Scientific Research Caucus

STATEMENT

for The Report of the Advisory Committee on Acoustic Impacts on Marine Mammals to the Marine Mammal Commission

3 January 2006

SCIENTIFIC RESEARCH CAUCUS

Congress, through the Omnibus Appropriations Act of 2003, Public Law 108-7, directed the Marine Mammal Commission to "fund an international conference or series of conferences to share findings, survey acoustic 'threats' to marine mammals, and develop means of reducing those threats while maintaining the oceans as a global highway of international commerce." To meet this directive, the Marine Mammal Commission established the 28-member Federal Advisory Committee on Acoustic Impacts on Marine Mammals, composed of representatives from various stakeholder groups, including the scientific research community. This document describes the views of the Scientific Research Caucus on the issues discussed by the Advisory Committee.

The Scientific Research Caucus unanimously and strongly supports the *Report of the Federal Representatives of the Marine Mammal Commission Advisory Committee on Acoustic Impacts on Marine Mammals.*

Therefore, rather than provide a duplicate statement of areas of consensus, we submit the following supplemental statement covering areas in which the Research Caucus has particular expertise or concern.

Above Image: Pacific White-sided Dolphin. Photo ©Tom Kieckhefer. Cover Image: Killer whales travel in groups (called pods) of up to 30 individuals. They produce discrete calls that are specific to their pod. Photo © Tom Kieckhefer.

The following statement reflects only the views of the individuals listed as submitting authors. The inclusion of this statement does not indicate support or endorsement by other members of the Advisory Committee on Acoustic Impacts on Marine Mammals or by the Marine Mammal Commission.

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Scientific Research Caucus

STATEMENT

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Background Image: Humpback Whales. Photo © J. Mobley, NOAA Permit No. 642-1536.

BACKGROUND

Any discussion of sound in the sea must start from one basic fact: the ocean is largely transparent to sound, but opaque to light and radio waves. Light travels only a few hundred meters in the ocean before it is absorbed, but sound can travel much greater distances underwater. Marine mammals therefore rely on sound to sense their surroundings, to communicate, and to navigate. Similarly, oceanographers, fishermen, and submariners—in short, all who work in the ocean—rely on sound to sense their surroundings, to communicate, and to navigate.

Sound is an unavoidable and often intentional addition to the marine environment for virtually all human endeavors in the oceans. Short of abandoning all use of the seas, it is simply impractical, and indeed in many cases inadvisable, to say that no human-generated sound may be produced in the oceans. If we are to continue to explore and use our marine resources, we must determine the critical parameters for safe, sustainable use of the oceans. Active sonar systems are a fundamental tool used by all the navies of the world to accomplish their mission. Towed arrays of acoustic sources and receivers are used in geophysical exploration to create images of geological structures below the seafloor in order to locate oil and gas reserves. Over 90% of the world's commerce depends on transport on the high seas, which produces sound as a by-product. For the scientific community, sound production is fundamental to determining the basic properties of the ocean environment and studying the animals that live in it, including, for example, the development of a more complete understanding of marine mammal foraging, social behavior, and habitats. In addition, acoustics-based subsea imaging techniques provide the most effective means to document and analyze significant natural geological processes such as earthquakes, volcanic activity, and seafloor slides, that can have profound effects not only for marine life, but also for coastal and island communities, as recent world events have made painfully obvious. Sound in the sea is not just noise. It is used for a wide variety of valuable and important purposes.

Four reports published by the National Research Council (1994b, 2000, 2003, 2005) summarize the state of scientific knowledge on the issue of marine mammals and anthropogenic sound, the progress that has been made in understanding the issue over the last ten years, and recommendations for future research. These reports are thoroughly researched documents produced by balanced panels of scientific experts in the relevant fields. Independent experts anonymously reviewed the reports for scientific accuracy. Thus, these reports represent nearly a decade of balanced and comprehensive studies of our knowledge of anthropogenic sound and its potential impacts on marine mammals. The U.S. Commission on Ocean Policy (2004) also considered the issues related to protecting marine mammals, including those related to anthropogenic sound. Their recommendations are fully consistent with those made in the National Research Council (NRC) reports. The findings and recommendations in these reports provide excellent guidance for the way forward. We believe that the Federal Advisory Committee process was less well suited to provide a review of the science than the NRC process, and we will therefore not attempt a detailed synthesis of the relevant research here.

"The basic goal of marine mammal conservation is to prevent human activities from

Dr. Darlene Ketten uses computerized tomography and magnetic resonance imaging, along with traditional physical dissections, to get detailed information about the hearing structures of animals. Inthis image, Dr. Ketten is preparing a harbor porpoise for a CT scan. Photo courtesy of Tom Kleindinst, Woods Hole Oceanographic Institution.

harming marine mammal populations."

