Marine Mammals and Noise

A Sound Approach to Research And Management

A Report to Congress from the Marine Mammal Commission

March 2007

Cover Photo: Blainville's beaked whale, or dense-beaked whale, (*Mesoplodon densirostris*) photographed off Kona, Hawaii, by Chris Newbert, Minden Pictures

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EXECUTIVE SUMMARY

Human activities are increasing the level of sound in the oceans, causing widespread concern about potential effects on marine mammals and marine ecosystems. Major human sources of sound include seismic surveys for oil and gas exploration and scientific research; commercial shipping for transportation of goods; and sonar systems for military purposes, fishing, and research. Sound also is important to marine mammals for communication, individual recognition, predator avoidance, prey capture, orientation, navigation, mate selection, and mother-offspring bonding. Potential effects of anthropogenic sounds on marine mammals include physical injury, physiological dysfunction (for example, temporary or permanent loss of hearing sensitivity), behavioral modification (for example, changes in foraging or habitat-use patterns, separation of mother-calf pairs), and masking (that is, inability to detect important sounds due to increased background noise). For individual animals, such effects and their secondary consequences may vary in significance from negligible to fatal—the worst outcome being documented in a small number of cases. The implications for conservation of marine mammal populations are undetermined.

In the late 1960s and early 1970s Congress provided a framework for protecting marine mammals and marine ecosystems when it passed a suite of environmental laws including the Marine Mammal Protection Act (MMPA), Endangered Species Act (ESA), and National Environmental Policy Act (NEPA). The MMPA provides a general prohibition on activities that take marine mammals, with limited exceptions for scientific research, commercial fisheries, subsistence harvest by Alaska Natives, activities that take marine mammals incidentally but that have a negligible impact on their populations, and military activities deemed essential for national defense. The ESA prohibits the taking of marine mammals listed as endangered or threatened, also with some exceptions. The NEPA requires that major federal actions that would have a significant impact on the environment—including those involving anthropogenic sound—be assessed to inform decision-makers about the consequences of such actions and alternatives to minimize impacts. With respect to sound effects, the management framework has been of limited effectiveness largely because of the considerable uncertainty regarding those effects, inadequate attention to management of certain sound producers, inadequate monitoring and mitigation methods to characterize and avoid or minimize effects, and implementation strategies that have proven to be less than optimal.

To address these matters, in 2004 Congress 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" (Public Law 108-7). The Commission convened an Advisory Committee on Acoustic Impacts on Marine Mammals and sponsored a series of meetings and workshops to gather information necessary to carry out the directive and prepare this report.

Important progress has been made toward understanding sound and its potential effects on marine mammals. The research effort has been led by the U.S. Navy with significant contributions by the Minerals Management Service, National Oceanic and Atmospheric Administration, National Science Foundation, several industry groups, and scientists from the academic community and private sector. In addition, the National Research Council has conducted four reviews of the sound issue, providing important recommendations for future research to address remaining uncertainties.

Despite these commendable efforts, the effects of anthropogenic sound on marine mammals remain uncertain and, as yet, the significance of sound as a risk factor cannot be assessed reliably. Other human-related risk factors appear to be at least as great a threat to marine mammals as is human-generated sound. For example, all known marine mammal mortalities caused to date by anthropogenic sound involve a limited number of species and are at least an order of magnitude less than the number of cetaceans killed annually in direct fisheries bycatch. However, because our ability to observe potential sound effects is limited, the documented level of mortality may be a poor indicator of actual effects. The 2005 National Research Council report indicated that "...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 warnings or 'tip of the iceberg'...." We can be certain that the need to address this issue will increase over time as the Nation's human population continues to grow and concentrate in coastal areas and as commercial vessel traffic, oil and gas exploration and production, military exercises, and other ocean-related human activities—both anticipated and unforeseen—expand with that growth.

The challenge facing the concerned community of decision-makers, managers, scientists, sound producers, and conservationists is to gain an understanding of the effects of sound in the oceans and to manage those effects in a judicious manner. Doing so will require recognition of remaining uncertainties and provision of a suitable buffer to ensure marine mammal conservation, while also endeavoring to avoid or minimize unnecessary constraints on human activities that introduce sound into the oceans. The major unresolved elements of this issue are as follows:

- **Uncertainty regarding the risks to marine mammals and marine ecosystems**. Risk assessment requires research to identify and characterize sounds that may be hazardous to marine mammals, determine their level of exposure, assess their responses to such exposure, characterize the significance of those responses for both individual animals and their populations, and manage the resulting risks of adverse effects. Such assessment must address individual sound effects, cumulative effects of multiple sound exposures over space and time, and the combined influence of sound and other risk factors for marine mammals and marine ecosystems.

- **Inadequate monitoring and mitigation measures**. Existing monitoring and mitigation methods are not adequate for detecting the presence of marine mammals and discerning the impacts of sound exposure. More effective monitoring and mitigation measures are needed to determine whether (1) harmful effects occur, (2) such effects are biologically significant, and (3) measures taken to mitigate impacts are necessary and effective.

- **Regulatory inconsistencies**. The requirements and procedures for obtaining authorizations to take marine mammals differ among and within various groups of sound producers—for example, commercial shippers, fishermen and aquaculture operators, the military, the oil and gas industry, and the academic community. Even when the same provisions apply, implementation and enforcement are inconsistent. The current framework is not well suited for managing some activities, such as commercial shipping, which is a major source of ocean noise and which may result in the taking of marine mammals. Some modification of existing regulations and statutes is necessary to ensure that, where feasible, all sound producers are subject to consistent standards.

Delays in issuing research permits and take authorizations also have been identified as a significant element of the sound issue. The Commission believes that such delays result from inadequate implementation of the relevant statutes and regulations and could best be resolved with increased management resources and improved procedures rather than statutory and regulatory changes.

The two cornerstones of a national approach to the sound issue should be an expanded research program to improve our understanding and a more effective, comprehensive management approach to ensure marine mammal conservation while minimizing unnecessary constraints on sound-producing activities. With that in mind, the Marine Mammal Commission makes the following recommendations.

Recommendation 1: Establish a coordinated national research program on the effects of anthropogenic sound on marine mammals and the marine environment

Congress should establish a research program to improve understanding of anthropogenic sound, its biologically significant effects on marine mammals and marine ecosystems, and effective means for mitigating and monitoring those effects.

Administration—The research program should be guided by an interagency coordinating committee with representatives from the Navy, Minerals Management Service, National Oceanic and Atmospheric Administration, Fish and Wildlife Service, U.S. Geological Survey, National Science Foundation, Marine Mammal Commission, and any other agencies with related responsibilities or interest in this issue. As the agency responsible for oversight of marine mammal research and management in the United States, the Marine Mammal Commission is the most appropriate agency to chair the committee and would be pleased to do so. The initial charge to the committee should be preparation of a research plan to study anthropogenic sound and its effects on marine mammals. To address other significant threats to marine mammals and marine ecosystems the committee should be granted the flexibility to expand or modify its membership, scope, and activities once the initial sound research plan is completed and critical uncertainties are being addressed through well-designed research projects. This administrative recommendation satisfies Congress's mandate to the Commission to provide guidance on research and management related to the sound issue, but also maintains consistency with the Commission's larger statutory mandate to be attentive to all factors that threaten marine mammals and the ecosystems upon which they depend.

Program Direction—Direction for the research program should be described in a comprehensive five- to ten-year plan focusing on (1) improving understanding of sound in the marine environment; (2) characterizing sound effects on marine life, including marine mammals, at the individual, population, and ecosystem levels; (3) evaluating existing prevention, mitigation, and monitoring measures and (4) developing more effective management measures. The plan should—

- identify the critical uncertainties and establish research priorities,
- describe the scope, time, equipment/infrastructure, logistics, and funding needed for the research,
- specify lead and cooperating agencies for each task and their funding and other responsibilities,
- be updated regularly to incorporate new findings and information,

- ensure peer-review and prompt publication of research and monitoring results,
- be open to public review and comment, and
- promote public education and training of scientists and students.

Funding and Resources—In view of the variety of research topics to be addressed, the difficulty of working in the marine environment, and the extensive infrastructure required, a substantial investment is needed. The research caucus that participated in the Commission's Advisory Committee process recommended that new funding be provided to participating agencies with the amount increasing over three or four years to an annual level of $25 million. This amount presumably represents the required minimum investment in basic research but does not include the substantial logistical and regulatory compliance costs associated with that research (for example, applying for authorizations, completing environmental assessments, processing such materials by permitting agencies). Although intermediate levels of new funding (that is, less than $25 million) may be appropriate initially, the best basis for establishing long-term funding levels will be a comprehensive, integrated, and focused research plan.

Funding for the sound research program should not be taken from other areas of marine mammal research. Rather, the national sound research program should be funded with additional appropriations as necessary to undertake the cooperative long-term research program recommended by the interagency coordinating committee. Affected industries and others with related interests, expertise, and specialized equipment and logistic capabilities should be invited to participate in or contribute to implementation of the long-term program plan.

Recommendation 2: Establish consistent standards for the regulation of sound in the marine environment

With two exceptions, the Commission finds no basis for different regulatory treatment of the various sources of anthropogenic sound that are likely to take marine mammals incidentally. Those exceptions are commercial shipping, which is addressed under recommendation 7, and Department of Defense activities that are necessary for national defense and may be exempted in accordance with section 101(f) of the MMPA.

Congress should provide the National Marine Fisheries Service and the Fish and Wildlife Service authority to regulate all anthropogenic sound sources in the marine environment. In particular, Congress should require assessment of the effects of fishery and aquaculture activities as an objective of the national sound research program described under recommendation 1 and grant the National Marine Fisheries Service the authority and responsibility to regulate those effects.

Recommendation 3: Ensure that all sound producers comply with statutory and regulatory requirements

Requirements for authorization to take marine mammals incidentally should be applied consistently to all sound producers. For example, the Navy should obtain authorizations for taking marine mammals incidental to its various exercises and operations, and the oil and gas industry should obtain authorizations for all of its operations unless they meet the standards for exception. Similarly, the potential for disturbance by whale-watching vessels as well as small watercraft should be evaluated to determine if regulation is needed to avoid harmful sound-related effects. Congress should advise the National Marine Fisheries Service and the Fish and Wildlife Service that sound producers in U.S. waters and U.S. sound producers (including those receiving funding from U.S. sources) on the high seas are required to obtain necessary taking authorizations if their activities have the potential to kill, injure, or harass marine mammals. Congress also should advise the Services to take action necessary to ensure that authorizations are obtained when any taking is likely.

Congress should amend the MMPA to make incidental take authorizations under section 101(a)(5) available to all sound producers operating in U.S. waters, regardless of nationality, provided that the substantive requirements (for example, the negligible impact standard) remain in place. As reflected in recommendation 7, such an amendment, by itself, is unlikely to solve the problem of how best to authorize the taking of marine mammals incidental to commercial shipping.

Recommendation 4: Retain mitigation and monitoring as requirements of the authorization and compliance process and designate the evaluation of existing measures and development of more effective measures as high priorities for the national research program

Although the effectiveness of existing mitigation, monitoring, and reporting measures is a matter of debate, those measures are vital to validating assumptions regarding the nature and significance of sound effects and improving our ability to manage sound-producing activities. Measures should—

- minimize unnecessary sound production—for example, preclude repetitious seismic surveys of the same area when a single, comprehensive survey will suffice to provide the information needed by the oil and gas industry;

- promote sound-reducing technologies—for example, encourage the seismic industry to develop airgun arrays that direct virtually all of their energy straight down and inform ship-builders of the need for ship-quieting technologies that will reduce marine noise as well as improve sound conditions on those ships. Note that this latter example should be accompanied by a research program to ensure that quieter ships do not result in an increase in ship/whale collisions;
- implement temporal and spatial measures to avoid sound-producing activities in seasons and areas that are especially important in the life history of marine mammals; and
- use the assets of sound producers to enhance mitigation, monitoring, and reporting of sound effects—for example, use the variety of Navy range assets to study marine mammal responses to different types and levels of sound.

In view of the limited value of current mitigation and monitoring measures, Congress should require that the evaluation of existing methods and development of more effective methods be identified as high priorities of the national research program.

Recommendation 5: Require the National Marine Fisheries Service and the Fish and Wildlife Service to develop a management system that accounts for the cumulative effects of sublethal exposure to anthropogenic sound and other human impacts on marine mammals

Successful conservation strategies for marine mammals must take into account the full impact of human activities on them. The full impact is a function not only of direct mortality but also of sublethal effects (for example, changes in stress level, condition, health) that, when combined, may significantly influence individual reproduction or survival, the factors that ultimately determine a population's status. Such sublethal effects are a major concern regarding human-generated sound in the marine environment, and a management system is needed to account for them.

The potential biological removal (PBR) system has been used effectively to account for incidental mortality of marine mammals in commercial fisheries. Whether this system can be extended to account for the sublethal effects of other risk factors, including sound (National Research Council 2005), or would serve better as a model for a separate management system is not clear. Nonetheless, any comprehensive and effective management strategy must account for sublethal as well as lethal effects. With that in mind, Congress should require the Services to develop a management system that accounts for the cumulative effects on marine mammals of sublethal exposure to anthropogenic sound as well as all other human impacts.

Recommendation 6: Direct the National Marine Fisheries Service and the Fish and Wildlife Service to streamline their implementation of permitting and authorization processes for research on sound effects and for activities that may take marine mammals incidentally

Permitting and authorization processes could be streamlined without statutory or regulatory changes by combining analyses required under different statutes, conducting programmatic analyses to provide large-scale consideration of proposed actions, and invoking use of categorical exclusions where analyses are not required. Congress should advise the National Marine Fisheries Service and the Fish and Wildlife Service to implement options for streamlining environmental analyses to avoid delays in processing applications for take authorizations and research permits.

Recommendation 7: Promote U.S. leadership in international matters related to anthropogenic sound in the marine environment

The United States has an important opportunity to lead international efforts to address the effects of anthropogenic sound in the oceans. Such leadership is needed to promote research and sharing of information and to coordinate management strategies for regional and global sound-related issues. All the major sources of anthropogenic sound in the oceans are active on a global basis (that is, commercial shipping, seismic surveys and research, military and other sonar). Any comprehensive research and management approach must recognize that sound effects extend beyond national waters. Coordination of military exercises using sonar, development of ship-quieting technologies for commercial ships, and incorporation of ambient noise assessment into developing ocean observing systems are examples of activities requiring international leadership.

Shipping appears to pose a particularly difficult challenge. The vast majority of the commercial shipping fleet is registered outside the United States, and most shipping noise originates in international waters. Thus, it would be best to work within the international treaty structure to develop an appropriate framework for addressing this issue. Congress should direct the Department of State to consult with the interagency national research program on sound recommended earlier, the National Oceanic and Atmospheric Administration, the Department of Justice, the Marine Mammal Commission, and any other affected agencies to determine what shipping-related proposals should be made to the International Maritime Organization.

I. Introduction

Since passage of the Marine Mammal Protection Act of 1972 (MMPA), an increasing level of sound introduced into the oceans by human activities has caused widespread concern about potential effects on marine mammals and marine ecosystems. The initial concerns were precipitated by studies beginning in the late 1970s that revealed changes in the movements, dive patterns, and other behavior of ringed seals and beluga and bowhead whales caused by sounds associated with offshore oil and gas exploration and development in Canada and Alaska (Burns et al. 1982, Fraker and Fraker 1981, Awbrey et al. 1983). Subsequent studies in California found that the behavior of gray whales could be affected in a variety of ways by sounds associated with oil and gas exploration and other activities (Malme et al. 1983, Richardson et al. 1995). Further concerns were raised in the early 1990s by oceanographic experiments to determine if sound transmissions could be used to detect changes in ocean temperature indicative of global warming (Bowles et al. 1994, Advanced Research Projects Agency et al. 1995 a,b). Related concerns were raised regarding shock testing of new classes of Navy ships and submarines to evaluate their likely performance under combat conditions (*Natural Resources Defense Council* v. *United States Department of the Navy* 1994; Marine Mammal Commission 1995; Department of the Navy 1998, 2001). Substantial opposition and controversy developed in 1996 when the Navy made public its planned deployment of a new low-frequency active sonar system—the Surveillance Towed Array Sensor System Low Frequency Active Sonar (SURTASS LFA)—to detect and track new classes of quiet submarines at distances in excess of 200 kilometers (*Natural Resources Defense Council* v. *Evans* 2002). Arguably, many concerns were substantiated between 1996 and 2002 when a series of stranding events involving mostly beaked whales occurred in Greece (Frantzis 1998), The Bahamas (Anonymous 2001), Madeira (Evans and Miller 2004), and the Canary Islands (Fernandez et al. 2005) after exposure to sounds from mid-frequency tactical sonar used by the Navy.

During the course of these noted events, the level of human-generated noise in the ocean has been steadily increasing, with evidence suggesting a doubling in deep water over each of the past four decades (McDonald et al. 2006). In nearshore ecosystems, ongoing coastal development has almost surely increased the level of anthropogenic noise with uncertain but potentially significant cumulative effects on marine mammals and other marine life.

Marine mammals use sound for communication, individual recognition, predator avoidance, prey capture, orientation, navigation, mate selection, and mother-offspring bonding (Wartzok and Ketten 1999). Depending on their frequency, intensity, and duration, anthropogenic sounds may affect marine mammal behavior, mask important natural sounds on which they depend, and alter their physiological function and physical well being. As observed in The Bahamas (Anonymous 2001), the consequences for some individual marine mammals have been lethal. The effects on marine mammal populations are uncertain.

Human-generated sound was not widely recognized as a potential risk factor in the marine environment when Congress passed the MMPA. Nonetheless, in passing the Act, Congress sought to provide a mechanism to address contemporary and future risks to marine mammals, and human-generated sound is now recognized as such a risk. To manage the effects of anthropogenic sound more effectively, the central issues to be addressed are (1) the extent to which anthropogenic sounds pose a risk to marine mammals, their populations, and marine ecosystems, and (2) how to avoid or mitigate those effects that are biologically significant.

To date, commendable progress has been made investigating a range of anthropogenic sounds and their physical characteristics, propagation, and effects on marine mammals. That progress is based largely on research conducted by the Navy, with additional contributions by the Minerals Management Service, National Oceanic and Atmospheric Administration, National Science Foundation, industry, and scientists from the academic community and private sector. Nonetheless, critical uncertainties remain.

Faced with uncertainty about sound effects, decision-makers and managers are presented with difficult choices. On the one hand, they may assume that human-generated sounds have more impact than they actually do. The consequences could be over-regulation of sound-generating activities with little conservation benefit. On the other hand, they may assume that human-generated sounds have less impact than they actually do. Here, the consequences could be insufficient regulation of sound-producing activities with higher risk of long-term or irreversible adverse impacts on marine mammals and marine ecosystems. The challenge is to ensure conservation of marine mammals and marine ecosystems while avoiding or minimizing unnecessary impediments to human activities that introduce sound into the oceans.

