEL | Sound Exposure Level |
| SL | Source Level |
| SOAR | Southern California Anti-Submarine Warfare Range |
| SOCAL | Southern California |
| SONAR | SOund Navigation And Ranging |
| SPE | Society of Petroleum Engineers |
| SPL | Sound Pressure Level |
| Spp | Species |
| SRP | Scientific Research Permit |

| | |
|---|---|
| TAG | Tag Attachment Vessel |
| TL | Transmission Loss |
| TOTO | Tongue of the Ocean |
| TTS | Temporary Threshold Shift |
| U.S. or US | United States |
| U.S.C. | United States Code |
| UN | United Nations |
| USFWS | United States Fish and Wildlife Service |
| WHOI | Woods Hole Oceanographic Institution |
| WTV | Whale Observation/Tag tracking Vessel |

| **Symbols** | |
|---|---|
| = | Equal to |
| / | Divided by |
| + | Plus |
| ≥ | Greater than or equal to |
| > | Greater than |
| < | Less than |
| ~ | Approximately |
| ± | Plus or minus |
| µ | Micro ($10^{-6}$) |
| Log | Logarithm |