NRC, 2005

STATEMENT OF THE ISSUE

Marine mammals face many threats from human activities, including fisheries bycatch, habitat degradation, whaling, ship strikes, and anthropogenic sound. Preventing harm to marine mammal populations requires an accurate understanding of the threats facing them.

The U.S. Marine Mammal Protection Act (MMPA) was designed to protect marine mammals from intentional whaling and from unintentional bycatch in fisheries. While the MMPA has reduced marine mammal bycatch in U.S. fisheries, globally hundreds of thousands of marine mammal deaths still occur annually from fisheries bycatch (Read *et al.,* 2003). Marine mammals are also killed by ship strikes, underwater explosions, and entrapment in power plants and other structures.

Sound is included in the list of threats because we know that it can affect marine mammals in a number of ways. It can alter behavior or compete with important signals (masking). Sound can cause temporary hearing loss or, if the exposure is prolonged or intense, permanent hearing loss. It can even cause damage to tissues other than the ear if sufficiently intense. At present, our knowledge of the extent and nature of these threats for marine mammals is severely limited.

Anthropogenic sound has also emerged as the most likely cause of some marine mammal strandings based on an association between the location and timing of naval activities using active sonar and mass strandings of beaked whales in their vicinity (Cox *et al.,* 2005). (Mass strandings are defined as the stranding of two or more animals simultaneously or in close proximity.) There are multiple causes of strandings, some natural and some related to human activities. Natural causes include toxic algal blooms, disease, and storm surges. Human activities that cause strandings include ship strikes, entanglement in fishing gear, and pollution. On average approximately 3,600 stranded marine mammals were reported per year in the United States alone during the period 1990–2000 (NMFS, 2000). Beaked whale strandings are uncommon and mass strandings of beaked whales are extremely rare. Seventeen beaked whales strandings were reported in the U.S. in 1999 and five in 2000, for example (NMFS, 2000).

The best-documented mass strandings of beaked whales involving activities using high-level, mid-frequency active naval sonar occurred in Greece (1996), the Bahamas (2000), Madeira (2000), and the Canary Islands (2002). In these cases, there is sufficient information about the sonar operations and the times and locations of the strandings to associate the strandings with the naval activities. Each stranding involved between 4 and 18 whales that were found stranded within two days of the sonar use. Approximately half of the stranded animals were found dead or subsequently died, for a total of nearly 40 known animal deaths in the four events. No deaths in any other

family of marine mammals have been clearly associated with sound (NRC, 2005; Cox *et al.*, 2005). Although these strandings are closely related in time and space to active naval sonar operations, the mechanism by which the sonars could have caused the strandings or the traumas observed in some of the stranded beaked whales is unknown.

The small number of known animals involved in the few well-documented strandings associated with active naval sonar activities does not provide adequate evidence to conclude that sound poses a global and critical threat to marine mammals. Until we have a full understanding of these events, however, it is appropriate to be concerned and to continue the investigations needed to fully understand the exact role, direct or indirect, of sound use in them. Until a mechanism is determined, we cannot say definitively whether these stranding events represent unique circumstances that adversely affect relatively few individuals from a single family of whales or if this is a harbinger of a potentially broader problem of anthropogenic sounds adversely impacting other marine animals on wider geographic and temporal scales.

Further, it is important that we look not only at these relatively limited and possibly special cases, but also proceed with investigations that can inform us of other possible impacts in advance and prevent more subtle, but in the long term perhaps more significant, effects. We suspect that the most significant effects of sound on marine mammal populations are more likely to result from cumulative effects of chronic exposures to sounds that cause hearing loss or disrupt behavior and habitats, rather than from a small number of extreme events. Effective protection requires differentiating activities that cause minor changes in marine mammal behavior from activities that cause significant disruption of behaviors critical to survival and reproduction or that cause direct physical harm. The MMPA was originally written to reduce "takes"—mortality, injury, or harassment of marine mammals. The current regulatory framework under the MMPA is not well suited to reducing adverse impacts of cumulative effects of chronic exposure to potential stressors such as sound or chemicals.