Without rigorous scientific investigation and effective management, the effects of human-generated sounds on marine mammals and marine ecosystems will increase over time. The U.S. Census Bureau projects that the U.S. population will increase by 120 million by 2050,[1] much of it concentrating in coastal regions. The sound-related consequences of coastal construction and development, recreation, and other sound-generating activities are largely unstudied but may be significant and are likely to become even more so with increasing human numbers and activities. The Department of Transportation (1999) projects that commercial shipping will double in the first two decades of this century, likely involving more, larger, and faster vessels. Similarly, the

[1] http://www.census.gov/ipc/www/usinterimproj/natprojtab01a.pdf

Department of Energy projects energy consumption will increase by 71 percent between 2003 and 2030 (Energy Information Administration 2006), no doubt accompanied by increases in offshore seismic exploration and drilling for oil and gas. With growing demand for ocean resources, exploration of and activity over continental shelf and deep pelagic areas are likely to increase. These and other projections indicate that we must not only understand and manage the effects of sound in the marine environment, but we must do so ever more efficiently and effectively.

II. Congressional Directive

Recognizing the growing concern over the potential harmful effects of sound on marine mammals, Congress, through the Omnibus Appropriations Act of 2003, 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" (Public Law 108-7).

After consulting with congressional staff, the Commission convened the Advisory Committee on Acoustic Impacts on Marine Mammals and sponsored a series of committee and subcommittee meetings and workshops. Advisory Committee members (28 total; see Appendix 1) represented entities whose activities introduce sound into the marine environment (the academic research community, shipping industry, oil and gas industry, and government agencies), non-governmental conservation organizations, scientific research programs, and federal and state government agencies with responsibilities concerning or affecting marine mammals. The committee met six times between February 2004 and September 2005 and provided the Commission with views of interested stakeholders, the state of current knowledge on this topic, and best practices for management of acoustic threats to marine mammals. Although there was broad agreement that additional research is needed, views differed on the significance of the possible risks and the regulatory measures that should be instituted, given the current state of knowledge. At the conclusion of their activities, members or groups of members prepared statements summarizing their points of view (see caucus reports, Appendix 1).

Together with the United Kingdom's Joint Nature Conservation Committee, the Commission held a separate workshop in London to discuss international perspectives on the issue of sound and its potential effects on marine mammals. The goal of the workshop was to obtain information on (1) the range of existing efforts outside the United States to manage, mitigate, and prevent impacts of human-generated sound on marine mammals; (2) the extent to which legal and regulatory frameworks, other than those provided by U.S. domestic laws and regulations, address acoustic impacts on marine mammals; (3) cross-boundary or multilateral issues regarding the management and mitigation of acoustic impacts on marine mammals; and (4) innovative research, management strategies, and policies that might be incorporated within national and international frameworks. More than 100 participants from more than 20 countries attended. They emphasized the need for regional rather than global approaches to reduce sound-related threats, with more international dialogue, a widening of perspectives, and a strengthening of the scientific knowledge base to promote more effective management of possibly harmful sound sources (Vos and Reeves 2005; Appendix 2).

The Commission also held a workshop specifically on beaked whales. The stranding events mentioned earlier suggest that beaked whales are particularly vulnerable to mid-frequency naval sonar (Cox et al. 2006; Appendix 3). The workshop goals were to (1) assess current knowledge of recent stranding events involving beaked whales and their biology and ecology; (2) identify and characterize factors that may have caused those strandings; (3) identify data needed to determine possible causal relationships; and (4) recommend research, management, and mitigation strategies specific to beaked whales and acoustic impacts. The workshop reviewed a number of possible mechanisms by which mid-frequency sonar could contribute to the stranding and death of beaked whales. None of the mechanisms could be ruled out based on current knowledge, but a behavioral response initiating a sequence of physiological reactions culminating in formation of gas bubbles and hemorrhaging in critical tissues appeared to be the best candidate for further investigation. Recommended approaches included controlled exposure experiments to study behavioral reactions to certain types of sound, tagging studies to learn about the normal diving behavior of beaked whales, studies of anatomy and physiology to determine why these species are particularly susceptible to sonar, and more standardized and complete examinations of all stranded beaked whales, whether stranding occurred in association with sonar or not. The workshop also recommended a retrospective study of all strandings. Finally it noted the need for better monitoring techniques to assess serious injury and mortality levels and guide mitigation activities.

III. Human Sources of Sound in the Oceans

A variety of human activities introduce sound into the oceans, including commercial shipping, seismic surveys associated with oil and gas exploration and academic research, naval operations, fishing activities, marine recreation, and coastal development. At low frequencies, commercial shipping and seismic surveys are the dominant sources of anthropogenic noise. At middle and high frequencies, naval, commercial, fishery, and recreational sonars are dominant (Table 1).

The Nature of Sound

Sound is energy manifested as a vibration or acoustic wave traveling through a medium such as air or water. The energy is characterized using various parameters, such as sound pressure and intensity. By convention, scientists transform these parameters to logarithmically scaled decibel (dB) units. The transformed values are referred to as sound pressure level or sound intensity level. For underwater sound, the reference pressure level is one microPascal (μPa), hence units of dB re 1μPa. Because the measured pressure level from a particular sound source decreases with distance from the source, the convention is to use one meter as a reference distance. Thus, the pressure level from a sound source is described in units of dB re 1μPa @ 1m (hereafter referred to simply as dB). Because sound pressure levels may vary over time, measurements may refer to a maximum (peak) level or to an average (that is, root-mean-squared) level. The sound pressure level of a quiet restaurant (adjusted to a water reference) is about 63 dB, a vacuum cleaner about 93 dB, and a rock concert about 133 dB.

Frequency is the rate of vibration in cycles per second (Hertz; Hz) or thousands of cycles per second (kiloHertz; kHz). Frequency determines the pitch of the sound: the higher the number of cycles per second, the higher the pitch. Human hearing ranges from about 20 to 20,000 Hz; for music enthusiasts, middle C is defined as 440 Hz. A tone is a sound of a constant frequency that continues for a substantial time. A pulse is a sound of short duration, and it may include a broad range of frequencies. The same acoustic energy can be obtained from a pulse of high sound pressure level lasting a short time or a tone of lower sound pressure level lasting a correspondingly longer time. Because the range of frequencies of a sound source may vary, the sound's frequency bandwidth should be specified and included in the reference units. The units for a power spectrum are dB re $1\mu Pa^2/Hz$.

The oceans contain natural sounds and sounds introduced by human activities. Although the sources of some sounds in the ocean can be identified, the sources of others cannot and they are considered part of the background noise. Ambient noise—the noise at a particular point in time and space—consists of a broad range of individual sources, some identified and others not. Although individual sources contributing to ambient noise do not necessarily create sound continuously, ambient noise is always present. Because ambient noise may involve a broad band of frequencies, the convention is to describe its characteristics (for example, pressure level) in frequency intervals of 1 Hz.

Sound waves spread out and dissipate as they travel away from their source. In the oceans, the characteristics of a sound at a receiver depend on the characteristics of the source, the distance between the source and receiver, and the intervening environment. As distance between the source and receiver increases, environmental factors become more important in defining the characteristics of the sound at the receiver. If ocean properties were more or less constant and the ocean were unlimited in extent, the sound waves emanating from an underwater source would spread or propagate in an expanding spherical manner. But the ocean is not constant, varying in depth, temperature, salinity, bottom topography, surface conditions, and so on. Furthermore, not all sounds travel and dissipate in the same manner. High-frequency sounds attenuate more quickly than low-frequency sounds: a 100-Hz sound may be detectable after propagating hundreds or thousands of kilometers, whereas a 100-kHz sound may be detectable only for a few kilometers. Certain ocean conditions create sound waveguides, which contain and conserve sound energy so that it propagates long distances. The oceanic sound channel is a waveguide in which low frequency sound propagates distances on the scale of ocean basins.

Table 1. Sound characteristics of major sound producers (Hildebrand 2005)

Sound source	Primary frequency range	Sound pressure levels	Distribution	Total energy
Commercial shipping	5–100 Hz	150–195 dB re 1µPa^2/Hz @ 1 m	Great circle routes, coastal and port areas	3.7 x 10^{12}
Seismic airgun arrays	5–150 Hz	up to 259 dB	Variable with emphasis on continental shelf areas with oil and gas	3.9 x 10^{13}
Naval sonars	100–500 Hz (SURTASS LFA) 2–10 kHz (Mid-frequency sonar)	235 dB 235 dB	Variable below 70º latitude Variable with emphasis in coastal areas	2.6 x 10^{13}
Fisheries sonars	10–200 kHz	150–210 dB	Variable, primarily coastal and over continental shelf	Unknown
Research sonars	3–100 kHz	up to 235 dB	Variable	Unknown
Acoustic deterrents, harassment devices	5–16 kHz	130–195 dB	Coastal	Unknown

Commercial Shipping—Commercial shipping is a major contributor to noise in all the world's oceans (Ross 1976). Ships generate noise primarily by propeller cavitation, propulsion machinery, hydraulic flow over the hull, and flexing of the hull. Ships produce noise primarily in the low frequency band (5–100 Hz) but also at higher frequencies.[2]

[2] Peak sound spectral levels for individual ships range from 198 dB re 1µPa ^{2}/Hz @ 1 m for fast-moving (20 knots) container ships (Greene and Moore 1995) to 156 dB re 1µPa ^{2}/Hz @ 1 m for small watercraft (Kipple and Gabriele 2003).

Shipping vessel traffic is not uniformly distributed. Major commercial shipping lanes follow great circle routes or coastlines to minimize the distances traveled (Figure 1). Dozens of major ports handle most of the traffic, but vessels also use hundreds of small harbors and ports. Vessels outside major shipping lanes include those used for fishing, military purposes, scientific research, and recreation, the last typically found near shore. Although the sounds of nearby ships are individually discernible, the sounds of distant vessels are not and contribute to the background noise level over large geographic areas. Vessel operation statistics indicate a steady growth over the past few decades in both the number of commercial vessels and in the tonnage of goods shipped, according to Lloyd's Register of Shipping 2006.[3] Furthermore, as noted earlier, the Department of Transportation has projected that the tonnage of goods transported by commercial ships will double in the next few decades (Department of Transportation 1999), involving more and larger ships capable of traveling at greater speeds and likely generating more noise in the low frequencies of particular concern.

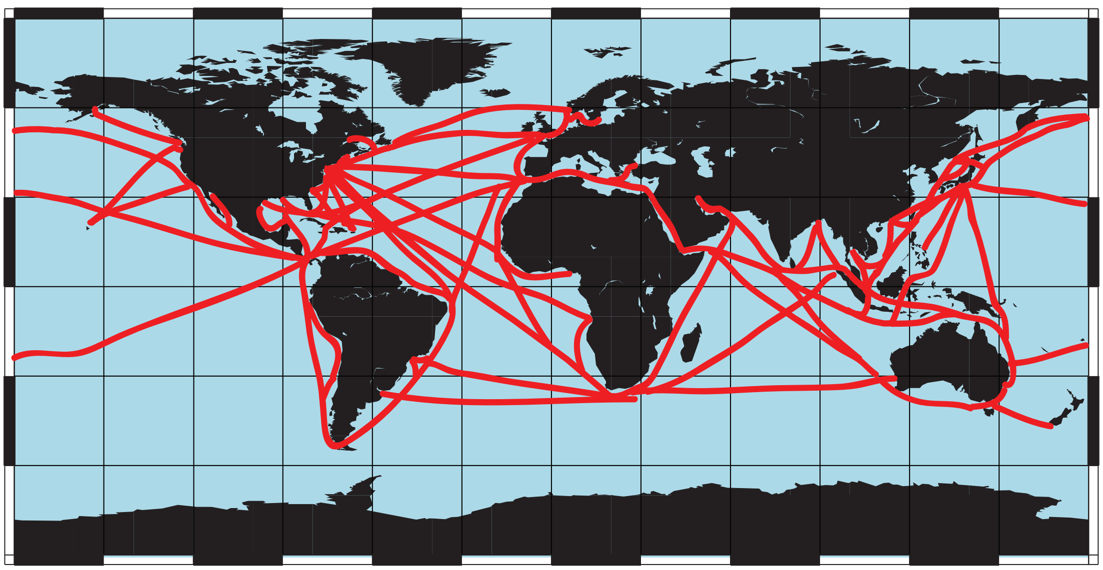

Figure 1. Major commercial shipping lanes of the world's oceans.

Seismic Surveys—Seismic surveys are another important contributor to low-frequency sound in the oceans (Hildebrand 2005). They are the primary means for finding and monitoring fossil fuel reserves and are used extensively by the oil and gas industry. They also are used by scientists to study the geology of the seafloor and the earth's crust, its role in plate tectonics, and such events as earthquakes and volcanoes. The sound-

[3] http://www.lr.org/Industries/Marine/Services/Shipping+information

producing elements in seismic surveys are arrays of airguns (Dragoset 2000).[4] To create the high sound pressure levels required, the airguns vent pressurized air into the water. Most of the resulting energy is low frequency (5–300 Hz), but some is at higher frequencies (Madsen et al. 2006).

The seismic survey industry that provides data to oil and gas companies operates about 90 ships worldwide with about one-quarter of them operating on any given day. Currently active areas include the waters off northern and south-central Alaska, eastern Canada, the United States and Mexican Gulf of Mexico, Venezuela, Brazil, West Africa, South Africa, the North Sea, the Middle East, northwestern Australia, New Zealand, southern China, Vietnam, Malaysia, Indonesia, and the Sea of Okhotsk (Figure 2). New areas of exploration in the past 5 to 10 years include the deepwater U.S. Gulf of Mexico and deep waters off West Africa. About 80 additional ships are capable of conducting seismic surveys for other purposes such as oceanographic research. Some of those vessels maintain heavy schedules (for example, ~150 days of operation per year for the

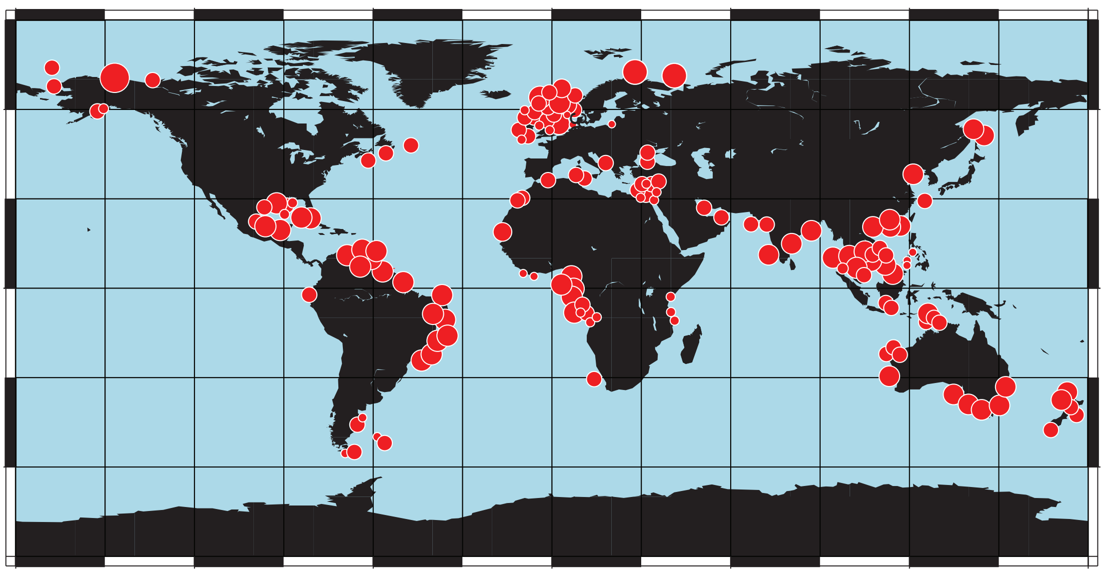

Figure 2. Major areas of oil and gas exploration and production in the world's oceans.

[4] A single airgun pulse lasts about 20 to 30 milliseconds, and pulses are generated every 10 to 20 seconds. Sound pressure levels near individual airguns are about 220 dB re 1µPa @ 1m (hereafter referred to as dB), but the combined source level output from an array of airguns, if viewed as a point source, can reach as high as 259 to 265 dB (Greene and Moore 1995). The airgun array directs sound mainly toward the seafloor, and sound levels in other directions are about 6 dB lower. Arrays used by the oil and gas industry typically involve 12 to 48 individual guns distributed over a 20-m by 20-m region and towed about 200 m behind a vessel. A seismic survey often involves a series of parallel passes through an area towing an airgun array as well as 6 to 10 seismic receiving streamers (hydrophone arrays). Repeated seismic surveys provide "time-lapse" or "4-D" views of producing oil fields.

R/V *Ewing* [University–National Oceanographic Laboratory System Council 2001]), although many conduct seismic surveys only on an occasional basis. Research surveys are conducted in a greater variety of settings, such as over extremely deep water and over tectonic features not associated with fossil fuels. A recent study of ambient noise in the North Atlantic (Nieukirk et al. 2004) revealed that airgun activity contributes significantly to ocean sound levels. Sounds propagated into the deep Atlantic Ocean were detected almost continuously during the summer at distances of more than 3,000 km from the sound sources.

Sonar—Sonar systems are used during naval, fishing, and research activities to probe the oceans, seeking information about objects within the water column, on the sea bottom, or within the sediment. The navies of a number of nations, including the United States, use sonars with different frequency ranges and high source levels during both training exercises and combat operations. The United States and several other countries have developed or are in the process of developing low-frequency active (LFA) sonars to search for, detect, locate, and track submarines over distances of hundreds of kilometers.[5]

A number of navies also use mid-frequency tactical anti-submarine warfare (ASW) sonars to search for submarines over shorter distances (for example, up to 60 km) (Gerken 1986, 655; Friedman 1997, 630). They are incorporated into the hulls of submarine-hunting surface vessels such as destroyers and frigates. The U.S. Navy currently has 117 of these sonars in active service, and equivalent systems in other navies bring the worldwide count to about 300 (Watts 2003).[6]

Other types of sonar systems are used by nearly all of the 90,000 vessels in the world's commercial fishing fleet and many of the 17 million small boats owned in the United

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[5] The U.S. Navy's Surveillance Towed Array Sensor System (SURTASS) LFA sonar uses an array of 18 projectors operating in the frequency range of 100 to 500 Hz, with 215 dB source level for each source element (Johnson 2001). The energy from these source elements is focused into a beam with combined array source levels of 235 dB or higher, projected in a horizontal direction. Transmissions include both constant-frequency and frequency-modulated components. A single transmission can last 6 to 100 seconds, with 6 to 15 minutes between transmissions and a typical duty cycle (portion of time system is actually transmitting) of 10 to 15 percent. Signal transmissions during training exercises may be emitted over the course of days or weeks (Department of the Navy 2001).

[6] The AN/SQS-53C (often referred to as 53-Charlie sonar) is the most advanced ASW sonar in use by the U.S. Navy (Anonymous 2001). It consists of a hull-mounted transducer array of 576 elements housed in a bulbous dome at a ship's bow. The AN/SQS-53C sonar generates frequency-modulated pulses of 1 to 2-second duration in the 1 to 5-kHz band, at source levels of 235 dB or higher. This sonar has a nominal 40-degree vertical beam width, directed 3 degrees down from the horizontal direction. It is used to track surface vessels as well as submarines.

States. They are used for finding fish, depth sounding, or sub-bottom profiling.[7] Depth sounders and sub-bottom profilers are designed to locate the sea bottom and to probe within the sea bottom, respectively. They are operated primarily in nearshore shallow environments. Fish-finding sonars are operated in both deep and shallow areas.

High-power sonars are assembled from arrays of sound projectors mounted on the hull of a vessel. Multibeam echosounding systems (for example, SeaBEAM or Hydrosweep) are used for precise depth sounding.[8] Oceanographers use low-frequency sound sources to map the physical properties of the oceans (for example, Acoustic Thermometry of Ocean Climate, or ATOC).

Acoustic Deterrents and Harassment Devices—Some fishermen and aquaculture operators use mid- to high-frequency sound sources to keep marine mammals away from fishing gear and deter them from preying upon fish caught in nets or on hooks and lines or being raised in aquaculture facilities (Olesiuk et al. 2002, Barlow and Cameron 2003, Reeves et al. 1996). Acoustic alarms have been suggested as a possible means of alerting manatees and right whales (species especially prone to vessel collisions) of vessels present in their habitat.

Acoustic deterrent devices, or "pingers," are intended to reduce bycatch of marine mammals by warning them of the presence of a net or other fishing gear. In contrast to deterrent devices, acoustic harassment devices emit tones or pulsed frequency sweeps of higher intensity and are intended to be painful to seals and sea lions and keep them away from aquaculture facilities or fishing gear. To reduce habituation, a single device may transmit sounds at a variety of frequencies over varying time intervals.[9]

Contributions to Ocean Sound Energy—The contributions of these various sound sources to the ocean sound budget have been compared using information on the energy imparted at the sources, their directionality, duration, and number of sources (Hildebrand 2005; Table 1). The most energetic sources operated on a regular basis are the seismic airgun arrays from 90 industry vessels operating on average for 80 days per year and naval sonars for anti-submarine warfare operated on 300 vessels for 30 days

[7] These sonars typically generate sound at frequencies of 3 to 200 kHz, with only a narrow frequency band generated by an individual sonar system. Source levels range from 150 to 235 dB. Commercial depth sounders and fish-finding sonars are typically designed to focus sound into a downward beam (Hildebrand 2005).

[8] These sonars form narrow directional beams (for example, 1-degree beamwidth) with source levels up to 235 dB. They typically emit 12 to 15 kHz energy in deep water and higher frequencies (up to 100 kHz) in shallow water (Hildebrand 2005).

[9] Pingers are low-power devices with source levels of 130 to 150 dB, whereas acoustic harassment devices have source levels of 185 to 195 dB. Both pingers and acoustic harassment devices use frequencies in the 5 to 160 kHz band, and generate pulses lasting from 2 to 2,000 msec.

per year. The energy contribution from 11,000 commercial supertankers, operating 300 days per year, was estimated to be an order of magnitude less, although their more widespread distribution makes them more pervasive. Lesser contributions are made by other vessel classes (for example, fishing vessels) and by fish-finder, navigation, and research sonars. The estimated energy contributions are based on suppositions that should be validated by appropriate research and monitoring. In addition, sound energy varies by time and space, and such large-scale estimates may be misleading with regard to particular periods or areas. Nonetheless, they provide a general basis for considering the approximate contributions of various human-produced sources of sound energy to the oceans.

Trends in Ocean Noise—Trends of anthropogenic noise in the oceans are poorly documented, both in terms of field measurements and use patterns for various sources. Nonetheless, it is clear that commercial shipping, offshore oil and gas operations including seismic surveys, and naval and other uses of sonar are contributing to increased ocean noise. Long-term noise trends are based on comparisons between the Navy's historical acoustic data at specific locations (Wenz 1969) and recent observations at the same sites. McDonald et al. (2006) observed a low-frequency noise increase of 10 to 12 dB over 39 years at a site off the southern California coast, suggesting that, on average, low-frequency noise doubled every decade. The increased number, size, and speed of commercial ships may explain this increase. It is also clear that trends in noise vary by region. Seismic operations are not considered to be a dominant anthropogenic noise source in the North Pacific, whereas in the North Atlantic, they make a significant contribution (Nieukirk et al. 2004). Naval and other uses of sonar presumably have increased in proportion to the number of vessels equipped with these systems. Because mid- and high-frequency sounds do not propagate as efficiently as low-frequency sounds, sonar systems using those frequencies contribute only to local and regional background noise. The extent to which fisheries have contributed to the increase in noise in recent years is not clear. The world's fisheries catch has remained relatively constant for the past several decades, but it is possible that current fleets are using larger, noisier vessels and newer, more powerful sonar systems for fish detection. Aquaculture, on the other hand, has increased markedly and now accounts for almost half of the world's food fish (Food and Agriculture Organization *in press*). In regions where such operations interact with marine mammals, aquaculture may be making a growing contribution to ocean noise through the use of acoustic harassment devices.

IV. Marine Mammal Use of and Responses to Sound

Marine mammals produce a variety of sounds and use hearing for communication, individual recognition, predator avoidance, prey detection and capture, orientation, navigation, mate selection, and mother-offspring bonding (Wartzok and Ketten 1999). At most frequencies, the ear is the most sensitive detector of acoustic energy although some evidence indicates that humans are affected by low-frequency sounds below their hearing threshold (Schust 2004). In most marine mammals that have been tested, the best hearing sensitivity appears to correspond to the presumed primordial ocean background noise at any given frequency. This seems a reasonable limit because greater sensitivity may not convey an additional advantage. Beluga whales can detect the return of their echolocation signals when they are only 1 dB above background (Turl et al. 1987), and gray whales can detect the calls of predatory killer whales at 0 dB above background (Malme et al. 1983). Whether anthropogenic sounds are detected at the low levels associated with detection of prey and predators is not known and likely varies with factors such as species and habitat.

Marine mammals have adapted to varying levels of natural sound, and the adaptive mechanisms may allow them to function normally in the presence of many anthropogenic sounds. The key question is when—because of its level, frequency, duration, location, or some other characteristic—introduced sound exceeds the adaptive capacity of marine mammals, causing physical injury or eliciting physiological reactions, behavioral responses, masking, or other effects, and thereby posing a threat to individual animals or their populations.

Behavioral Responses—At the detection threshold, or at some level above that, sound may evoke a behavioral response. Whether an animal responds to a detected sound depends on a suite of variables including the characteristics of the sound (for example, frequency, duration, temporal pattern) and of the animal (for example, age, sex, habitat being used, prior exposure to the sound, behavioral state) (Wartzok et al. 2004). Examples of behavioral responses include changes in habitat use to avoid areas of higher sound levels; diving and surfacing patterns or direction of movement; and vocalization intensity, frequency, repetition and duration (Richardson et al. 1995, Kraus et al. 1997, Olesiuk et al. 2002, Würsig et al. 1998, Finley et al. 1990, Cosens and Dueck 1993). Some of these behavioral responses may affect vital functions (for example, reproduction, feeding). Whether such changes are significant—where significance is defined as having a measurable impact on either an animal's reproduction or survival or a population's status—often is not clear. However, in some cases these changes have had significant consequences, including stranding and death, as has been documented for some beaked whales in response to the use of mid-frequency naval sonar (Anonymous 2001). Scientists have hypothesized that the gas bubbles found in a number of tissues of stranded whales (Fernandez et al. 2005) resulted from a change in diving behavior that allowed supersaturated gases to come out of solution (Cox et al. 2006).

Masking—Masking occurs when a sound is more difficult to hear because of added noise (Southall et al. 2000). In this case, an animal's behavior may be affected because it is not able to detect, interpret, and respond to biologically relevant sounds. For example, masking may affect (1) reproduction if a female cannot hear potential mates vocalizing at a distance, (2) mother-offspring bonding and recognition if the pair cannot communicate effectively, (3) foraging if animals cannot detect prey or animals that hunt cooperatively cannot communicate, and (4) survival if an animal cannot detect predators or other threats. Masking may occur at received levels less than those required to stimulate observable responses and therefore may affect marine mammals at greater distances from the sound source than those at which the animal shows a behavioral response. Natural sounds such as rain, waves, snapping shrimp, and vocalizations of other marine mammals can mask important signals. Marine mammals have developed ways of overcoming certain levels of masking by increasing the level, changing the temporal pattern, and shifting the frequency of their vocalizations. These methods may be used in an attempt to overcome masking by anthropogenic and other noise. At least some marine mammals are thought to have good underwater directional hearing (Au and Moore 1984), which also helps distinguish signals of interest from noise sources provided they are not coming from the same direction (Holt and Schusterman 2007). Pervasive shipping noise is of particular concern because it occurs in the frequency band used by baleen whales for communication.

Physiological Reactions—Exposure to sound energy may result in a range of physiological effects in marine mammals. The auditory system is thought to be the most sensitive to sound exposure, but sound exposure also may cause non-auditory physiological effects such as stress and tissue injury. Even relatively low-level pervasive noise can increase stress levels in humans. Intense sound levels[10] increased levels of stress markers in the blood of beluga whales (Romano et al. 2004), whereas moderate levels[11] did not result in similar evidence of stress (Thomas et al. 1990).

Exposure of marine mammals to high intensity sound[12] may cause a temporary threshold shift, or a temporary loss of hearing sensitivity (Finneran et al. 2005). A reduction in sensitivity is the usual response of a mammalian sensor exposed to an intense or prolonged stimulus and, within limits, is reversible. Nonetheless, because of the importance of sound in the daily lives of marine mammals, even temporary threshold shifts have the potential to increase an animal's vulnerability to predation, reduce its foraging efficiency, or impede its communication.

[10] > 220 dB peak to peak.
[11] 153 dB.
[12] 195 dB re 1μPa^2 for 1 sec.

Physical Injury—Permanent threshold shifts—or permanent loss of hearing sensitivity—can result when animals are exposed even briefly to very intense sounds, over a longer duration to moderately intense sounds, or intermittently but repeatedly to sounds sufficient to cause temporary threshold shifts (Clark 1991). Permanent threshold shifts result in the loss of sensory cells and nerve fibers. In terrestrial animals, temporary reductions in sensitivity of about 40 dB have been required to cause permanent threshold shifts. To date, temporary shifts of only about 20 dB have been induced experimentally in marine mammals, which is much less than required for a permanent shift if marine mammals respond similarly to terrestrial animals.

Injuries have been reported in humpback whales exposed to the pressure waves from explosions (Ketten et al. 1993, Todd et al. 1996). Scientists also have hypothesized a number of other potential physical injuries, such as tissue shear, acoustic resonance, and acoustically driven bubble growth or acoustic activation of micro-bubbles (Houser et al. 2001). Because of tissue dampening and the small displacements associated with expected sound exposure levels, these mechanisms may not explain the injuries observed in sound-associated strandings (Krysl et al. 2006).

Ecological Effects—Ecological (indirect) effects may occur if ecologically related species are affected by anthropogenic sound, thereby changing the nature of their relationship with marine mammals or the structure of the affected ecosystem. The best-studied indirect effects suggest that, in some cases, seismic activity may cause a decrease in the number of fish in the survey region (Skalski et al. 1992, Engås and Løkkeborg 2002). If and when such effects occur, they may reduce the foraging efficiency of marine mammals, potentially compromising their growth, condition, reproduction, and survival.

Population Effects—The effects of sound on marine mammal populations are uncertain. The National Research Council (2005) characterized that uncertainty as follows: "...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 warnings or 'tip of the iceberg'...." Sound has not been considered a factor in several major declines over the past few decades involving pinnipeds and sea otters, species more easily monitored than cetaceans. Abundance and trends of cetacean populations often are poorly known and difficult to monitor; many populations could decline by half without such loss being detected (Taylor et al. *in press*). Thus, it is difficult to form reliable conclusions about the potential effects of sound or other risk factors on many marine mammal populations. At least one cetacean population that is well monitored, the southern resident killer whale, is subject to disturbance from vessel presence and noise, which have been identified as potential factors in the population's decline and subsequent listing under the ESA (70 *Federal Register* 69903).

The MMPA and the ESA establish conservation goals for ecosystems, species, population stocks, and discrete population segments. In many respects, those goals are implemented by regulating activities with potentially discernible effects on individual animals, which are amenable to study and protective actions. Translating observed sublethal (for example, masking, behavioral, physiological, some types of injury) and lethal effects of sound on individuals into consequences at the level of populations, species, or ecosystems requires information that is not presently available. Such information includes the frequency and severity of direct sound effects; secondary effects on natural history functions (for example, feeding, breeding, nurturing); subsequent effects on individual reproduction and survival; cumulative effects on population growth, status, and extinction risk; and consequences for ecological interactions and ecosystem structure and function.

The long-term, cumulative significance of repeated sublethal effects is an important topic of debate and central to the concerns of many with respect to anthropogenic sound. To address this issue, the 2005 National Research Council report described a model of Population Consequences of Acoustic Disturbance (PCAD; Figure 3), which identifies the desired information at behavioral, physiological, individual, and population levels and the understanding needed to use information at one level to predict responses at the next higher level. The report indicated that at least a decade of focused research would be required to provide the information needed to implement the model.

Cumulative Effects—Effects that are individually insignificant may become significant when repeated over time or combined with the effects of other sound sources. Baleen whales, for example, use low-frequency sound for communication and therefore may be affected by both seismic airguns and shipping noise. Similarly, the effects of sound may interact additively or synergistically with the effects of other risk factors. Beluga whales, for example, may be compromised in their ability to survive and reproduce if climate change has altered the distribution and availability of their prey, persistent organochlorine contaminants have altered their immune function and made them susceptible to disease and parasites, and noise from oil and gas operations, icebreakers, or commercial vessels has caused them to abandon important habitat.

Detection of cumulative effects, attribution to particular risk factors, and mitigation will require more sophisticated, quantitative research and management strategies. If properly expanded, the PCAD model described earlier, or similar quantitative techniques, may be of value in investigating and addressing such cumulative effects that, over time, will determine the status of marine mammal populations and marine environments. The limitations of current knowledge and the difficulty of assessing sound effects, both by themselves and in combination with other risk factors, underscore the Commission's longstanding recommendation that sound be considered in a holistic, precautionary framework that includes other threats to marine mammals (Reynolds et al. 2005).

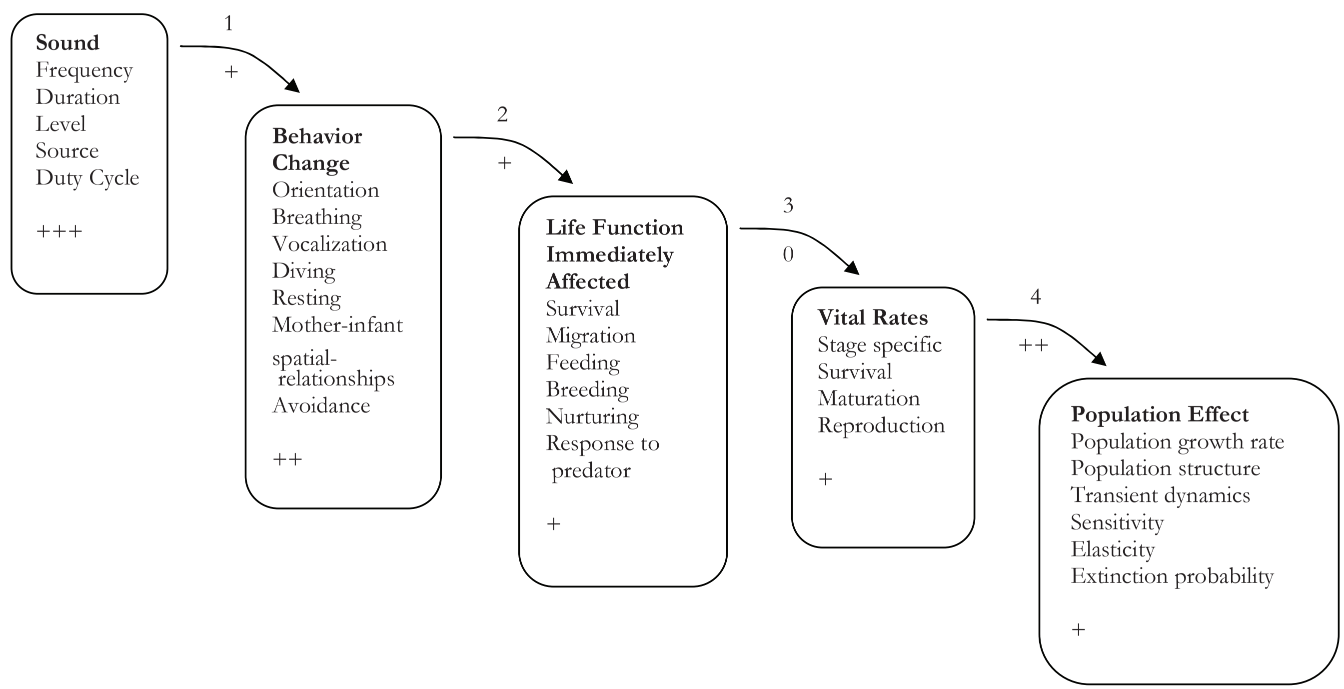

Figure 3. The conceptual Population Consequences of Acoustic Disturbance model (National Research Council 2005) describes five stages of information and associated transfer functions required to relate acoustic disturbance of individual animals to effects on a marine mammal population. Each stage (box) lists variables with observable, measurable features. The actual causal mechanisms may not be known. For example, survival is included as a life function that could account for beaked whale strandings where it is generally agreed that exposure to sound can lead to death. The mechanisms by which death occurs are still under investigation, but the result is clear. The "+" signs at the bottoms of the boxes indicate how well the variables can be measured using current methods. The indicators between boxes show how well the transfer functions are understood; these indicators scale from "+++" (well known and easily observed) to "0" (unknown). Progress is difficult because the behavioral response of any given animal is itself a probabilistic function of the intensity of the received sound. A range of factors may influence the response, such as the age and gender of the animal, its health, its prior exposure to the sound, the social behavioral context during the exposure, the environment where the exposure occurs, and the season of the year when the exposure occurs.

V. Research Progress to Date

Federal agencies and industry groups have undertaken or supported research to investigate sound-related risks to marine mammals and marine ecosystems. The research has expanded our understanding of the physics of sound in the marine environment, its potential effects on marine organisms including marine mammals, and measures needed to reduce the probability that sound-generating activities have biologically significant effects. As such, the research already undertaken provides a foundation for future studies and, ultimately, for effective management. The following discussion highlights some of the accomplishments to date.

U.S. Navy—Since the early 1990s the Navy has been the primary sponsor of research on the effects of underwater sound on marine life, with annual expenditures in excess of $10 million. The funding has been distributed among universities, independent research organizations, government laboratories, and private industry. The research generally has been conducted in collaboration with other agencies, particularly the National Oceanic and Atmospheric Administration, and has been administered by the Offices of Naval Research and Naval Operations, as well as through the National Ocean Partnership Program and the Strategic Environmental Research and Development Program. Major areas of investigation have included marine mammal hearing; behavioral, physiological, and physical responses to sound; marine mammal abundance, distribution, and habitat use; and technology for detecting and monitoring marine mammals. The Navy plays a leading role in characterizing sound-source acoustic fields, signal processing and analysis, and modeling of acoustic data. The Navy has conducted research to estimate risks to marine life from sonar and explosives used in ship shock trials, and the operational fleet collects extensive data on sound propagation and ocean conditions based on experiments at training ranges and at-sea use of sonar. Recent and future emphases include the effects of sonar training ranges and sonar on marine life, the use of training-range assets (especially passive acoustic sensors, radars, and platform observers) to study the behavioral responses of marine life to Navy activities, the use of evoked auditory potential techniques to study the hearing capabilities of marine mammals, the development of effective monitoring and mitigation techniques, the study of the ecology of beaked whales, and the use of controlled-exposure experiments to investigate the responses of marine mammals to sound.