A great deal of controversy surrounds the issue of marine mammals and anthropogenic sound. At present, how-

ever, it is not scientifically verifiable whether or not anthropogenic sound is a first order problem in the conservation of marine mammal populations. The most recent National Research Council report (2005) concludes:

> *"With the exception of beaked whale strandings, connections between anthropogenic sound in the oceans and marine mammal deaths have not been documented. In the presence of clear evidence of lethal interactions between humans and marine mammals in association with fishing and vessel collisions…, the absence of such documentation has raised the question of the relative importance of sound in the spectrum of anthropogenic effects on marine mammal populations… On the one hand, sound may represent only a second-order effect on the conservation of marine mammal populations; on the other hand, what we have observed so far may be only the first early warning or "tip of the iceberg" with respect to sound and marine mammals."*

The four reports published by the National Research Council (1994b, 2000, 2003, 2005) make recommendations for the research required to resolve this fundamental uncertainty.

Photo Below: Humpback whales are commonly sighted in nearshore waters near Kauai, Hawaii during the winter months. Photo courtesy of Ann Zoidis.

RISK ASSESSMENT

The issue of protecting marine mammals from adverse effects of sound shares similarities with the problem of protecting humans and wildlife from toxic chemicals. The classic way to manage this kind of problem is called risk assessment. We therefore argue that the intellectual framework required for thinking in a rigorous way about the threats to marine mammals and how best to ameliorate them is also that of risk assessment (Harwood, 2000; Tyack *et al.,* 2003/04). Risk assessment has been reviewed in several reports by the National Research Council (1983, 1993, 1994a) and by the Environmental Protection Agency (1992). It involves several stages:

- Hazard identification
- Exposure assessment
- Exposure-response assessment
- Risk characterization
- Risk management

Hazard identification. The first stage in risk assessment is called hazard identification. As early as 1971, scientists warned that the global increase in low frequency sound from shipping could reduce the range of communication in marine mammals (Payne and Webb, 1971). However, there is still no evidence to indicate whether or not this increased sound poses a hazard. Abundant studies describe how marine mammals avoid anthropogenic sounds, and other changes in behavior have also been described (e.g., Richardson *et al.,* 1995). However, a recent report of the National Research Council (2005) points out that we do not have the scientific techniques required to evaluate whether these changes pose a hazard to marine mammal populations. The one known lethal hazard related to sound involves the mass strandings of beaked whales associated with mid-frequency naval sonars.

Exposure assessment. The next step in risk assessment is exposure assessment. To predict the sound exposure at a marine mammal, one must know the characteristics of the sound source, how sound propagates through the ocean, and the hearing sensitivity of the species. The acoustic characteristics of human sources of sound and the propagation of sound in the marine environment are relatively well understood. It is unrealistic to expect that research conducted to understand effects of noise on marine mammals could make significant improvements in our knowledge of sound propagation. However, as the federal government develops ocean observatories, action agencies should be directed to include acoustic monitoring that can be used to measure trends in ambient noise at a variety of scales.

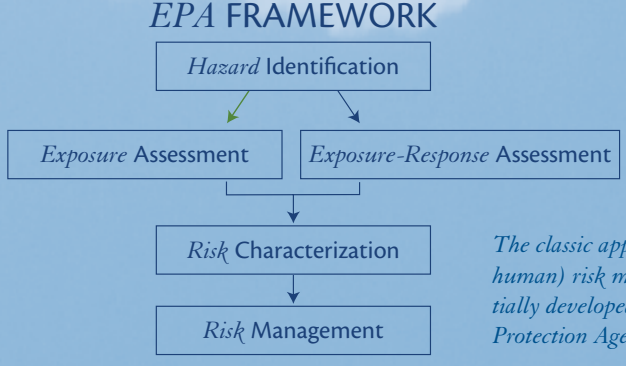
Assessing the exposue of marine mammals to a sound in a specific area requires knowledge of the distribution and abundance of all marine mammal species that can hear the sound in that area. The National Marine Fisheries Service (NMFS) conducts an extensive series of sighting cruises each year within the U.S. EEZ. However, these data are collected to assess the stocks or populations of marine mammals, and the analysis provided by NMFS is not suitable for predicting the probability of encountering animals at different ranges from a source. NMFS should make the raw data public, so that other analyses could be performed. Although this would help resolve uncertainties in U.S. waters, additional survey efforts will likely be needed. Many U.S. activities are conducted all over the globe, however, and additional coordination is required with other nations to predict which species might be exposed when sources operate outside of U.S. waters.

Coordination of data sharing with other nations will reduce uncertainty, but new survey efforts may be required.

Assessing exposure of animals requires knowledge of their hearing. Hearing ability has been measured in a few individual animals from species that can be trained in the laboratory, such as dolphins and seals. Recently researchers have developed a technique that can be used to study hearing in untrained animals in the wild (Nachtigall *et al.*, 2005). This technique is called auditory brainstem response, or ABR, and it depends upon detecting the electrical activity of the brain when an animal hears a sound. A research program should be developed to apply this technique to study hearing in whales and other species for which hearing has not been studied.