Minerals Management Service—The Minerals Management Service also has been a significant contributor to research on the effects of sound. It has funded, or required industry to fund, most of the research designed to identify and determine how to avoid or mitigate the possible adverse effects of oil and gas exploration on bowhead whales and other Arctic marine mammals. The Service provided primary support for the authoritative review by Richardson et al. (1995) entitled *Marine Mammals and Noise*. More recently, the Service has collaborated with other federal agencies and industry to study the effects of seismic operations on marine mammals, particularly sperm whales, in the Gulf of Mexico. The studies included controlled-exposure experiments using vessels provided by the National Science Foundation and the International Association of Geophysical Contractors. When completed in 2007, the Sperm Whale Seismic Study will have cost about $20 million.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service—With its mandate to protect and conserve most species of marine mammals, the National Marine Fisheries Service has lead responsibility for their study and for the management of activities that may affect them. Funding for the Service's marine mammal research and management programs has varied considerably, increasing from approximately $15 million in 2000 to about $50 million in 2001, due largely to new funding for Steller sea lion research, and then decreasing to $30 to $35 million in 2003 and 2004. The Service's research program covers a wide range of topics including determination of stock structure, estimation of abundance and distribution, characterization of natural history, and investigation and mitigation of risk factors. Among other things, management responsibilities include coordination of responses to marine mammal stranding events, including those that may have been caused by exposure to sound. Such investigations are critical to understanding the mechanisms leading to injury or death of marine mammals exposed to excessive sound. The National Marine Fisheries Service also is responsible for authorizing the taking of marine mammals incidental to oil and gas exploration and other activities and for specifying monitoring and mitigation measures to detect, minimize, or avoid potential adverse effects. With its responsibilities to address all factors that pose risks to marine mammals, the National Oceanic and Atmospheric Administration has directed only minor amounts of funding to sound-related research and management. The Administration's Ocean Acoustics Program, which presently receives about $200,000 annually, is developing exposure criteria, promoting public and user group (for example, commercial shipping) education, developing passive noise monitoring systems, and supporting limited research on such topics as the effects of sound on marine mammal hearing, behavior, and non-auditory systems.

National Science Foundation—The National Science Foundation, which has long supported a wide range of oceanographic studies, has recently invested about $1 million to study sound propagation from sources used for geophysical seismic surveys. The Foundation also has supported a range of studies on marine mammals in polar regions, as well as technology development for tracking marine mammals.

National Research Council—The National Research Council of the National Academy of Sciences, with support provided by the Navy and other federal agencies, has conducted four major reviews related to the sound issue. Specific topics addressed in these reviews include two reports on the effects of low-frequency sound, *Low-Frequency Sound and Marine Mammals* (National Research Council 1994) and a progress review on that topic entitled *Marine Mammals and Low-Frequency Sound* (National Research Council 2000), a broader look at *Ocean Noise and Marine Mammals* (National Research Council 2003), and a more focused look at sound effects at the population level entitled *Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects* (National Research Council 2005). These reviews resulted in explicit recommendations for—

- investigation of marine mammal hearing physiology and animals' use of sound;
- investigation of potential cause-and-effect relationships between sound and changes in marine mammal distribution, behavior, and physiology;
- a centralized database for data integration, analysis, and modeling purposes;
- development of modeling efforts to assess impacts and guide research;
- development of methods for assessing population-level effects of sound;
- investigation of sound as one of multiple risk factors that cumulatively may affect marine mammals;
- investigation of the effects of sound on other marine organisms; and
- long-term monitoring to determine the noise budget for the world's oceans.

Taken together, the reviews and recommendations of the National Research Council illustrate the breadth of scientific and management issues involving underwater sound and provide important guidance for future research on sound and its potential effects on marine mammals and marine ecosystems.

VI. Research Challenges

Although progress has been made toward understanding the impacts of anthropogenic sound on marine mammals, much work remains to be done. Risk assessment provides a useful framework for identifying the critical research questions still to be addressed. Risk assessment consists of identifying the hazards involved, determining the level of exposure to those hazards, evaluating the response to exposure, and characterizing the risk. Together, these provide a basis for managing the risks.

Hazard Identification and Characterization—Research is needed to characterize more completely the types of anthropogenic sound introduced into the marine environment and their key features with regard to potential impacts on marine mammals. Key questions include—

- What are all the significant sources of anthropogenic sound and what are their key characteristics?
- How do sound levels and characteristics change over time and space and with environmental features such as depth and bottom topography?
- How do sounds interact with each other and with other risk factors in the marine environment?

As evident in section III, considerable progress has been made addressing the first of these questions, although sound sources will likely expand and change over time so this will remain a necessary area of investigation. Much less is known about how sound levels change over time and space and with certain environmental features, the circumstances surrounding particular sound-related events (for example, use of sonar associated with strandings), and how sounds interact with each other and with other risks to marine mammals.

Determination of Exposure—Exposure is determined by the overlap in the distributions of marine mammals and sound energy. Distribution and movement/migration patterns are known for some marine mammal species (most pinnipeds, some small cetaceans, and some large cetaceans) and largely unknown for others (beaked whales and other cetaceans that primarily inhabit offshore waters). For virtually all species, detailed information on local habitat use within their distribution would improve projections of exposure to anthropogenic sound.

The distribution of sound energy in the oceans is determined by the distribution and movement patterns of sound sources and the propagation of sound from those sources as a function of both source characteristics and environmental features. Exposure to individually distinguishable low-frequency sounds will depend on proximity to those sounds, but exposure to low-frequency sounds also will be determined by trends in background noise over ocean basin scales. Exposure to mid- and high-frequency sounds is determined more by the location of sound sources relative to the location of animals in the near vicinity because those frequencies do not propagate well. Although a considerable amount is known about the locations and movements of some sound sources (for example, commercial ships, which tend to use coastal or great circle routes), the location of others (for example, naval and fishing vessels) is not as well known. To the extent that such information can be made available, it will be useful for characterizing the exposure of marine mammals to sound energy.

Important questions regarding the exposure of marine mammals to sound-related risks include—

- What are the distributions, movement/migration patterns, and local habitat-use patterns of marine mammals?
- How is sound energy distributed in the oceans, and how does it change over time and space?
- Where are the key areas of overlap between marine mammals and sound energy?

Evaluation of Responses—The sensitivity of marine mammals to sound is a function of, among other things, their hearing and susceptibility to non-auditory physiological or physical effects. The information collected to date indicates marine mammal hearing is consistent with general mammalian patterns although the range of frequencies over which they are sensitive to sound varies somewhat by species (Figure 4). Most sensitivity measurements have been obtained through behavioral conditioning in which a marine mammal is trained to respond when it detects a sound or by measurements of brain activity in response to sound stimuli. The measurements are from studies of relatively few individuals of a few species amenable to laboratory experiments, a category that generally excludes baleen and beaked whales. More testing is needed to determine if the tested individuals are representative of their own and other species, and how hearing might vary as a function of such factors as age and sex. The technique involving measurements of brain activity can be used with stranded animals before they are released, euthanized, or expire naturally, and holds promise for hearing assessments on species previously untested, including the large baleen and toothed whales and beaked whales (Cook et al. 2006). Recent studies of 42 captive bottlenose dolphins revealed the same age- and sex-specific declines in hearing ability as seen in humans, including some individuals with aberrant hearing apparently due to genetic causes and some individuals with profound hearing loss (Houser and Finneran 2006).

Sound is known to have direct and indirect effects on mammals (including humans) in addition to its effects on hearing. Stress has been demonstrated in marine mammals exposed to sound (Romano et al. 2004) despite the fact that the tools for this kind of study are limited. Further research is needed to assess marine mammal nervous, immune, or other systems before and after exposure to anthropogenic sound or other stressors. Chronic physiological changes associated with sustained exposure to anthropogenic sound are likely to result in a more generalized stress syndrome common to most mammals faced with a persistent stressor (Reeder and Kramer 2005). In those cases, the result is usually not injury or death but rather reduced functional capacity in physiological systems including those associated with reproduction and nurturing. Long-term exposure also may lead to changes in behavior, including habitat-use patterns. When the responses are due to extended exposures to a multitude of stressors, detecting the responses can be difficult without pre-exposure baseline information, and attributing the responses to single sources (for example, anthropogenic sound) is an even greater challenge.

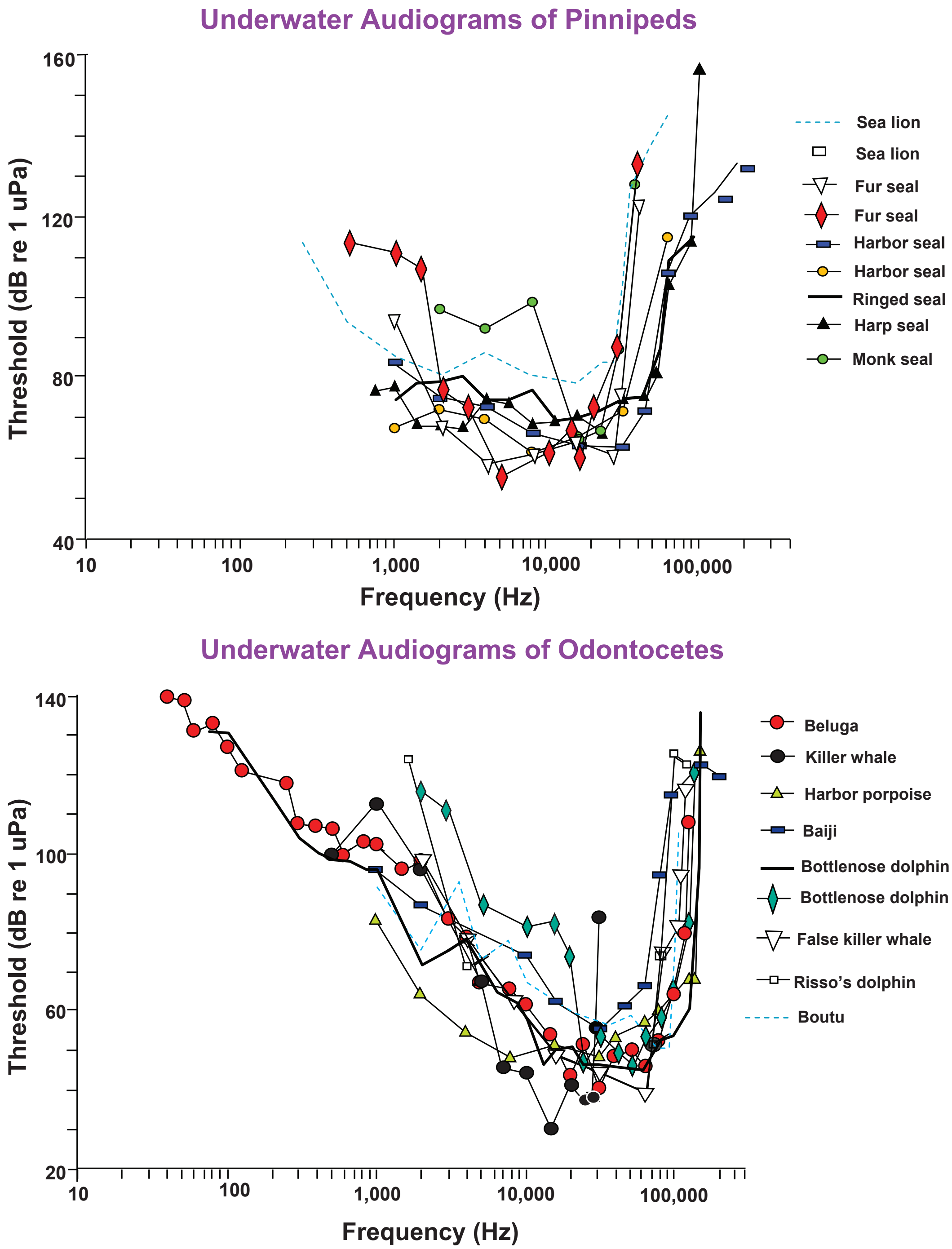

Figure 4. Audiograms of various marine mammal species illustrating hearing sensitivity (threshold) as a function of sound frequency. Points lower on the graph illustrate greater sensitivity (that is, the tested animal could detect sounds of lower level at the corresponding frequency). Source: Wartzok and Ketten 1999.

Potential responses of marine mammals to sound are described in section IV. For wild populations, these responses are difficult to observe and particularly difficult to interpret. Important lessons for investigating sound and marine mammals can be learned from other scientific fields, such as toxicology to assess "dose-response" relationships for understanding marine mammal sensitivity to sound and epidemiology to investigate temporal and spatial relationships between strandings and identified sound sources.

Controlled and opportunistic sound exposure experiments are valuable for determining the response of marine mammals to anthropogenic sound (Miksis-Olds and Miller 2006). Controlled sound exposure experiments involve intentionally exposing animals to specific sound stimuli where the received sound levels can be measured and controlled and the physiological or behavioral reactions of the targeted marine mammals can be assessed. Opportunistic sound exposure experiments involve documenting the reaction of marine mammals to the presence of anthropogenic sounds in their environment, for instance, when animals are located near shipping lanes, naval training grounds, or areas of ongoing oil and gas exploration, development, and production. Such experiments require documentation of the relevant characteristics of the intrusive sound, the environmental conditions, and the responses of the marine mammal. Controlled exposure experiments were used by the Navy's Low Frequency Sound Scientific Research Program (Miller et al. 2000) and were recommended by participants of the Commission's beaked whale workshop to test for effects of naval sonar on beaked whales (Cox et al. 2006).

Major questions regarding exposure-response relationships include—

- What are the hearing capabilities of the many marine mammal species that have not yet been tested by either behavioral or physiological methods, and how do they vary within species by such factors as age and sex?
- What are the non-auditory sensitivities of marine mammals to sound?
- How do marine mammals respond to different sounds, and how do responses vary within and among species?
- How does the environment influence marine mammal responses to sound?
- What are the effects of both short- and long-term sound exposure?

Full Characterization of Risk—The risk posed by anthropogenic sound to marine mammals is a function of all of the above considerations, including the amount and nature of sound introduced into the marine environment, marine mammal exposure to that sound, and the responses of marine mammals to both short- and long-term exposure. Full characterization of risk requires taking into account the cumulative effects of multiple sound sources and the interactions of sound effects with the effects of other risk factors. For most marine mammal species, we lack the understanding and monitoring tools needed for a full characterization of risk.

Key questions regarding a full characterization of risk include—

- To what extent can observed effects be attributed to single or combined sound sources?
- What are the effects of sound sources on individual marine mammals and marine mammal populations?
- How do sound-related effects interact with other risk factors to cause cumulative effects?
- What level of monitoring is needed to characterize the risk of sound sources to marine mammals?

Risk Management—Because of existing uncertainty, managers are faced with significant challenges in implementing the MMPA, the ESA, and the NEPA while avoiding unnecessary constraints on sound-producing activities. Research and monitoring are needed to develop clearer guidance as to whether (1) a sound-producing activity is likely to take a marine mammal and a taking authorization is needed, (2) the taking will be by harassment only or might result in injury or death, and (3) any such impacts might result in non-negligible population-level effects. A variety of factors have bearing on these determinations, including the nature of the sounds to which the animals are exposed, the species involved, the season of the year, the activities being engaged in by the animals, whether the animals can detect and avoid the sounds before exposure reaches a critical level, how often animals are exposed to the sounds, the other stressors acting on the affected stocks, etc. Although these variables present a large number of permutations, each with different potential impacts, further well-directed research should make it possible to establish applicable, objective standards to guide user groups regarding the types of authorizations needed and to guide managers in their evaluation of requests for authorization.

The National Marine Fisheries Service has applied sound exposure thresholds to determine whether taking is likely to be by harassment only. The Service assumes that exposures below these levels will not result in deaths or serious injuries. The Service also is preparing a matrix of exposure thresholds to guide regulators in their evaluation of applications for permits and small-take authorizations. The matrix would provide guidance as to whether various types of exposures would result in takings and whether the effects of those exposures would be negligible. The matrix has not been finalized but is expected to be available for public review and comment in the near future. Additional guidance of this type is needed and should be made a priority for the agency.

Mitigation and monitoring measures also are important elements of risk management. Their purposes are to validate assumptions made in projecting possible effects, to minimize actual effects and ensure that they are negligible, and to verify that marine mammals are taken only in anticipated and authorized ways and numbers.

With regard to risk management, research is needed to—

- Characterize the sensitivity of marine mammals to sounds under a range of conditions;
- Determine threshold sound levels needed to protect marine mammals under those conditions;
- Characterize the effectiveness of existing mitigation and monitoring measures;
- Develop more effective means for mitigation and monitoring; and
- Provide reasonable certainty that cumulative sound exposure will have no more than negligible effects on marine mammal populations.

To date, research efforts have been driven largely by specific agency needs, with a modest level of cooperation among agencies. Better coordination among those agencies would enhance the efficiency, effectiveness, and cost-effectiveness of the overall research effort. The Navy can contribute expertise on the physics of sound and considerable infrastructure; the National Oceanic and Atmospheric Administration can contribute expertise on the biology and ecology of marine mammals; the Minerals Management Service and the oil and gas industry can contribute expertise on oil and gas operations as well as logistic support for seismic studies; the National Science Foundation can contribute infrastructure for working at sea as well as the scientific expertise of its staff and grantees, peer review, and granting expertise; and the Marine Mammal Commission can contribute scientific expertise and independent review. Combining these strengths will promote a more efficient and effective research effort.

VII. Regulation of Taking by Anthropogenic Sound

Pertinent Statutes—Several federal statutes apply to the management of anthropogenic sound in the marine environment. In 1972 the MMPA established a moratorium on the taking of marine mammals. However, the Act also provided certain exceptions as well as procedures to obtain a waiver if the affected species or populations were within their optimum sustainable population levels and would not be disadvantaged by the taking. Because the waiver requirements were complex and dependent on substantial information, Congress amended the Act in 1981 by adding section 101(a)(5) to authorize the taking of small numbers of non-depleted marine mammals incidental to activities other than commercial fisheries (covered by other provisions of the Act) when certain requirements are met. In 1986 this provision was expanded to allow taking of small numbers of depleted species, such as bowhead whales, if the taking would have negligible effects on those species and stocks and no unmitigable impact on the availability of the affected animals for subsistence taking by Alaska Natives. In 1994 an additional provision was added—section 101(a)(5)(D)—providing a streamlined notice-and-comment procedure (similar to that used to obtain scientific research permits) for obtaining small-take authorizations when the taking would be by harassment only.

Other statutes also apply. The ESA prohibits the taking[13] of marine mammals listed as endangered or threatened, with some exceptions. The NEPA requires that major federal actions that would have a significant impact on the environment—including those involving anthropogenic sound—be assessed to inform decision-makers about the consequences of such actions and alternatives to minimize impacts. The Coastal Zone Management Act encourages coastal states and territories to preserve, protect, develop, and, where possible, restore or enhance valuable coastal resources, and this broad purpose includes management prerogatives to address the effects of sound-producing activities that might affect coastal waters and ecosystems.

The need for a general prohibition of activities that cause injury or death to significant numbers of marine mammals is readily apparent. The need for prohibiting or limiting harassment—the element of taking often at issue for anthropogenic sound—may be less apparent. The underlying concern is that harassment may alter important behaviors (for example, foraging, habitat use, nurturing) or physiology (for example, cause stress and reduction in health or condition) to an extent that it affects individual reproduction or survival and, if sufficient numbers of animals are involved, also may affect population status. Such linkages are conceptually straightforward, but the possible population-level effects are difficult to quantify. Until such potential effects are understood, managers will continue to face considerable uncertainty in their attempts to regulate sound sources in a manner that ensures marine mammal protection and conservation while avoiding or minimizing unnecessary impediments to sound-producing activities.

To that end, the MMPA provides five types of authorization that allow taking related to the generation of sound—scientific research permits, small-take authorizations, incidental harassment authorizations, waivers, and taking incidental to commercial fisheries. In addition, although not an authorization *per se*, a provision enacted by Congress in 2003 allows the Secretary of Defense to exempt actions of the Department of Defense from the MMPA requirements if determined necessary for national defense.

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[13] The term "take" is defined in the MMPA to mean "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" and in the ESA to mean "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."

Scientific Research Permits—Section 104 of the MMPA enables the National Marine Fisheries Service and the Fish and Wildlife Service (the Services)[14] to issue permits authorizing the taking or importing of marine mammals for purposes of *bona fide* scientific research[15] if certain findings are made. An applicant also must demonstrate that any taking will be humane,[16] that the objectives of any proposed lethal taking cannot be met by nonlethal methods, and that the taking will be consistent with the purposes of the Act. Before authorizing the lethal taking of depleted marine mammals, including any species listed under the ESA, the responsible Service must determine that the results of the research will directly benefit the species or stock or that the research fulfills a critically important research need.

The MMPA permitting provisions include a number of mechanisms to mitigate potential deleterious effects of scientific research. For instance, the requirement that research be humane means that the method of taking proposed to meet the research objectives must involve the least degree of pain and suffering practicable. More generally, opportunities for mitigation arise from the statutory directive that the Services specify appropriate terms and conditions in permits they issue. Such conditions may require, for example, that research activities be suspended pending further review if animals are taken in unexpected ways or numbers.

The permitting provisions of the ESA are less specific, requiring only that (1) the application be submitted in "good faith," (2) any authorized taking not operate to the disadvantage of listed species, and (3) the permit be consistent with the purposes and policies of the Act. More specific requirements and issuance criteria are set forth in agency regulations.[17] In general, meeting the permit requirements of the MMPA also satisfies those of the ESA.

Research permits cannot be issued to authorize the taking of marine mammals incidental to research not directly pertaining to the biology or ecology of marine mammals (for example, geophysical research). Rather, taking in the course of other types of research is generally addressed through the issuance of a small-take authorization or an incidental harassment authorization.

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[14] NMFS has jurisdiction over all cetaceans and all pinnipeds except walruses. FWS has jurisdiction over all other marine mammals (that is, walruses, polar bears, manatees, dugongs, sea otters, and marine otters).
[15] By definition, *bona fide* research will produce results that are likely (1) to be accepted for publication in a refereed scientific journal, (2) to contribute to the basic knowledge of marine mammal biology or ecology, or (3) to identify, evaluate, or resolve conservation problems. 16 U.S.C. § 1362(22).
[16] Humane taking means "that method of taking which involves the least possible degree of pain and suffering practicable to the mammal involved." 16 U.S.C. § 1362(4).
[17] 50 C.F.R. § 17.22 for the FWS and 50 C.F.R. § 222.308 for NMFS.

Small-take and Incidental Harassment Authorizations—Section 101(a)(5) of the MMPA directs the Services to issue authorizations to U.S. citizens[18] to take marine mammals incidental to various activities other than commercial fishing, subject to certain requirements and conditions. This provision can be used only to authorize the unintentional taking of small numbers of marine mammals incidental to "a specified activity…within a specified geographical region."[19, 20]

Two types of authorizations, subject to different procedural requirements, are available under section 101(a)(5), depending on the type of taking involved. The more general provision, set forth in section 101(a)(5)(A)-(C), applies to all types of taking but is required when an activity could result in the capture, injury, or killing of marine mammals. This provision mandates the promulgation of regulations, and authorizations may be issued for periods of up to five years. The MMPA does not specify time frames for reviewing applications for these incidental take authorizations, and Executive Branch procedures for reviewing proposed and final regulations may be lengthy.

A more streamlined process is available under section 101(a)(5)(D) for activities that involve the taking of marine mammals by harassment only. These are commonly referred to as incidental harassment authorizations (IHAs), and are valid for no more than one year. The process for issuing IHAs is comparable to that used to issue scientific research permits. It applies to both Level A and Level B harassment, requires opportunity for public comment (but not rulemaking), and must be completed within 120 days of receipt of the application (including a 30-day public comment period).

Both of these authorization procedures contain similar issuance criteria and mitigation and monitoring requirements, including—

- the taking will have a negligible impact[21] on the affected species and stocks,
- the taking will not have an unmitigable adverse impact on the availability of marine mammals for subsistence uses by Alaska Natives,

[18] The Services have defined "citizens" to include individual U.S. citizens, corporations organized under U.S. laws, and federal, state, or local government agencies. 50 C.F.R. §§ 18.27(c) and 216.103.
[19] Under amendments enacted in 2003, the requirements pertaining to geographic region and small numbers no longer apply to military readiness activities (16 U.S.C. § 1371(a)(5)(F)).
[20] The fact that such authorizations are limited to U.S. citizens means that they are not available for some activities that may take marine mammals in U.S. waters. For example, if it were determined that sound produced by foreign vessels resulted in takings, the operators could not obtain incidental take authorizations. Rather, they would be required to seek a waiver of the MMPA's taking moratorium under section 103 of the Act, procedurally a much more burdensome process and one that does not apply to depleted species.
[21] Negligible impact is defined as an impact "…that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival" (50 C.F.R. § 216.103).

- the authorization prescribes permissible methods of taking and other means of effecting the least practicable impact on the marine mammals and their habitat and on their availability for subsistence uses, and
- the authorization specifies monitoring and reporting requirements.

Mitigation under both of these types of authorization is considered during at least two phases of agency review. First, the Services must determine that the taking will have no more than a negligible impact on the affected populations. In some cases, proposed actions may need to be altered to achieve that standard. Second, even if the taking is not expected to have adverse population-level effects, the Service is required to identify ways to reduce those impacts to the lowest level "practicable." The legislative history accompanying the addition of section 101(a)(5) to the Act[22] further states that Congress expects that persons operating under this authority "shall engage in appropriate research designed to reduce the incidental taking of marine mammals pursuant to the specified activity concerned."

For species listed as threatened or endangered under the ESA, a separate incidental taking authorization is required under section 7(b)(4) of that Act. Before such an authorization is issued, the Service must complete a section 7 consultation and conclude that the activity will not jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat. In the case of marine mammals, these requirements will always be met because the negligible impact standard of the MMPA is more rigorous. For listed marine mammals, authorization under section 101(a)(5) of the MMPA is a prerequisite for issuance of an ESA authorization.

Waivers—The MMPA specifies that the moratorium on taking marine mammals may be waived "from time to time" provided that certain requirements are met. For non-U.S. citizens, waivers may be the only avenue available to allow the incidental taking of marine mammals. However, waivers require that adjudicatory, formal rulemaking procedures be followed. Waivers are not available for depleted species and stocks. Because such species and stocks may be widely distributed and because sound is an indiscriminate form of taking, waivers may not be a viable mechanism for authorizing the taking of marine mammals by anthropogenic sound in many situations.

Take Incidental to Commercial Fisheries—The taking of marine mammals incidental to commercial fishing operations is governed by section 118 of the MMPA. That provision aims first to maintain or reduce mortality and serious injury[23] of marine mammals incidental to commercial fisheries below the potential biological removal level

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[22] H.R. REP. NO. 228, 97th Cong., 1st Sess. 20 (1981).

[23] Serious injury is defined by regulation as "any injury that will likely result in mortality." 50 C.F.R. § 216.3.

(PBR)[24] of each affected stock, and then to reduce them to insignificant levels approaching a zero mortality rate. Although the focus of the incidental take regime for commercial fisheries is on deaths and serious injuries, other types of taking (for example, incidental harassment) are authorized as well. Thus, for all commercial fishermen covered by the regime (which may require registration and adherence to regulations designed to achieve the mandated reduction in deaths and serious injuries), an unlimited number of sublethal takes may occur without any restrictions or regulation. For example, taking is authorized and unregulated if it results from sounds emanating from the operation of commercial fishing vessels, the deployment or retrieval of gear, the use of fish-finding sonars, or from the use of acoustic harassment devices used by some aquaculture facilities, provided that such taking does not result in marine mammal deaths or life-threatening injuries.

The taking by fishermen of marine mammals listed as endangered or threatened under the ESA[25] is further governed by section 101(a)(5)(E) of the MMPA. Under that provision, the incidental taking of listed species is to be authorized for periods of up to three years if the Service determines that any incidental mortality and serious injury will have a negligible impact on the recovery of the affected species or stocks, a recovery plan has been or is being developed, and, as required under section 118 of the MMPA, monitoring, vessel registration, and take reduction measures are in place. Taking authority under the ESA is provided through an incidental take statement issued under section 7(b)(4) of that Act.

VIII. Avoidance, Minimization, and Mitigation of Adverse Sound Effects

As noted above, most of the available mechanisms for authorizing the taking of marine mammals require mitigation, which may include avoidance and/or minimization of effects. In general, measures used to mitigate impacts from anthropogenic sounds fall into four categories: (1) modification or removal of a sound source, (2) sound attenuation, (3) temporal or spatial limitations on use of the source, and (4) operational requirements.

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[24] The potential biological removal level is "the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population." It is the product of three factors—the minimum population estimate of the stock, one-half the maximum theoretical or estimated net productivity rate of the stock, and a recovery factor between 0.1 and 1.0. 16 U.S.C. § 1362(20).

[25] Other than California sea otters, which are subject to the provisions of Public Law 99-625.

Elimination or Modification of the Sound Source—The most straightforward method of mitigating the potential adverse effects of sound is to either eliminate or modify the source. In some cases, a source simply is not allowed to operate. Although a total prohibition on use of a source may be reasonable in limited cases, such prohibitions are not feasible for the major sound-producing activities that routinely occur in the world's oceans and are of current concern. In such cases, the intensity, frequency, duration, or other characteristics of the sound source might be modified to reduce the effects on marine mammals. The use of some high-intensity sound sources might be reduced with enhancements in signal processing or better focusing of source energy. Ship-quieting technologies provide another example of possible sound source modification to reduce sound levels. Such efforts should be carefully evaluated to ensure that the reduction in sound does not inadvertently result in an increased likelihood of ship strikes of marine mammals that may be less able to detect and move out of the path of quieter vessels.

Sound Attenuation—Under some circumstances, technology can be used to reduce or attenuate sound output by human activity without affecting the source itself. For instance, bubble curtains, blasting mats, dampening screens, and similar devices and techniques can limit (attenuate) the amount of acoustic energy leaving a sound source and propagating through the water column. These techniques are primarily employed around stationary sources, such as pile drivers and explosions, although tests have been conducted for moving sources as well.

Spatial and Temporal Measures—A more targeted approach is to limit or modify the use of a sound source in certain areas or at certain times. For example, use of a sound source could be prohibited or limited in particularly sensitive areas such as critical habitat, breeding grounds, marine protected areas, migratory pathways, or where marine mammal abundance or diversity is particularly high. Likewise, sound-producing activities could be limited temporally to avoid breeding or calving seasons, migratory periods, or other sensitive times. Spatial and temporal limitations also could be applied in combination. For example, a spatial limitation would be imposed only during the season in which the impact would need to be mitigated. Spatial and temporal mitigation measures are difficult to apply when the distribution, movement patterns, and sensitivity of potentially affected marine mammals to particular sounds are poorly known.

Operational Requirements and Limitations—The last category of mitigation methods is the establishment of operational requirements and limitations. The ramping up of a sound source often is required to give marine mammals a chance to detect and move away from the source before it reaches a level where it can harm them. However, the limited evidence available on the efficacy of ramp-up is inconclusive. Another common mitigation approach is to establish and monitor a safety zone around a sound source. If marine mammals are detected within or approaching the safety zone, operation of the source may be suspended or altered until the zone is again free of marine mammals. Although useful, this approach also is limited in its efficacy because marine mammals often are difficult to detect under the best conditions, and detection declines significantly with distance from the observer, worsening sea state, increasing ice cover, and decreasing light.

IX. Monitoring and Reporting of Taking Incidental to Sound-generating Activities

Monitoring and reporting are essential for determining the effects of sound-generating activities on marine mammals, for assessing the efficacy of mitigation measures, and for planning sound-generating activities so that they have the minimum impact on marine mammals. Typically, recipients of authorizations and permits are responsible for monitoring and reporting. Real-time monitoring efforts have been based primarily on visual observation, sometimes supplemented with passive and active acoustic monitoring.

Visual Monitoring—Visual monitoring is the most commonly used method to detect marine mammals. Observers (ranging from trained biologists to vessel crew members) visually scan for marine mammals within certain areas, which are limited by sighting conditions (for example, weather, sea state, daylight) and the sighting platform (that is, ship, aircraft, land-based station). The efficacy of observer efforts also is limited by the natural history patterns of the marine mammals. Animals that tend to occur close to shore, aggregate in groups, spend more time at the surface, or exhibit more conspicuous surface behavior are more easily observed and documented than solitary animals that occur in more remote locations, exhibit long dive times, and have inconspicuous surface behavior. Observation methods are relatively well developed but vary in efficacy for different marine mammal species. They are least effective for beaked whales, which represent about one-fourth of all cetacean species and appear to be vulnerable to certain types of anthropogenic sound (for example, mid-frequency naval sonar). A recent analysis of sighting efficiency suggests that under ideal weather conditions experienced observers would detect 23 percent of Cuvier's beaked whales directly in the path of a survey vessel and 7 percent of those directly under a survey aircraft (Barlow and Gisiner 2006). Monitoring during typical seismic surveys was estimated to detect 2 percent of the beaked whales in the area of the survey vessel (Barlow and Gisiner 2006). Thus, visual monitoring is subject to significant limitations.

Passive Acoustic Monitoring—Passive acoustic monitoring systems may use near-surface, mid-water, bottom, towed, or hull-mounted hydrophones (listening devices) to detect the presence of marine mammals based on their vocalizations or other sound-producing behaviors (for example, breaching, tail slapping). Such systems provide a means to detect many species of marine mammals over broad temporal and spatial scales (for example, Nieukirk et al. 2004, Moore et al. 2006). Passive acoustic monitoring is less affected by weather and sighting conditions than is visual observation and can increase detection rates over visual surveys alone (Barlow and Taylor 2005). However, when used alone, these systems are limited in their utility because some marine mammals do not vocalize or do so in ways that are difficult to detect, and some detected sounds may be difficult to attribute to marine mammals. For example, diving beaked whales may not vocalize until they are at a depth where detection of their vocalizations by surface hydrophones is problematic. Hydrophones placed on the ocean bottom are more useful under such circumstances, but their deployment is more difficult and costly. Nonetheless, passive acoustic monitoring is a proven component of an integrated mitigation, monitoring, and observation system (for example, Blackwell and Greene 2006).

Active Acoustic Monitoring—Active acoustic monitoring is used to investigate the marine environment by emitting high-frequency pulses and detecting echoes from objects of interest. The Navy has developed and used its High Frequency Marine Mammal Monitoring active sonar system for detecting and tracking cetaceans (Stein et al. 2001). The Navy also uses this system when deploying its Low Frequency Active sonar. The major drawbacks of active acoustic monitoring systems are that they are expensive, of limited availability, and produce false positives. For example, other biological and physical phenomena may cause echoes that cannot be distinguished from marine mammals. In addition, because they use active sonar, these systems introduce another source of anthropogenic sound that may itself have adverse effects on marine mammals.

Radar, infrared detection, and LIDAR (Light Detection and Ranging) have been used with varying degrees of success to detect marine mammals. These techniques are limited to detecting animals at or near the surface and thus are likely to have a low detection probability for animals that are small in size and spend large portions of their time below the surface.

Real-time monitoring may be facilitated or supplemented by information gained from other marine mammal monitoring efforts. Design of effective monitoring strategies depends on the region and season where and when sound-generating activities are planned, the marine mammals that may be present, their abundance, and their natural history traits including migration and distribution patterns, social structure, foraging and diving behavior, and sensitivity to anthropogenic sound. Stock assessment studies by the National Marine Fisheries Service and Fish and Wildlife Service and additional ocean observation programs are important sources of information for effective management of sound-related issues. The value of such information underscores the need for sustained support of the long-term marine mammal research programs carried out by the Services, as well as the valuable contributions that can be made by other agencies whose activities may involve the collection of related information, including the Navy, Minerals Management Service, and National Science Foundation.

X. Management Challenges

With regard to the management of sound effects, the framework established by the MMPA, ESA, NEPA, and Coastal Zone Management Act has several shortcomings.

Inconsistent requirements for sound producers—The take prohibitions of the MMPA and ESA apply broadly to most activities in waters subject to U.S. jurisdiction and conducted by U.S. citizens and vessels on the high seas. However, the types of authorizations available and the requirements placed on those involved in the taking are not equitable among all sound producers. Commercial fisheries and aquaculture industries, in particular, are not regulated to the same extent as are other sound-generating activities. Current laws do not address the noise produced by these industries if it does not kill or seriously injure marine mammals. As a result, their use of fish-finders, pingers, and acoustic harassment devices is virtually unregulated (Reeves et al. 1996). Others using similar devices for another purpose (for example, research) would need an authorization contingent upon a determination of negligible impact and the adoption of mitigation measures. To an increasing extent, fishing and aquaculture industries have been directing sound toward marine mammals as a deterrent, and these activities should be regulated in a manner consistent with the activities of other sound producers. For example, aquaculture facilities that use acoustic harassment devices should be required to obtain authorizations from the Services to ensure that the sound levels and frequencies produced by those devices do not result in non-negligible effects on marine mammals and are mitigated to the extent practicable. In addition, in certain situations, acoustic harassment devices should be excluded from areas of important marine mammal habitat. To do so, management agencies must have the authority to control where aquaculture facilities are located and how they operate. These are only examples of sound sources that may be used in the marine environment, now and in the future, and the Services must have the authority to regulate such sources if their potential adverse impacts are to be effectively managed.