Exposure-response assessment. The next step in risk assessment involves determining how animals respond to a particular sound exposure. In recent years, this kind of dose-response study has been used to define what kinds of acoustic exposure begin to pose a risk to hearing in seals and dolphins. ABR studies can help extend these results to other species. However the greatest ambiguity of all for assessing the risk of sound on marine mammals involves our uncertainty in what kind of behavioral response is evoked by a specific dosage of sound. In many cases, we do not even know the correct way to represent the sound dosage. The behavioral responses an animal makes to a sound are more variable than physiological responses, and can depend on the species, population, age-sex class, behavioral context, hearing sensitivity, and history of exposure of the individual. It is impossible to study responses of all species to all sounds, so studies must be prioritized based upon expectation of the potential for harm.

Risk characterization and risk management. Once one can characterize the exposure of animals to a sound source, and one knows the relationship between exposure and the effects of concern, it is possible to calculate the total effect of the summed exposure to characterize the hazard to the population. If the hazard is significant enough to require management, then a final stage involves comparing the benefits of different strategies to manage the risk. Many management strategies in use today involve shutting down a source when animals are detected within a zone of adverse impact. There are considerable uncertainties about the effectiveness of different methods for detecting animals, however. Another management strategy is to slowly increase the level of a source when it is turned on, to give animals an opportunity to move out of harm's way, but there are few data to confirm whether this strategy is successful or not.



The classic approach to environmental (and human) risk mitigation uses aframework initially developed by the US Environmental Protection Agency

Background Image: Humpback whales are known for their songs. These songs, most often heard on their breeding grounds, are associated with courtship displays. Photo ©Tsuneo Nakamura.

RECOMMENDATIONS

Risk assessment methodology provides the framework for rational management of the risks from various threats to marine mammals. In many, if not most, cases the information needed to conclude that a given source of sound will result in biologically significant effects is simply not available (NRC, 2005). There is therefore an urgent need for a *U.S. National Research Program on Marine Mammals and Sound* that engages multiple federal agencies in order to provide the needed information. A second implication is that there is an urgent need for developing a process for *Rational Management with Incomplete Data,* by "identifying activities that do not reach a de minimus standard for biological significance" (NRC, 2005). A related, but distinct, issue is that the complex and lengthy permitting process under the MMPA, ESA, and NEPA has become a major impediment to conducting ocean research, hindering the research needed to improve our understanding of the effects of anthropogenic sound on marine mammals and of the environment in which they live. The ocean science community is urgently in need of an *Improved Regulatory Process* designed to foster badly needed research, while ensuring protection for marine mammals. Finally, given the controversy and misinformation surrounding the topic of marine mammals and sound, there is a need for a program of *Public Education and Outreach*.

U.S. NATIONAL RESEARCH PROGRAM ON MARINE MAMMALS AND SOUND

We strongly endorse the following recommendation by the U.S. Commission on Ocean Policy (2004):

Weddell seals locate breathing holes by listening for cracking ice at the surface. Photo courtesy of Michael Van Woert, NOAA, NESDIS, ORA.

Recommendation 20–9. The National Science Foundation, National Oceanic and Atmospheric Administration, U.S. Geological Survey, and Minerals Management Service should expand research on ocean acoustics and the potential impacts of noise on marine mammals. These additional sources of support are important to decrease the reliance on U.S. Navy research in this area. The research programs should be complementary and well coordinated, examining a range of issues relating to noise generated by scientific, commercial, and operational activities.

Hearing sensitivity studies provide information on what frequencies an animal can hear and how loud a sound must be to be heard. This dolphin is stationed underwater, waiting for the presentation of a sound from an underwater speaker. A suction-cup hydrophone is attached to its chest to record heartbeat sounds. In this experiment, heart rate changes were used as a response to sounds presented. Photo courtesy of Jen Miksis, University of Rhode Island.

A U.S. national research program should be established to support research to understand interactions between marine mammals and all sources of sound in the world's coastal and global oceans. This should be an interagency program with a mechanism to allow the participating Federal agencies to coordinate decisions with regard to disbursement of funding. Provision should be made to allow private, as well as public, funders to contribute to this program. At the U.S. federal level, participating agencies should include the National Science Foundation, U.S. Navy, National Oceanographic and Atmospheric Administration, Minerals Management Service, U.S. Fish and Wildlife Service, and other interested agencies. Diversity of funding sources is essential to bring a variety of perspectives to the research program and to help maintain the long-term stability needed for research on marine mammals.

The first step in this national research program would be a national workshop charged with converting the research recommendations in the National Research Council reports (NRC, 1994b, 2000, 2003, 2005) into a research strategy and implementation plan. We recommend that a national program office be established to assist with coordination and public outreach. The research strategy and implementation plan should call for proposals from the broad scientific community, including those at universities and at research institutions outside of the mission and regulatory agencies, to ensure that the greatest possible pool of expertise is brought to bear on the problem. In addition, since one obstacle to progress in the required research is a shortage of trained personnel, the research strategy and implementation plan should include a component designed to increase graduate student and postdoctoral training and participation in the research projects. Although it would be a U.S. national program, the goal is to foster a cooperative, international research effort as soon as possible. This is, in fact, a global issue and its solution will be best sought via international cooperation. The total program should grow over its first 3-4 years to a funded level on the order of $25M/year. New appropriations to the participating agencies are required to support this activity.

The well-established procedures of the scientific process should be followed in

this program. For example, all grants under the program would be competitively selected using established peer review procedures. Each year, a Program Announcement will be published defining the priorities for the program. The content of the program announcement would be agreed to by the agency program managers, but would be based on priorities determined by input from all stakeholders. The program should place strong emphasis on the open, peer-reviewed publication of research results. An initial 10-year commitment should be made to support this program, at which time a thorough, independent, expert review of accomplishments is important.

Marine Mammal Observers watching for whales & dolphins from the flying bridge of R/V Maurice Ewing in the Northern Gulf of Mexico, May, 2003. Photo courtesy of John Diebold, L-DEO.

Appendix A provides an initial assessment of research priorities, using the risk assessment framework to prioritize the research recommendations in the NRC reports (1994b, 2000, 2003, 2005).

RATIONAL MANAGEMENT WITH INCOMPLETE DATA

In the long term we strongly support the recommendation of NRC (2005) that a conceptual model, such as the Population Consequences of Acoustic Disturbance (PCAD) model "should be developed more fully to help assess impacts of acoustic disturbance on marine mammal populations. Development of such a model will allow sensitivity analysis that can be used to focus, simulate, and direct research..." The U.S. National Research Program should be designed to provide the data needed to populate, refine, and complete the PCAD model developed by the NRC in its 2005 report. This type of risk assessment model not only serves as a framework for identifying existing data gaps, but also ultimately provides the mechanism needed to assess the likelihood that specific acoustic sources will have adverse effects on marine mammal populations. Development of the PCAD model would provide the scientific foundation to move toward the recommendation of NRC (2005) that in the long term management actions regulating "takes" should be based on the concept of Potential Biological Removal (PBR), broadened to include behavioral effects.

Development of the PCAD model is some years in the future, however, and in the interim NRC (2005) recommends determining a de minimus standard for deciding which sound-related activities require authorization for "takes." Although there are substantial gaps in our knowledge concerning the issue of marine mammals and sound, it is still possible using our current knowledge and the framework of risk assessment to "identify activities that have a low probability of causing marine mammal behavior that would lead to significant population effects" (NRC, 2005). For example, activities that result in exposure of only a very small fraction of a population are unlikely to lead to population level effects, except in the case of highly endangered populations where every individual is significant. In another example, activities in which exposure results in only minor behavioral responses that are well within the

range of natural behavioral variability are unlikely to cause biologically significant effects. The fact that we are far from knowing all that we need to know about marine mammals and sound does not mean that we do not know anything. Congress should provide the necessary funding and direct the agencies to work with the scientific community to develop an intelligent decision system for identifying activities that do not reach a *de minimis* standard for biological significance (NRC 2005). Congress should also direct the agencies to develop a PBR-like regime for all forms of "take."

IMPROVED REGULATORY PROCESS

From the perspective of the scientific research community, a related problem is that the current regulatory structure makes obtaining the necessary authorizations for using sound in the sea for scientific research purposes so time-consuming and expensive that it is having a chilling effect on a wide variety of important and valuable uses of sound in the ocean, as well as on the very research needed to improve our understanding of the impacts of underwater sound on marine life and of the environment in which marine animals live. The implications are:

- The permitting and authorization process for scientific use of sound in the ocean urgently needs to be streamlined, so that it is timely, predictable, and assures compliance with all applicable legal requirements.
- The regulatory agencies need to be provided with the necessary resources to fulfill their mandates with oversight to assure that permits are being reviewed and given in a timely manner. Both NMFS and USFWS require additional funding to adequately fulfill their regulatory mandates.