Inconsistent implementation and enforcement of existing requirements—Even when requirements for sound producers are consistent, the implementation and enforcement of them may vary considerably. In some cases, entire categories of activity have not complied with existing regulations. In other cases, compliance has been partial or incomplete. For example, recreational boating and, specifically, whale-watching activities that produce noise have not been subject to regulation although noise and associated disturbance have been identified as a potential problem in at least one case, that of endangered southern resident killer whales in the Puget Sound region (70 *Federal Register* 69903). Similarly, authorizations have been obtained for only a portion of seismic exploration activities conducted within U.S. waters or by U.S. agencies operating on the high seas. For instance, seismic surveys have been conducted in Alaska's Cook Inlet without MMPA taking authorization despite the presence of a depleted stock of beluga whales. Similarly, to date, oil companies have not obtained authorizations for seismic surveys in the Gulf of Mexico whereas they generally have done so in the waters off the North Slope of Alaska. The National Marine Fisheries Service is working to correct this problem in the Gulf of Mexico. Seismic research studies funded by the National Science Foundation have been conducted without authorization in a variety of areas known to be inhabited by marine mammals, including some endangered cetaceans. Finally, the Navy has obtained authorizations for some specific activities (for example, ship shock trials, low-frequency active sonar testing) but not for all sonar training exercises and ranges.

Questionable applicability of existing statutes and regulations to commercial shipping—Commercial shipping appears to be a special case inasmuch as the application of existing statutes and regulations to shipping companies may not be feasible. If large sectors of the industry sought authorizations collectively, they might not be able to satisfy the MMPA requirements pertaining to small numbers and geographic specificity. Moreover, demonstrating that their operations have a negligible impact on the affected marine mammal species and stocks also could be difficult. Even if each vessel sought its own authorization, it might not be able to meet the statutory requirements. What is clear, however, is that, because of the sheer number of vessels involved in shipping operations in U.S. waters, use of the existing mechanisms to authorize such taking would overwhelm the resources of the authorizing agencies. This is a matter of concern because shipping noise has increased by at least a factor of ten over the past few decades. It is also an international issue because the vast majority of the maritime fleet is registered outside of the United States and most of the shipping noise originates in international waters.

Exclusion of some sound producers from available authorizing mechanisms—Incidental take authorizations and incidental harassment authorizations under the MMPA can be issued only to U.S. citizens. As a result, the only type of authorization available to foreign vessels operating in the U.S. Exclusive Economic Zone is a waiver of the MMPA's taking moratorium. However, the issuance of a waiver may be precluded if depleted marine mammals are likely to be taken.

Inadequate monitoring to determine whether effects occur, whether they are significant, and whether mitigation measures are complied with and are effective—The MMPA requires that holders of small-take authorizations monitor the effects of their activities on marine mammals. Monitoring programs should collect information sufficient to determine that marine mammals are taken only in anticipated and authorized ways and numbers and to verify that the effects of the taking are, in fact, negligible. In practice, monitoring programs rarely have met those standards. Usually baseline information on population density, distribution, and behavior in an action area is not gathered before an activity is initiated, and potential effects during the activity are difficult to assess without a basis for comparison. Similarly, little or no survey effort is conducted after an activity is concluded to look for animals that may have been injured or killed by the activity and to determine whether conditions have returned to a baseline state.

The MMPA also requires minimization and mitigation of the effects of sound-producing activities, when practicable, but the available mitigation measures often are untested and only assumed to be effective. As noted earlier, the presumed effectiveness of ramp-up as a mitigation measure is based on the assumption that marine mammals will move away from a sound source to avoid an exposure capable of causing injury or death. Whether and to what extent marine mammals actually do move away from a sound source is not clear and such a response is likely to depend on a variety of factors. In the limited number of documented cases, marine mammals have sometimes avoided or moved away from a sound source and other times have remained in the presence of or been attracted to the source (Bryant et al. 1984, Tyack 1999, Miller et al. 2000).

Similarly, the use of safety zones around sound sources is based on the assumption that observers can detect marine mammals entering or within the safety zone. As noted earlier (Section VIII), this ability depends on several factors, including the observer's experience, the size and behavior of the animals to be detected, and the conditions under which observations are being made. Extensive information from marine mammal surveys clearly demonstrates that observers are unlikely to detect all marine mammals within a safety zone, even under optimal conditions (Barlow and Gisiner 2006). This is especially true for intense sources with large safety zones. Despite these and related problems, authorizations continue to rely on safety zones and visual observations as the primary means of avoiding exposures to sound levels that might result in significant effects on marine mammals or that might result in deaths or serious injuries if only taking by harassment has been authorized.

Insufficient accounting of individually insignificant effects that may be cumulatively significant—Many effects of anthropogenic sound may be individually insignificant, but when combined with effects of other natural and anthropogenic sounds and other human activities may have additive or synergistic significance. Such effects are not well addressed under the current management framework, in part because their cumulative impacts are difficult to characterize or predict. As noted earlier, sublethal effects are not considered in the current management framework for commercial fisheries in which tolerable levels of mortality are based on the PBR concept. This may be a significant shortcoming, as described in the 2005 National Research Council report mentioned earlier. The report recommended that the PBR concept be revised to incorporate consideration of sublethal effects and that this management approach be considered for all sources of human impacts. Until the significance of sublethal effects is determined and incorporated into management programs—whether based on PBR or some other concept—the true impacts of human activities, including anthropogenic sound, likely will be underestimated and assessments of population status may be incorrect.

Delays in issuing permits and authorizations—Applicants have complained frequently about delays in issuance of scientific research permits and small-take authorizations. The complaint is widespread and is made in relation to a variety of activities, including those pertaining to sound. In some cases, it is justified. In others the delay can be traced back to applicants who may not have provided the necessary information or who do not respond promptly to requests for additional information. Additional factors that can slow the processing of permit applications are lawsuits, or the threat of lawsuits, and the need to comply with other statutes such as NEPA.[26]

The National Marine Fisheries Service has recently revised its permit application instructions to make them more understandable, streamlined, and user-friendly. Several additional options are available for further streamlining the permitting and authorization process. For example, the processing of small-take authorizations and incidental harassment authorizations may be expedited if the underlying activity already is subject to separate NEPA review (for example, by the Minerals Management Service for seismic surveys related to oil and gas exploration). In addition, a negligible impact finding to meet MMPA requirements should be sufficient to support a finding of no significant impact on marine mammals under NEPA.[27] Other possible ways to streamline review processes include establishing general guidelines for determining what types of exposures would be considered negligible under both the MMPA and NEPA and better use of categorical exclusions and programmatic analyses.

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[26] As the Ninth Circuit Court of Appeals ruled in *Jones* v. *Gordon*, 792 F.2d 821 (9th Cir. 1986), the time limit for processing permits under the MMPA does not obviate the need to comply with NEPA. The court believed that the requirements of the two statutes could be reconciled by delaying publication of the initial notice of an application, which starts the clock for agency action.

[27] A NEPA analysis still may be required to assess the impacts of the proposed activities on the remaining affected environment.

The need for international cooperation—The oceanic domain, and the influence of human activities on it, clearly extend beyond the waters of any given nation. Participants at the international workshop on sound sponsored by the Commission and the Joint Nature Conservation Committee favored regional solutions rather than a single global approach to sound-related issues, but even regional solutions require bilateral and multilateral cooperation in research and management. As noted, the international arena is likely the best place to address the need for regulation of commercial shipping. Multi-national naval exercises using sonar (such as occurred in association with beaked whale strandings) are another type of activity where international agreement is essential. Addressing the sound issue is an endeavor in which the United States has an opportunity to demonstrate research and management leadership that will benefit not just the marine ecosystems in U.S. waters but also those throughout the world's oceans. Because the oceans are largely a global commons, failure to show such leadership will increase the chance that the state of our waters will be determined by factors outside our influence and control.

XI. Recommendations

To address the described needs for scientific information and shortcomings in management requirements and efforts, the Marine Mammal Commission makes the following recommendations to Congress.

Recommendation 1: Establish a coordinated national research program on the effects of anthropogenic sound on marine mammals and the marine environment

Congress should establish a research program to improve understanding of anthropogenic sound, its biologically significant effects on marine mammals and marine ecosystems, and effective means for mitigating and monitoring those effects.

Administration—The research program should be guided by an interagency coordinating committee with representatives from the Navy, Minerals Management Service, National Oceanic and Atmospheric Administration, Fish and Wildlife Service, U.S. Geological Survey, National Science Foundation, Marine Mammal Commission, and any other agency with related responsibilities or interest in this issue. As the agency responsible for oversight of marine mammal research and management in the United States, the Marine Mammal Commission is the most appropriate agency to chair the committee and would be pleased to do so. The initial charge to the committee should be preparation of a research plan to study anthropogenic sound and its effects on marine mammals. In recognition of other significant threats to marine mammals and marine ecosystems (for example, fishing, contaminants, harmful algal blooms, disease, habitat loss, environmental change), the committee should be granted the flexibility to expand or modify its membership, scope, and activities once the initial sound research plan is completed and critical uncertainties are being addressed through well-designed research projects. This administrative recommendation satisfies Congress's mandate to the Commission to provide guidance on research and management related to the sound issue, but also maintains consistency with the Commission's larger statutory mandate to be attentive to all factors that threaten marine mammals and the ecosystems upon which they depend.

Program Direction—Direction for the research program should be described in a comprehensive five- to ten-year plan focusing on (1) improving understanding of sound in the marine environment; (2) characterizing sound effects on marine life, including marine mammals, at the individual, population, and ecosystem levels; (3) evaluating existing prevention, mitigation, and monitoring measures; and (4) developing more effective management measures. The plan should—

- identify the critical uncertainties and establish research priorities,
- describe the scope, time, equipment/infrastructure, logistics, and funding needed for the research,
- specify lead and cooperating agencies for each task and their funding and other responsibilities,
- be updated regularly to incorporate new findings and information,
- ensure peer-review and prompt publication of research and monitoring results,
- be open to public review and comment, and
- promote public education and training of scientists and students.

Funding and Resources—In view of the variety of research topics to be addressed, the difficulty of working in the marine environment, and the extensive infrastructure required, a substantial investment is needed. The research caucus that participated in the Commission's Advisory Committee process recommended that new funding be provided to participating agencies with the amount increasing over three or four years to an annual level of $25 million. This amount presumably represents the required minimum investment in basic research, but it does not include the substantial logistical and regulatory compliance costs associated with that research (for example, applying for authorizations, completing environmental assessments, processing such materials by permitting agencies). When completed, a comprehensive, integrated, and focused research plan will provide the best basis for establishing long-term funding levels.

Funding for the sound research program should not be taken from other areas of marine mammal research. Rather, the national sound research program should be funded with additional appropriations as necessary to undertake the cooperative long-term research program recommended by the interagency coordinating committee. Affected industries and others with related interests, expertise, and specialized equipment and logistic capabilities should be invited to participate in or contribute to implementation of the long-term program plan.

Recommendation 2: Establish consistent standards for the regulation of sound in the marine environment

With two exceptions, the Commission finds no basis for different regulatory treatment of the various sources of anthropogenic sound that are likely to take marine mammals incidentally. Those exceptions are commercial shipping, which is addressed under recommendation 7, and Department of Defense activities that are necessary for national defense and may be exempted in accordance with section 101(f) of the MMPA.

Congress should provide the National Marine Fisheries Service and the Fish and Wildlife Service authority to regulate all anthropogenic sound sources in the marine environment. In particular, Congress should require assessment of the effects of fishery and aquaculture activities as an objective of the national sound research program described under recommendation 1 and grant the National Marine Fisheries Service the authority and responsibility to regulate those effects, including regulatory authority over the siting of aquaculture facilities and whether and how acoustic harassment devices may be used to prevent depredation by marine mammals. Such control might be imposed by requiring aquaculture facilities to obtain authorizations from the Service to ensure that any sound levels produced do not result in non-negligible impacts to marine mammals and are mitigated to the extent practicable. The Service should have authority to exclude acoustic harassment devices from important marine mammal habitat.

Recommendation 3: Ensure that all sound producers comply with statutory and regulatory requirements

Requirements for authorization to take marine mammals incidentally should be applied consistently to all sound producers. For example, the Navy should obtain authorizations for taking marine mammals incidental to its various exercises and operations, and the oil and gas industry should obtain authorizations for all of its operations unless they meet the standards for exception. Similarly, the potential effects of whale-watching vessels as well as small vessels and watercraft should be evaluated to determine if regulation is needed to avoid harmful sound-related effects. Congress should advise the National Marine Fisheries Service and the Fish and Wildlife Service that sound producers in U.S. waters and U.S. sound producers (including those receiving funding from U.S. sources) on the high seas are required to obtain necessary taking authorizations if their activities have the potential to kill, injure, or harass marine mammals. Congress also should advise the Services to take such actions as necessary to ensure that authorizations are obtained when any taking is likely.

Congress should amend the MMPA to make incidental take authorizations under section 101(a)(5) available to all sound producers operating in U.S. waters, regardless of nationality, provided that the substantive requirements (for example, the negligible impact standard) remain in place. As reflected in recommendation 7, such an amendment, by itself, is unlikely to solve the problem of how best to authorize the taking of marine mammals incidental to commercial shipping.

Recommendation 4: Retain mitigation and monitoring as requirements of the authorization and compliance process and designate the evaluation of existing measures and development of more effective measures as high priorities for the national research program

Although the effectiveness of existing mitigation, monitoring, and reporting measures is a matter of debate, those measures are vital to validating assumptions regarding the nature and significance of sound effects and improving our ability to manage sound-producing activities. Measures should—

- minimize unnecessary sound production—for example, preclude repetitious seismic surveys of the same area when a single, comprehensive survey would suffice to provide the information needed by the oil and gas industry;
- promote sound-reducing technologies—for example, encourage the seismic industry to develop airgun arrays that direct virtually all of their energy straight down, and inform ship-builders of the need for ship-quieting technologies that will reduce marine noise as well as improve sound conditions on those ships. Note that this latter example should be accompanied by a research program to ensure that quieter ships do not result in an increase in ship/whale collisions;
- implement temporal and spatial measures to avoid sound-producing activities in seasons and areas that are especially important in the life history of marine mammals; and
- use the assets of sound producers to enhance mitigation, monitoring, and reporting of sound effects—for example, use the variety of Navy range assets to study marine mammal responses to different types and levels of sound.

In view of the limited value of current mitigation and monitoring measures, Congress should require that the evaluation of existing methods and development of more effective methods be identified as high priorities of the national research program.

Recommendation 5: Require the National Marine Fisheries Service and the Fish and Wildlife Service to develop a management system that accounts for the cumulative effects of sublethal exposure to anthropogenic sound and other human impacts on marine mammals

Successful conservation strategies for marine mammals must take into account the full impact of human activities on them. The full impact is a function not only of direct mortality but also of sublethal effects (for example, changes in stress level, condition, health) that, when combined, may significantly influence individual reproduction or survival, the factors that ultimately determine a population's status. Such sublethal effects are a major concern regarding human-generated sound in the marine environment, and a management system is needed to account for them.

The PBR system has been used effectively to account for incidental mortality of marine mammals in commercial fisheries. Whether this system can be extended to account for the sublethal effects of other risk factors, including sound (National Research Council 2005), or would serve better as a model for a separate management system is not clear. Nonetheless, any comprehensive and effective management strategy must account for sublethal as well as lethal effects. With that in mind, Congress should require the Services to develop a management system that accounts for the cumulative effects on marine mammals of sublethal exposure to anthropogenic sound as well as all other human impacts.

Recommendation 6: Direct the National Marine Fisheries Service and the Fish and Wildlife Service to streamline their implementation of permitting and authorization processes for research on sound effects and for activities that may take marine mammals incidentally

Permitting and authorization processes could be streamlined without statutory or regulatory changes by combining analyses required under different statutes, conducting programmatic analyses to provide large-scale consideration of proposed actions, and invoking use of categorical exclusions where analyses are not required. Congress should advise the National Marine Fisheries Service and the Fish and Wildlife Service to implement options for streamlining environmental analyses to avoid unnecessary delays in processing applications for take authorizations and research permits.

Recommendation 7: Promote U.S. leadership in international matters related to anthropogenic sound in the marine environment

The United States has an important opportunity to lead international efforts to address the effects of anthropogenic sound in the oceans. Such leadership is needed to promote research and sharing of information and to coordinate management strategies for regional and global sound-related issues. All the major sources of anthropogenic sound in the oceans are active on a global basis (that is, commercial shipping, seismic surveys and research, military and other sonar). Any comprehensive research and management approach must recognize that sound effects extend beyond national waters. Coordination of military exercises using sonar, development of ship-quieting technologies for commercial ships, and incorporation of ambient noise assessment into developing ocean observing systems are examples of activities requiring international leadership.

Shipping appears to pose a particularly difficult challenge. The vast majority of the commercial shipping fleet is registered outside the United States, and most shipping noise originates in international waters. Thus, it would be best to work within the international treaty structure to develop an appropriate framework for addressing this issue. Congress should direct the Department of State to consult with the interagency national research program on sound recommended earlier, the National Oceanic and Atmospheric Administration, the Department of Justice, the Marine Mammal Commission, and any other affected agencies to determine what shipping-related proposals should be made to the International Maritime Organization.

XII. Concluding Remarks

The introduction of anthropogenic sound into the oceans began in earnest with the industrial revolution but has only recently been recognized as one of a number of potential threats to the fauna of the world's oceans. Both individually and collectively, these factors put at risk our goal of passing healthy, sustainable marine ecosystems to future generations. Our success will depend on efficient study of such risk factors and implementation of effective solutions, whether the problem is sound, contaminants, dead zones, loss of habitat, or any of a number of other consequences of human activities.

Sound is but one of those consequences. Nonetheless, it presents a potentially significant threat and warrants a rigorous response. Uncertainty regarding sound effects on marine mammals will persist for years to come because scientific study on this topic is still in an early stage of discovery and development, the amount of sound energy introduced into the oceans is increasing, and the assessments that we depend on for determining marine mammal status are often coarse and insufficient. Clearly, our research and assessment efforts must be improved.

To avoid irreversible effects in the face of uncertainty, the Commission believes that a reasoned, precautionary management approach is essential. The intent of such an approach is not to preclude sound-producing activities but to manage them in a manner that errs on the side of caution with respect to the protection granted to marine mammal populations and marine ecosystems. Such an approach should provide incentives for management agencies and sound producers to support an adaptive research program aimed at ensuring conservation of marine mammals and ecosystems without unnecessarily impeding human activities in the oceans. The challenge and the opportunity before us all is to organize a cooperative effort that maximizes our efficiency and effectiveness in this important undertaking.

XIII. Acknowledgements

The Marine Mammal Commission was directed by the United States Congress 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." The Commission appreciates the opportunity to provide leadership and direction for this important issue, one that has implications for our country's military readiness, energy production, and ecosystem and species conservation. We hope that this report provides a useful document as Congress, agencies, and other organizations look ahead.

The Commission greatly appreciates the time and commitment of the members of the Advisory Committee on Acoustic Impacts on Marine Mammals and the many people who served on various subcommittees or provided other types of support for the committee, including facilitators Suzanne Orenstein and Lee M. Langstaff. The Commission gratefully acknowledges the members and staff of the United Kingdom's Joint Nature Conservation Committee, which co-sponsored the international workshop on sound and its effects on marine mammals. The Commission also is grateful to the many scientists who participated in the Commission's beaked whale workshop. Three Commission staff members who have since moved to other positions played especially meaningful roles in the evolution of this project: David Cottingham, Erin E. Vos, and Dr. Tara M. Cox. The Commission appreciates very much their dedication and efforts.