Experimenter holding infant stranded Risso's dolphin while testing hearing using Auditory Evoked Potential (AEP) procedure (Nachtigall et al, 2005).

The various NRC reports and the U.S. Commission on Ocean Policy (2004) all agree that the current regulatory structure requires improvement and make a number of specific recommendations for doing so. NRC (1994), for example, suggests that a set schedule should be established for processing applications for scientific research permits to provide applicants with assurance that applications will be processed within a set period of time. Most research proposals to the federal government take about nine months to be funded. If permit processing had a deadline less than this duration, it would make the permit process much less onerous to research. Recent litigation has increased the burden on NMFS and USFWS for authorizing research, including environmental assessments under NEPA. The agencies must be provided with adequate resources to ensure timely authorizations that can stand up in court. We support the efforts of NMFS to develop general authorization procedures for common research activities, but note the need for this to be combined with streamlined authorization of individual research projects.

Effective protection of marine mammals requires that finite regulatory resources and efforts should be devot-

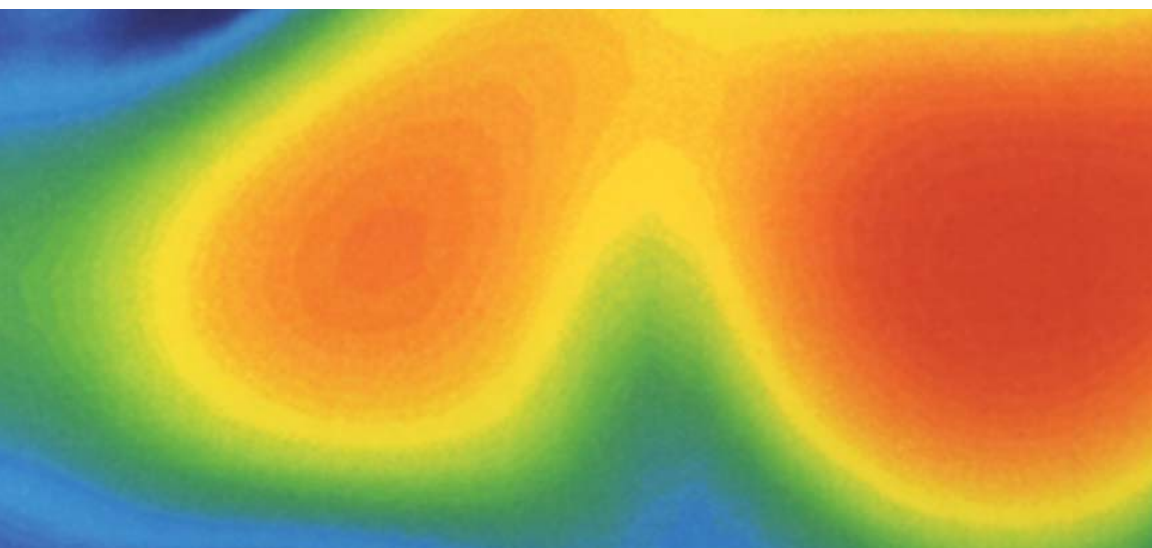
ed to the management of activities with potentially serious impacts on marine mammals, rather than to the management of activities that potentially cause momentary and inconsequential changes in behavior. NRC (2000) concluded that it "does not make sense to regulate minor changes in behavior having no adverse impact; rather, regulations must focus on significant disruption of behaviors critical to survival and reproduction." Unfortunately the Marine Mammal Protection Act has at times been interpreted to mean that any *detectable* change in behavior constitutes harassment that requires permitting (Swartz and Hofman, 1991). The U.S. Commission on Ocean Policy (2004) concluded:

> *Recommendation 20–6: Congress should amend the Marine Mammal Protection Act to revise the definition of harassment to cover only activities that meaningfully disrupt behaviors that are significant to the survival and reproduction of marine mammals.*

The recommendations made in the NRC reports are fully consistent with this recommendation. The need for this redefinition was highlighted in the testimonies of members of the scientific research community during the 2003 Congressional proceedings involving the reauthorization of the MMPA (Ketten, 2003; Tyack, 2003; West, 2003; Worcester, 2003). The Research Caucus urges Congress to make the suggested changes to the definition of harassment.