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APPENDIX 1

The Advisory Committee on Acoustic Impacts on Marine Mammals:

Report to the Marine Mammal Commission

The Advisory Committee on Acoustic Impacts on Marine Mammals

Report to the Marine Mammal Commission

Advisory Committee on Acoustic Impacts on Marine Mammals

Report to the Marine Mammal Commission

1 February 2006

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Advisory Committee on Acoustic Impacts on Marine Mammals

PROCESS SUMMARY

11 November 2005

Prepared by the facilitation team of
Suzanne Orenstein
Lee Langstaff

In 2003 the U.S. Congress, through the Omnibus Appropriations Act of 2003, directed the Marine Mammal Commission (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."[1] The potential for human-generated (anthropogenic) sources of sound to affect marine mammals had been discussed in many forums in recent years, and had been the subject of four reports since 1994 from the National Research Council of the National Academy of Sciences. These previous efforts pointed to the need for more specific information about the effects of chronic and episodic sound on marine mammals and the means of reducing them.

To meet the Congressional directive, the Commission initially consulted with a variety of interested stakeholders regarding various approaches the Commission might take. Taking the input from these discussions into account, the Commission then entered into an agreement with the U.S. Institute for Environmental Conflict Resolution (Institute) to create a multi-stakeholder dialogue focused on addressing the potential impacts of anthropogenic sound on marine mammals. Through the Institute, the Commission engaged a team of neutral facilitators to help construct and manage a dialogue process among the groups concerned about this issue. In the autumn of 2003, the facilitators conducted confidential interviews with over 80 interested stakeholders representing the various interested parties. Concurrently, a *Federal Register* Notice was issued announcing the potential for the formation of a Federal Advisory Committee and soliciting comment, including nominations for participants and issues for discussion.[2] Those interviewed by the facilitation team were generally positive about participating in a policy dialogue, because they believed that existing fora and efforts to date had not adequately integrated issues of science, management, and mitigation and that it was desirable to discuss the issues in an open and collaborative forum.

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[1] Public Law 108-7
[2] 68 *Federal Register* 203 (21 October 2003)

The Commission established the 28-member Advisory Committee on Acoustic Impacts on Marine Mammals (Advisory Committee) in November 2003, under the provisions of the Federal Advisory Committee Act of 1972.[3] The Advisory Committee was directed in its charter to:

1) Review and evaluate available information on the impacts of human-generated sound on marine mammals, marine mammal populations, and other components of the marine environment,
2) Identify areas of general scientific agreement and areas of uncertainty or disagreement related to such impacts,
3) Identify research needs and make recommendations concerning priorities for research in critical areas to resolve uncertainties or disagreements, and
4) Recommend management actions and strategies to help avoid and mitigate possible adverse effects of anthropogenic sounds on marine mammals and other components of the marine environment.[4]

The Commission selected the Advisory Committee members to represent a balance of stakeholder interests, including (a) entities whose activities introduce sound into the marine environment (academic research scientists, U.S. shipping industry, oil and gas industry, U.S. Navy and other government agencies); (b) environmental and animal welfare non-governmental organizations; (c) research scientists with pertinent expertise; and (d) federal and state government agencies with responsibilities concerning or affecting marine mammals. The individuals and organizations that participated in the Advisory Committee are listed at the end of this document.

Between February 2004 and September 2005 the Advisory Committee met in six plenary meetings:

1) February 3–5, 2004, in Bethesda, Maryland

2) April 28–30, 2004, in Arlington, Virginia

3) July 28–30, 2004, in San Francisco, California

4) November 30–December 2, 2004, in New Orleans, Louisiana

5) April 19–21, 2005, in Silver Spring, Maryland

6) September 20–21, 2005, in Bethesda, Maryland

In addition, Committee members and additional experts participated in numerous Subcommittee and Working Group meetings and conference calls to develop materials for Advisory Committee consideration (see Attachment 2 for Subcommittee membership and meeting dates). Consistent with Federal Advisory Committee Act, summaries of all Advisory Committee meetings and copies of all

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[3] 68 *Federal Register* 238 (11 December 2003)
[4] Full charter available at http://www.mmc.gov/sound/committee/committee.html.

presentations and working drafts brought to the full Committee for consideration are publicly available, with most documents available on the Commission's website at www.mmc.gov/sound. Advisory Committee members agreed at the outset on operating procedures, including the following:

> The Committee's charge is to develop recommendations to the Commission for inclusion in a report to Congress from the Commission. The Commission asks the Committee to develop as much consensus on these recommendations as is achievable. On issues where the Committee does not or cannot reach consensus, this will be noted and the Commission may develop, if it so chooses, its own recommendations to Congress on those issues.[5]

After extensive deliberations, the Advisory Committee found that it was unable to reach consensus on a report to the Commission. Significant differences of opinion on a number key issues remained unresolved at the Advisory Committee's final meeting in September 2005. Acknowledging this, Committee members agreed unanimously to discontinue efforts to reach agreement on a single consensus report to the Commission. They agreed instead to implement an alternative plan proposed by the Marine Mammal Commission, consistent with the Committee's Operating Procedures as described above. The plan included:

1) Development of this summary of the Advisory Committee process;

2) Development of non-consensus statements by individual Advisory Committee members or groups of members that express views on the issues discussed by the Advisory Committee in response to its charter. These statements are attached to this summary and together with the summary constitute the report of the Advisory Committee to the Commission;

3) Development of a Marine Mammal Commission report to Congress, with this summary and the non-consensus statements (described in 1 and 2 above) appended; and

4) Distribution to all Advisory Committee members of the Commission's report to Congress, upon its transmittal to Congress.

<u>List of Non-Consensus Statements (in alphabetical order by submitting member's surname)</u>

- Statement A submitted by Committee Member Kenneth C. Balcomb, III
- Statement B: Federal Caucus—Submitted by RDML Mark Boensel, Martin Kodis, Robert LaBelle, Michael Reeve, Charles Schoennagel, V. Frank Stone, Frederick Sutter, RADM Steven Tomaszeski, Donna Wieting, and JamesYoder
- Statement C: Environmental Caucus—Submitted by Sarah Dolman, Marsha Green, Erin Heskett, Joel Reynolds, and Naomi Rose

[5] The full text of the Advisory Committee's Operating Procedures is attached (Attachment 1).

- Statement D: Energy Producers Caucus—Submitted by G. C. (Chip) Gill, James P. Ray, and Bruce A. Tackett
- Statement E: Commercial Shipping Industry Representative—Submitted by Kathy J. Metcalf
- Statement F: Scientific Research Caucus—Submitted by Submitted by Paul E. Nachtigall, RADM Richard Pittenger (Ret.), G. Michael Purdy, Peter Tyack, RADM Richard West (Ret.), and Peter F. Worcester
- Statement G: California Coastal Commission—Submitted by Sara Wan

Advisory Committee Members and Alternates

Laurie K. Allen, National Marine Fisheries Service Office of Protected Resources; replaced by **Donna Wieting,** National Marine Fisheries Service Office of Protected Resources (Alternate: **Stephen Leathery**, National Marine Fisheries Service Office of Protected Resources)
Kenneth C. Balcomb III, Center for Whale Research (Alternate: **John Calambokidis**, Cascadia Research)
David Cottingham, Marine Mammal Commission (Designated Federal Official)
Sarah Dolman, Whale and Dolphin Conservation Society (Alternate: **Mark Simmonds**, Whale and Dolphin Conservation Society)
G. C. "Chip" Gill, International Association of Geophysical Contractors (Alternate: **Philip Fontana**, Veritas DGC, Inc.; replaced by **Jack Caldwell**, Consultant)
Marsha L. Green, The Ocean Mammal Institute (Alternate: **Linda Weilgart**, Dalhousie University)
Erin M. Heskett, International Fund for Animal Welfare (Alternate: **Carole Carlson**, International Fund for Animal Welfare)
John A. Hildebrand, Marine Mammal Commission and Scripps Institution of Oceanography
Martin Kodis, U.S. Fish and Wildlife Service (Alternate: **Diane Bowen**, U.S. Fish and Wildlife Service)
Robert LaBelle, Minerals Management Service (Alternate: **Richard Wildermann**, Minerals Management Service; replaced by **James Kendall**, Minerals Management Service; replaced by **Judy Wilson**, Minerals Management Service)
Kathy Metcalf, Chamber of Shipping of America (Alternate: **Joe Cox**, Chamber of Shipping of America)
Paul E. Nachtigall, Hawaii Institute of Marine Biology, University of Hawaii
Richard F. Pittenger, Woods Hole Oceanographic Institution (Alternate: **Darlene Ketten**, Woods Hole Oceanographic Institution and Harvard University)
G. Michael Purdy, Lamont-Doherty Earth Observatory (Alternate: **John Orcutt**, Scripps Institution of Oceanography)
James P. Ray, Oceans Environmental Services and Shell Global Solutions (US) Inc. (Alternate: **Dan Allen**, Chevron Texaco)
Joel Reynolds, Natural Resources Defense Council (Alternate: **Michael Jasny**, Natural Resources Defense Council)

Naomi A. Rose, The Humane Society of the United States (Alternate: **Sharon Young**, The Humane Society of the United States)
Charles J. Schoennagel, Jr., Minerals Management Service (Alternate: **Pasquale Roscigno**, Minerals Management Service; replaced by **William Lang**, Minerals Management Service)
V. Frank Stone, U.S. Navy Office of the Chief of Naval Operations
Frederick C. "Buck" Sutter III, National Marine Fisheries Service (Alternate: **David Bernhart**, National Marine Fisheries Service)
Bruce Tackett, Exxon Mobil Corporation
Steven J. Tomaszeski, U.S. Navy Office of the Chief of Naval Operations–Oceanographer of the Navy; replaced by **Mark S. Boensel**, U.S. Navy Office of the Chief of Naval Operations (Alternate: **Roger Nolan**, Naval Reserve Readiness; replaced by **Tim McGee**, Naval Meteorology and Oceanography Command)
Peter L. Tyack, Woods Hole Oceanographic Institution (Alternate through April 2005: **Dan Costa**, Long Marine Laboratory, University of California at Santa Cruz)
Sara Wan, California Coastal Commission (Alternate: **Mark Delaplaine**, California Coastal Commission)
Richard D. West, Consortium for Oceanographic Research and Education; replaced until July 2005 by **Penelope Dalton**, Consortium for Oceanographic Research and Education
Peter Worcester, Scripps Institution of Oceanography (Alternate: **Gerald D'Spain**, Scripps Institution of Oceanography)
James A. Yoder, National Science Foundation Division of Ocean Sciences; replaced by **Michael Reeve**, National Science Foundation Division of Ocean Sciences (Alternate: **Alexander Shor**, National Science Foundation Division of Ocean Sciences)
Nina M. Young, The Ocean Conservancy; replaced by **Morgan Gopnik**, The Ocean Conservancy

Independent Facilitators (Contracted through the U.S. Institute for Environmental Conflict Resolution)

Suzanne G. Orenstein
Lee M. Langstaff
Linda Manning, SRA International

Additional Subcommittee and Working Group Participants (Alphabetical)

Melissa Anderson, U.S. Fish and Wildlife Service
Daryl Boness, Smithsonian Institution (retired) and Marine Mammal Commission
Colleen Corrigan, U.S. Fish and Wildlife Service
Tara Cox, Marine Mammal Commission
Cynthia Decker, Office of the Oceanographer of the Navy
Roger Gentry, National Marine Fisheries Service
Robert Gisiner, Office of Naval Research
Mardi Hastings, Office of Naval Research
Rodger Melton, ExxonMobil
James Miller, University of Rhode Island

Linda Petitpas, Office of the Chief of Naval Operations
Tim Ragen, Marine Mammal Commission
Brandon Southall, National Marine Fisheries Service
Erin Vos, Marine Mammal Commission
Andrew Wigton, ExxonMobil
Andrew Wright, Marine Mammal Commission and National Marine Fisheries Service

Attachment 1

Advisory Committee on Acoustic Impacts on Marine Mammals

OPERATING PROCEDURES

For any voluntary collaborative forum to operate smoothly, it is helpful for those involved to agree at the outset on the purpose for the process and on the procedures by which the group will govern its discussions, deliberations, and decision-making. These draft procedures will be reviewed, discussed, revised and adopted by the Advisory Committee at its first meeting.

1. PURPOSE AND GOAL FOR THE ADVISORY COMMITTEE

The Omnibus Appropriations Act of 2003 (Act), Public Law 108-7, directed the Marine Mammal Commission (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 assist in meeting this directive, the Commission establishes the Advisory Committee on Acoustic Impacts on Marine Mammal (Committee), under the Federal Advisory Committee Act, to:

1) Review and evaluate available information on the impacts of human-generated sound on marine mammals, marine mammal populations, and other components of the marine environment,

2) Identify areas of general scientific agreement and areas of uncertainty or disagreement related to such impacts,

3) Identify research needs and make recommendations concerning priorities for research in critical areas to resolve uncertainties or disagreements, and

4) Recommend management actions and strategies to help avoid and mitigate possible adverse effects of anthropogenic sounds on marine mammals and other components of the marine environment.

The Committee's charge is to develop recommendations to the Commission for inclusion in a report to Congress from the Commission. The Commission asks the Committee to develop as much consensus on these recommendations as is achievable. On issues where the Committee does not or cannot reach consensus, this will be noted and the Commission may develop, if it so chooses, its own recommendations to Congress on those issues.

2. STRUCTURE OF THE COMMITTEE

Advisory Committee: The Advisory Committee will consist of those members appointed by the Commission. The full Committee will be the decision-making forum for the Committee. The Commission will have two members on the Committee.
Subcommittees: The Committee may establish subcommittees to assist it in developing draft proposals or products for consideration at specific Committee meetings. The membership of subcommittees is subject to the approval of the Committee and may be drawn from individuals who are not Committee members. All subcommittees work at the direction of and report to the Committee. The Committee will develop a scope of work for each subcommittee, outlining the desired membership and expertise, schedule, and product. Subcommittees will operate by the same consensus rule as the Committee.

Technical Resources: The Committee may identify the need for assistance from technical resource experts for the Committee or for Subcommittees. For expertise for the Committee, the Committee will identify experts through discussion and consensus to ensure that all members obtain information that they find useful. For Subcommittees, the Subcommittee will seek to develop the consensus on the experts it requests. If the Committee or Subcommittee cannot reach consensus on one specific expert, technical experts representing differing views may be consulted. The Commission will assist the Committee to obtain the requested technical experts to the extent that it is economically and practically feasible to do so.

3. PARTICIPATION

Interests Represented: Committee membership is limited to those appointed by the Commission. The list of appointed members can be found on pages 4 and 5.

Responsibilities of Committee Members: Committee members are responsible for representing the views of other members in their constituency to the maximum extent feasible, and for communicating with others in their interest group. Members are responsible for ensuring that all significant issues and concerns of their organizations and constituents are fully and clearly articulated during Committee meetings. Members are also responsible for ensuring, to the maximum extent feasible, that any eventual recommendations or agreements are acceptable to their constituents and/or the agencies or organizations that they represent.

Alternates: Each member is expected to attend all meetings in their entirety. Each member can also recommend to the Commission an alternate who will, upon Commission approval, attend meetings or portions of meetings when the member is unable to fill his or her seat. The Committee does not intend for this provision to allow for the de facto representation of two members from a constituency in one seat. Alternates who attend meetings with their Committee member can address the Committee in the public comment period. It is the responsibility of the member and the alternate to communicate to ensure that there are no disruptions in the process when an alternate joins the Committee deliberations.

Participation of Those Who Are Not Committee Members: Committee members may request to hear from experts who are in the room but are not on the Committee.

Other Commitments of Members: Members are asked to:

- Share all relevant information that will assist the Committee in achieving its goals;
- Keep their organizations' decision-makers informed of potential decisions and outcomes in order to expedite approval for the final product to the greatest extent possible;
- Resolve issues being addressed within the Committee structure, not through side bar discussions and agreements that may place other Committee members at a disadvantage;
- Refrain from characterizing the views of other Committee members, or the Committee as a whole, in any interactions with the press; and
- Support the eventual product if they have concurred in it.

Addition of Members: Additional members may join the Committee only with the agreement of the Commission and the Committee, and only if they represent an interest that is not already represented.

4. DECISION-MAKING AND COMMITMENT

Consensus: When concurrence among the members is desired, the Committee will make decisions by consensus. The Committee will use the following definition of consensus: all Committee members can live with a given recommendation or decision. Committee members are responsible for making known any areas of disagreement throughout the process. If the group cannot reach consensus, members will evaluate the consequences of their disagreement and decide together how to address the lack of agreement with due consideration of the need for full, fair and equitable discussion of all perspectives on any issue. The disagreements will be summarized and can become part of the Committee's report if the Committee so chooses.

Role of the Commission: The Commission will participate as full members of the Committee, engaging in the Committee on the issues and exchanging views on the topics discussed. The Commission will provide technical support to the Committee as requested, to the extent feasible. The Commission intends to use any recommendations on which there is consensus in its report to Congress. On issues where the Committee does not or cannot reach consensus, the disagreements will be described in the Committee report. The Commission will include those disagreements in its report to Congress and may develop, if it so chooses, its own recommendations to Congress on those issues.

Decision-Making Process: Decisions will be made by consensus of those present at the meeting except in the case of concurrence on major products, for which consensus and sign-off from all Committee members will be sought. Major products include draft and final Committee reports.

5. SAFEGUARDS

Good Faith: All Committee members agree to act in good faith in all aspects of the Committee's operation. They further agree that specific offers made in open and frank problem-solving conversations will not be used against any other member in future litigation or public relations. Good faith requires that individuals not represent their own personal or organization's views as views of the entire Committee, and that the views and opinions they express in the Committee deliberations are consistent with the views they express in other forums.

Committee Products: The Advisory Committee will develop draft and final reports to the Commission outlining consensus recommendations and areas of disagreement. The Committee may also develop preliminary draft recommendations, chapters of its final report, and other documents that will assist the Committee in reaching consensus on a final report. All agreements on preliminary products will be considered provisional until the Committee has reached consensus or otherwise finalized its final report.

Commission Report: The draft final Report to Congress from the Commission will be sent by electronic mail to the Committee members and the Committee members will have an opportunity to review and comment. The Commission Report will include verbatim the Committee's report.

Press and External Contacts: All meetings of the Committee will be open to the public, and members of the press may attend. Committee members and facilitators may speak to the press and other entities but all agree to refrain from characterizing the views of other Committee members, or the Committee as a whole, in any interactions with the press.

6. MEETING PROCEDURES

Caucusing: Any member may request a caucus with any other member(s) at any time. The person requesting the caucus will specify who is included in the caucus and how much time is being requested. (This technique will be most useful when the Committee is working to make decisions or to finalize recommendations.)

Facilitation: The Committee meetings will be facilitated. The facilitators will work with the Committee to create a forum that is constructive and balanced for all participants. They will be unbiased in their facilitation and not take positions on the issues before the Committee. The facilitators will work to ensure that the meetings stay on topic and that all points of view are heard during discussions. Facilitators will keep confidential information disclosed to them in confidence.

Open to the Public: Meetings of the Committee will be conducted consistent with the Federal Advisory Committee Act (FACA), and will be open to the public and announced in the *Federal Register*. Recommendations made by subcommittees will be brought to the full Committee for consideration, and will be posted on the Commission's website.

Meeting Summaries: The facilitators will develop summaries of each meeting, in consultation with the Commission. The summaries will be distributed to the Committee or appropriate subcommittee for review prior to their posting on the Commission's web site. The Committee will have ten business days to provide comments and corrections, after which the draft summary will be posted on the Commission's web site. Committee members who desire to do so are free to tape record the Committee meetings.