PUBLIC EDUCATION AND OUTREACH

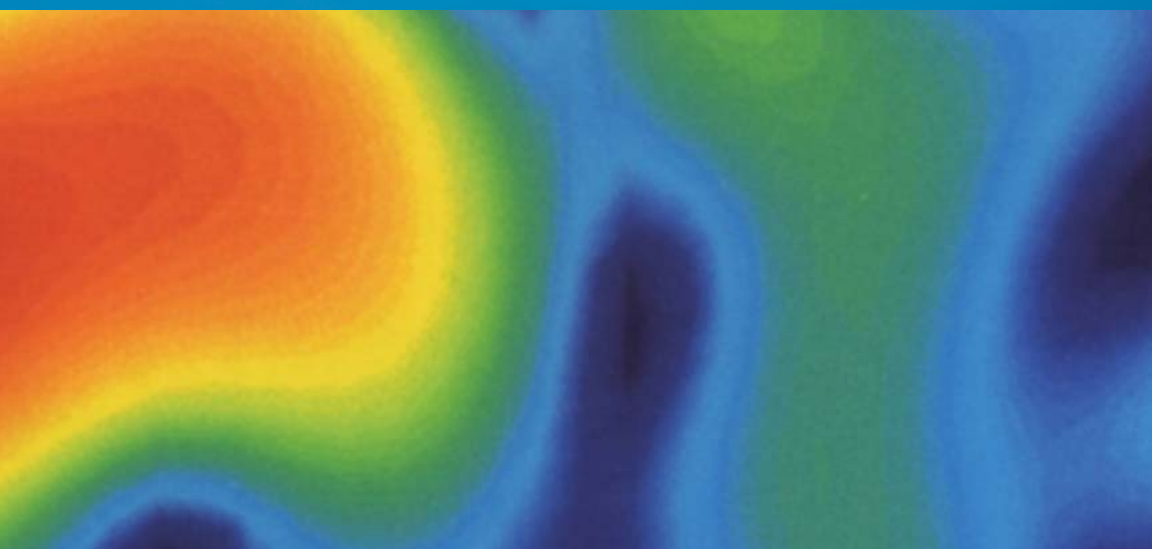
Given the controversy surrounding the issue of marine mammals and anthropogenic sound, it is extremely important that scientifically valid information be readily available to the public. One of the few such sources of scientifically sound information available to the public and the educational community is the *Discovery of Sound in the Sea* web site (www.dosits.org). This web site provides information on the basic science of sound in the sea, on how both animals and people use sound in the sea, and the effects of anthropogenic sound on marine life. One web site is not an adequate program of education and public outreach, however. A more complete, coherent program is needed. The educational efforts should also include programs to educate producers of ocean sound. The educational and outreach program could be included as part of the *U.S. National Research Program on Marine Mammals and Sound* recommended above.



SUMMARY

The recommendations given above are not new. Fundamentally the same recommendations were made by the scientific community in the National Research Council reports (1994b, 2000, 2003, 2005), in testimony to Congress (Ketten, 2003; Tyack, 2003; West, 2003; Worcester, 2003), and in published papers (e.g., Tyack *et al.*, 2003/04; Worcester and Munk, 2003/04). Fundamentally the same recommendations were made by the U.S. Commission on Ocean Policy (2004). It is time for action if we are to develop the knowledge needed to effectively protect marine mammals from the threats facing them.

Image Below: Forward-looking sonar systems provide a three-dimensional picture of the ocean depths and any submerged obstacles ahead of a vessel. These systems are able to detect marine animals that are in the water. This is an example from a 1998 test involving northern right whales. The range to the animal is about 50 meters and the water depth is approximately 40 meters. The colors indicate target strength, ranging from red (strongest) to blue (weakest). Image courtesy of Jim Miller, University of Rhode Island.



APPENDIX. RESEARCH PRIORITIES

Risk assessment methodology provides a framework to prioritize different research needs. We suggest differentiating between specific research projects likely to resolve critical management issues in a well-defined time and longer term research programs that are highly relevant to management but that require regular sustained funding over long periods to provide basic support for management decisions. We set priorities for targeted projects, but list with no prioritization the longer term areas requiring increased support.

The research area with the greatest uncertainty and the greatest opportunity for directing management decisions in the next decade involves effects of sound on marine mammals. There are a variety of areas where targeted research programs would be likely to resolve critical uncertainties within a 5–10 year period. These should be the top priority research recommendations.

Of special immediate concern is research to understand the one case where exposure to underwater sound has been related to mortalities – the relation between mid-frequency sonar and mass strandings of beaked whales (Cox *et al.,* 2005). We recommend a directed research program to decrease response times for experts in pathology to study stranded animals associated with sound, to standardize data collection and reporting from strandings associated with sound, and to determine, where possible, any human activities coinciding with the stranding that might be involved in the event. This program should also support rigorous scientific studies to test all feasible hypotheses of mechanisms consistent with the observed traumas. If new mid-frequency sonar signals can be designed to reduce impact on beaked whales while retaining the military sonar function, cooperative analyses of these alternate signals should be a high priority and should be conducted employing combined expert analysis of potential behavioral and physiologic responses to the new source characteristics. Questions have been raised about the effect of low frequency sonar and airguns on beaked whales, but the evidence for an association with stranding is much weaker for these sources. Therefore, testing these signals should be a lower priority, but to assure all impacts are considered and because of the value of comparisons from responses to non-traumatic sources, some funding should be devoted to these as well as other common man-made sound sources such as conventional fish finding and research sonar, noise associated with construction, shipping, etc.

Another area of immediate importance involves research to evaluate untested assumptions used in current management. Of high importance is testing whether different marine mammal species avoid intense sources such as airguns at ranges sufficient to prevent injury and to test the effectiveness of ramp up as a mitigation tool. Determinations of level of impact depend critically upon such untested assumptions, but these can be tested within five years using existing methods through a focused research program.

Most monitoring and mitigation plans rely heavily on visual observers to sight marine mammals. There is a low probability of sighting many species under most conditions. Recent work has demonstrated that passive acoustic monitoring can enhance monitoring efforts, and there has been preliminary research on new techniques such as whalefinding sonar and radar. A high priority for improving the effectiveness of mitigation efforts involves research to test the effectiveness of these different methods and how to optimally integrate them. Such an effort should have the goal of improving the effectiveness of monitoring by an order of magnitude within 5–10 years.

Of longer term importance is research to test whether there is a hazard from currently unregulated sources of sound. The potential effect of low frequency ship noise on animals sensitive to low frequencies is perhaps of highest importance here, since ship noise has increased global ambient noise and is relevant for endangered baleen whales. We know that shipping has

elevated average noise levels ten to 100 fold in the frequency range at which baleen whales communicate, but we have no evidence whether this poses a risk of adverse impact. A 5–10 year research program focused on studying the effective ranges of communication in these whales (especially calls used for breeding), studying effects of shipping noise on communication, and studying whether they have mechanisms to compensate for increased noise could help resolve this uncertainty. These studies should be balanced with continued research on risk factors for ship collision in baleen whales, which is known to be a significant hazard for some populations, and involves lack of response or insufficient response to the sound of oncoming ships.

High frequency sound travels less far than low frequency, but the increase in high frequency sources such as acoustic devices designed intentionally to harass marine mammals creates a priority for studying the impacts of these devices on coastal toothed whales that use high frequencies. The few studies on these impacts suggest strong avoidance responses at low received levels. We recommend continued funding for studies of the impact of these sources on toothed whales, especially porpoises and river dolphins.

Another area that may not yield immediate results, but will be critical to improve judgments of biological significance of disturbance was highlighted by the NRC 2005 report. There are few if any models or methods available to calculate the effect specific disturbances will have on vital rates of individual animals. If policy is to move towards population analysis of the consequences of acoustic disturbance, there must be new funding to start a completely new area of research on this topic.

Summary of research priorities for focused projects in order of priority

1. Study effects of mid-frequency sonars (and airguns and alternate sources) on odontocete whales (with focused effort on beaked whales where possible).
2. Test assumptions about which species avoid intense sound sources enough to avoid adverse impact, including testing ramp-up.
3. Develop new methods to monitor, detect, and/or predict the presence of marine mammals and test their effectiveness
4. Test effects of low frequency shipping noise on baleen whales, which are presumed to use low frequencies.
5. Test effects of high frequency sound sources designed to affect marine mammals on coastal species specialized for high frequencies.
6. Develop new modeling and empirical efforts to link changes in behavior and physiology to vital rates of individuals.
7. Tie controlled laboratory data to expanded field tests.

Summary of research projects requiring sustained funding to reduce important uncertainties.

These are important, but are judged less likely to provide rapid resolution of management problems. They are therefore not ranked in priority.

- Design acoustic sensing for ocean observation networks capable of monitoring ambient ocean noise levels and trends on global, regional, and local scales.
- Survey the status, abundance, and distribution of marine mammals globally to develop an improved capability for assessing the exposure of marine mammals to sound producing activities.
- Develop a broadly accessible data base of results from strandings with standardized necropsies capable of detecting most causes of death.
- Support the development of more sophisticated methods to sample behavior and physiology of marine mammals both in the laboratory and in the wild.
- Support long term field studies of baseline behavior for selected marine mammal populations.

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Report production provided courtesy of the Center for Earth Observations & Applications (CEOA), UCSD.