Attachment 2

Advisory Committee on Acoustic Impacts on Marine Mammals

SUBCOMMITTEE MEMBERSHIP AND MEETINGS

<u>Subcommittee on Synthesis of Current Knowledge</u>

This group was created by the Advisory Committee during its first plenary meeting.

Membership

Jack Caldwell, consultant
Gerald D'Spain, Scripps Institution of Oceanography
Roger Gentry, National Marine Fisheries Service (Alternate: Brandon Southall, National Marine Fisheries Service)
Robert Gisiner, Office of Naval Research (Alternate: Mardi Hastings, Office of Naval Research)
John Hildebrand, Scripps Institution of Oceanography and Marine Mammal Commission
Jim Kendall, Minerals Management Service
Rodger Melton, ExxonMobil (Alternate: Andrew Wigton, ExxonMobil)
James Miller, University of Rhode Island
Paul Nachtigall, Hawaii Institute of Marine Biology, University of Hawaii
Naomi Rose, Humane Society of the U.S.
Peter Tyack, Woods Hole Oceanographic Institution
Linda Weilgart, Dalhousie University (added for final Subcommittee meeting only)

Lead Facilitator: Lee Langstaff

Marine Mammal Commission Staff Participants: Daryl Boness, David Cottingham, Tara Cox, Tim Ragen, and Erin Vos

Meeting Dates and Locations

1) April 1, 2004 in Warwick, Rhode Island
2) April 30, 2004 in Arlington, Virginia
3) June 3–4, 2004 in Arlington, Virginia
4) September 16–17, 2004 in Silver Spring, Maryland
5) October 13–15, 2004 in Arlington, Virginia
6) November 30, 2004 in New Orleans, Louisiana
7) January 18–20, 2005 in Shepherdstown, West Virginia
8) March 1–3, 2004 in Silver Spring, Maryland
9) July 19–21, 2005 in Alexandria, Virginia

Subcommittee on Management and Mitigation

This group was created by the Advisory Committee during its second plenary meeting.

Membership

Jay Barlow, National Marine Fisheries Service (withdrew from participation prior to first Subcommittee meeting)
David Cottingham, Marine Mammal Commission
Phil Fontana, Veritas DGC, Inc. (Alternate: Chip Gill, International Association of Geophysical Contractors)
Erin Heskett, International Fund for Animal Welfare
Michael Jasny, Natural Resources Defense Council
Martin Kodis, U.S. Fish and Wildlife Service (Alternate, Colleen Corrigan, U.S. Fish and Wildlife Service, replaced by Melissa Anderson, U.S. Fish and Wildlife Service)
Kathy Metcalf, Chamber of Shipping of America
Michael Purdy, Lamont-Doherty Earth Observatory
James Ray, Shell Global Solutions (US) Inc. and Oceanic Environmental Solutions, LLC
V. Frank Stone, U.S. Navy Office of the Chief of Naval Operations (Alternate: Linda Petitpas, U.S. Navy Office of the Chief of Naval Operations)
Bruce Tackett, ExxonMobil
Sara Wan, California Coastal Commission
Linda Weilgart, Dalhousie University
Donna Wieting, National Marine Fisheries Service (Alternate: Stephen Leathery, National Marine Fisheries Service)
Judy Wilson, Minerals Management Service

Lead Facilitator: Suzanne Orenstein

Marine Mammal Commission Staff Participants: Tara Cox, Jeannie Drevenak, Erin Vos, and Andrew Wright

Meeting Dates and Locations

1) July 13, 2004 in Arlington, Virginia
2) July 30, 2004 in San Francisco, California
3) September 14, 2004 in Silver Spring, Maryland
4) October 12, 2004 in Arlington, Virginia
5) November 15, 2004 in Arlington, Virginia
6) February 7–8, 2005 in Arlington, Virginia
7) March 8–9, 2005 in Arlington, Virginia
8) May 16–17, 2005 in Arlington, Virginia
9) July 18, 2005 in Alexandria, Virginia

Statement for

The Report of the Advisory Committee on Acoustic Impacts on Marine Mammals

to the

Marine Mammal Commission

<u>Submitted by Committee Member:</u>

Kenneth C. Balcomb, III

Submission Date: 1 February 2006

Statement A submitted by Balcomb

To the US Marine Mammal Commission and the Congress of the United States

I thank you for the opportunity and honor of participating as a member in a FACA process concerning acoustic threats to marine mammals. Unfortunately, the process did not produce a consensus report. As you review the caucus reports and the report of the Commission, I hope that you will take into account my first-hand observations of incidents involving military mid-frequency sonar and marine mammals.

I was in the Bahamas on March 15, 2000 when beaked whales of two species swam into shallow water and stranded in astonishing numbers within a few hours following a US Naval mid-frequency tactical sonar exercise. Three beaked whales live-stranded within a mile of my location; and, at least two other beaked whales live-stranded a few miles further away. By day's end, fifteen beaked whales and two minke whales live-stranded in the region within fifty miles of me, and at least six of the beaked whales died. Having spent my lifetime studying cetaceans taken commercially and incidental to commerce, and having assisted with salvage efforts in other strandings, I found it remarkable that these otherwise hardy animals died so quickly. I collected fresh specimen materials from two of the beaked whales that died that day, and I provided these specimens to the US National Marine Fisheries Service (NMFS) for analysis. Unfortunately, the NMFS analyses were seriously flawed with respect to forensic methodology that has subsequently been found to demonstrate decompression-like traumas – gas and fat embolisms – in sonar-exposed stranded whale tissues. It **was** reported that there were hemorrhage patterns in acoustic fats, around the ears, and adjacent to the brain that were thought to result from "some sort of acoustic or impulse trauma". The preliminary NMFS/Navy report of the March 15, 2000 mass stranding of whales in the Bahamas concluded that the strandings were caused by the presence of beaked whales in a constricted channel with limited egress, a complex oceanographic environment, and intensive operation of Naval mid-frequency tactical sonar over an extended period of time. A subsequent presentation at the July 29, 2005 FACA meeting demonstrated that the received levels of the mid-frequency sonar signals at the most probable initial locations of the whales were on the order of 160-165 dB re 1uPa or less, and reverberations of the sonar signals were on the order of 145 dB re 1 uPa throughout the channel for much of March 15, 2000.

I was at home on San Juan Island, Washington State, on May 5, 2003 when hundreds of porpoises of two species and a minke whale swam at the surface at what appeared to be their maximum speed heading northwestward in Haro Strait parallel to San Juan Island, while a pod of killer whales gathered into a tight group at the surface and swam in an eastward direction in Haro Strait toward the shoreline of San Juan Island. About ten miles away on bearings that were reciprocal to the respective courses of these groups of cetaceans was a US Naval Destroyer (USS *Shoup*) operating its mid-frequency tactical sonar at 235 dB re 1 uPa at approximately 25-second intervals. I do not think that observers aboard that ship could have seen any of the cetaceans without high-powered binoculars, and perhaps even then they would not have seen them. The ship turned to an approximately northwest course up Haro Strait as the killer whales swam very near shore in a group toward my location. When the ship passed directly in front of me in mid-strait (about 1.5 mile distant), the killer whales stayed near the surface, changed directions several times, and divided into two groups that swam parallel to and near shore in opposite directions. The behavior of the killer whales, the minke whale, and the porpoises during the USS *Shoup* operations has been described as "abnormal" and/or extreme avoidance behavior by myself and all experienced observers that witnessed these incidents. An abnormally high number of harbor porpoises stranded around this time, and eleven specimens were collected for analysis (I collected a very freshly deceased harbor porpoise floating in Haro Strait and provided it to NMFS for analysis). Unfortunately, **all** specimens were kept in a walk-in frost-free freezer at NOAA in which freeze-thaw cycles were considered a potential source for free blood or hemorrhage artifact. The NOAA conclusion: "Therefore, definitive differentiation amongst congestion, hypostasis, and red staining of tissues found during necropsy examinations (antemortem versus post-mortem injury or post mortem dependent pooling) was hindered. The reddened tissue discoloration observed in all the animals was considered to be related to a combination of freezer artifact and autolytic (liquefactive) change." Nonetheless, NMFS reported, "Along the dorsolateral aspect and occasionally circumferentially investing the cranial cervical spinal cord and basioccipital region of the hindbrain, there was variable accumulation of either acute hemorrhage or hematoma formation (in 03NWR05001, 03NWR05005, 03NWR05008, 03NWR05011, and 03NWR05012)." Acute retrobullar and peribullar hemorrhage frequently mixed with moderate and more rarely, marked accumulations of nematode parasites, were noted in eight of ten necropsied animals…" I provided specimen 03NWR0512, for which "The blood clot overlying the spinal cord was attributed to agonal or terminal thrashing at the time of stranding." Sorry folks, this specimen was found floating freshly deceased and bleeding from its left eye, and it had not stranded – there were no bruises or scratches on the delicate skin, or on its thin film of fragile diatoms! NMFS subsequently reported a Naval Research Laboratory analysis that the received levels of the mid-frequency sonar signals were at least 145 dB re 1 uPa intermittently over large areas of Haro Strait, and were on the order of 169.3 dB re 1 uPa at the closest point of approach to the killer whales on May 5, 2003.

I conclude, as do NMFS and the Navy, that these tragic strandings, deaths and extreme behavioral disruptions are due to the presence of these animals in habitats where intense and prolonged sonar operations are conducted. Hearing damage is not the issue. One is led to believe that it is the whales' fault for being there, and for being terrified to the point that they abandon caution and their habitat. In too many cases, they die. Furthermore, from all reports and observations, I conclude that the received levels that initiated these lethal events were somewhere between 145 and 169.3 dB re 1 uPa. Some species, such as beaked whales and harbor porpoises, are more sensitive (published research indicates that harbor porpoises react aversely to anthropogenic sounds well below 145 dB re 1 uPa). Other acoustic impacts may also be threatening the oceans most magnificent creatures and causing them to abandon their habitats, but military operations are the gorilla in the room, followed by other intense (200+ dB re 1uPa SL) fast-rise acoustic impacts (e.g. airguns, explosions).

Clearly, 180 dB re 1 uPa or higher received level of mid-frequency sonar "pings" is not safe for marine mammals, particularly if there are multiple sources or if the exposures are of long duration. It is absolutely bogus to claim otherwise, based on captive animal hearing threshold shifts. The dead animals will tell the story if properly analyzed. The fleeing animals can reveal the range of received levels that initiate response, but one must look over the horizon to see them. Unfortunately, they cannot swim fast enough to escape a destroyer at 25 knots using active sonar, if one happens to be headed toward them.

Very respectfully submitted,

Kenneth C. Balcomb, III
Citizen/Scientist

Federal Caucus Statement for

The Report of the Advisory Committee on Acoustic Impacts on Marine Mammals

to the

Marine Mammal Commission

Submitted by:

Committee Members

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Martin Kodis, Chief, Resource Management Support, U.S. Fish and Wildlife Service

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The Advisory Committee on Acoustic Impacts on Marine Mammals formed two Subcommittees,
the Subcommittee on Synthesis of Current Knowledge and
Subcommittee on Mitigation and Management.
The work of the Subcommittees supported much of the work in this Federal Caucus Report.

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Statement B submitted by Boensel, Kodis, LaBelle, Reeve, Schoennagel, Stone, Sutter, Tomaszeski, Wieting, and Yoder

I. INTRODUCTION

The U.S. Congress, through the Omnibus Appropriations Act of 2003, directed the Marine Mammal Commission (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."[i] The Commission requested Federal agencies with statutory, regulatory or operational interest in this issue to participate with multiple stakeholders in an Advisory Committee process to develop consensus recommendations to the Commission to include in their report to Congress. The U.S. Navy, NOAA National Marine Fisheries Service, U.S. Fish and Wildlife Service, Minerals Management Service, and National Science Foundation agreed to participate. Between February 2004 and September 2005, the Advisory Committee met in six plenary sessions and numerous subcommittee sessions. At the sixth plenary meeting the Advisory Committee agreed that it could not come to consensus and voted to adopt the Commission's proposal for providing individual, caucus, or cross-caucus statements that express their perspectives on the issues the Advisory Committee discussed. The following is the perspective of the Federal Agency members of the Advisory Committee.

The Federal Caucus report to the Marine Mammal Commission represents the consensus of the Federal agency participants at this time. As a consensus document, it may not represent the full scope of any one agency's views and positions; rather, the document represents elements upon which the Federal agencies reached consensus.

The Federal members of the Advisory Committee recognize the body of work published by the National Research Council Ocean Studies Board over the past 10 years (NRC, 1994; 2000; 2003; 2005). Their work has been a valuable source of information. Our intent is not to repeat that work here but to reference it and sometimes emphasize their findings. This was also the approach taken by the Scientific Research Caucus Committee members in their report to the Marine Mammal Commission. A detailed discussion and prioritization of research devoted to advancing understanding and management of anthropogenic noise impacts is provided in the Appendix of the Scientific Research Caucus statement and is not repeated here. The purpose of the present document is to provide the perspective of the Federal agencies on the current state of science and management on the subject of sound[1] and marine mammals, and propose actions to improve the knowledge base and management system. The Federal agencies identified the following 5 key needs.

1) Narrow the tremendous gap between the information available and the information needs.
2) Continue to make decisions in the face of scientific uncertainty.
3) Improve the management system while investing in research.
4) Determine the efficacy of current mitigation measures in the near-term.

[1] The NRC reports use the terms noise and sound. Sound is an all-encompassing term referring to any acoustic energy. Noise is a subset of sound, referring to sound unwanted to a particular receiver (*i.e.*, someone who hears it). The opposite of noise is a signal: a sound containing useful or desired information. For this reason, the sound may be a signal to some and noise to others. We use the neutral term sound throughout the document, except where referring to scientifically accepted technical terms such as ambient or masking noise.

5) Continue strong support for Federal coordination and collaboration in research and management.

This report will elaborate on these needs and identify efforts and steps to address them.

II. STATEMENT OF CONTEXT OF THE ISSUE

Marine mammals have evolved over millions of years and rely on sound for vital life functions. Anthropogenic sound in the oceans has increased since the start of the industrial revolution. Increases in background noise levels, as well as the number of individual sound sources, may have adverse effects on marine mammals, the extent and type of which are not well understood. These sound sources include, among others, vessels, sonar operations, seismic surveys, coastal construction, and acoustic harassment devices.

The introduction of anthropogenic sound into the marine environment is a by-product of modern life. There are significant, tangible benefits derived from the protection provided by national defense, the energy supplied by oil and gas exploration, the seismic research carried out to enable prediction of earthquakes and tsunamis, and the transport of goods and materials by commercial shipping. In addition, marine mammals are an important component of marine ecosystems, with esthetic, recreational, and economic significance and value and should be protected Historically, the balancing among multiple societal interests has been a recurring theme of legislation and national policy formulation that continues to the present.

Recent cetacean strandings coincident with exposure to naval or seismic operations have increased public concern about the effects of anthropogenic sound (Cox *et al.,* 2006). Although no scientific correlation has been established, there is currently sufficient information about four beaked whale stranding events coincident with military mid-frequency sonar use to conclude that they were associated with, and most likely caused by, exposure to the sonar. These occurred in Greece (1996), the Bahamas (2000), Madeira (2000) and Canary Islands (2002).

The extent to which various anthropogenic sounds pose a threat to marine mammal individuals or populations remains in question. Peer-reviewed scientific literature indicates that different marine mammals are affected by exposure to the range of anthropogenic sounds in ways varying from none to harmful, or even lethal (for a few individuals). However, there are significant gaps in information available to understand and manage these effects. This is particularly the case because marine mammals are extremely difficult to study, and the marine environment is extraordinarily complex and dynamic.

Marine mammals and the ecosystems in which they live are protected under provisions of the Marine Mammal Protection Act (MMPA) and, in the case of marine mammals federally listed as endangered or threatened, the Endangered Species Act (ESA).[ii] Federal agencies recognize anthropogenic sound is one of many threats facing marine mammals, such as fisheries by-catch, habitat degradation, ocean pollution, commercial whaling, vessel strikes, and others. The relative importance of anthropogenic sound compared to other threats is unknown. Comprehensive evaluation of all the cumulative and synergistic effects from the full suite of risk factors is limited by the current state of the science and would be improved with the development of new research techniques. Many threats to marine mammals require research and management efforts. However, additional efforts to research and manage the effects of anthropogenic sound should not unduly detract from efforts to address other threats to marine mammals.

III. OVERVIEW OF FEDERAL CAUCUS FINDINGS

To respond to the needs outlined above, we support the following:

a. A sustained national research program to: (1) improve information available to decision-makers by increasing our understanding of anthropogenic sound sources, marine mammals and the effects of sound exposure on marine mammals, and (2) investigate new means of mitigating potential impacts of anthropogenic sound on marine mammals;
b. Continuing agency efforts for more effective, efficient, and transparent management and mitigation of sound producing activities and their potential adverse effects on marine mammals;
c. Strengthen the capabilities of Federal agencies to understand acoustic impacts and improve management systems to protect marine mammals while maintaining ocean activities important to the nation; and
d. Better coordination internationally to address information gaps and apply new knowledge to the development of mitigation technologies.

A sustained national research program. There are significant gaps in information concerning mechanisms of marine mammal responses to sound and the effects of sound on marine mammals. Currently knowledge of marine mammal hearing, behavior, physiology, ecology, and abundance and distribution is limited.

The level of risk posed by sound exposure is case-specific, because responses, if any, will vary based on the particular animals and sources involved, in combination with other factors. Detailed assessments of indirect impacts, the cumulative effects of exposure to multiple types of sound (concurrently or sequentially), as well as sound exposure in combination with other factors, are limited by the information currently available. Research and other credible means of gathering information play an important role in management systems as the primary means of quantifying uncertainties and gaining other useful information for policy decisions. Activities useful to managers include opportunistic information gathering, systematic data collection, experimentation, modeling, and research and development.

More effective, efficient, and transparent management. The Federal agencies have identified measures to improve management of the potential adverse effects of sound. These measures are related to granting, permitting, and authorization activities and mitigation practices, and depend in large part on obtaining improved information to inform management decisions. Improved information on the effectiveness of various management and mitigation approaches and technologies is necessary to reduce impacts to marine mammals to the maximum extent practicable.

Strengthen the capabilities of Federal agencies. Agencies need the appropriate resources to address the important information gaps and to make any significant improvement to the management system as it exists.

Strengthen and improve international collaboration. Given the broad spatial occurrence of marine mammal impacts possibly connected to sound-producing activities, and the concerns expressed in a variety of international fora, the Federal Caucus supports efforts to better coordinate with their counterparts around the world. Better coordination in addressing information gaps and applying new knowledge to the development of mitigation technologies that might be needed will be crucial in particular for trans-boundary populations of marine mammals.

A. Key Findings Regarding Information and Research Issues

Clearly, the various potential effects of anthropogenic sound on marine life are exceedingly complex, highly context-specific, and in general poorly understood. As such, it is (and will likely remain for some time) difficult to estimate with a high degree of precision the potential effects of various sound sources on individuals, populations, and ecosystems. However, over the past several decades, a considerable amount of information has been obtained regarding sound sources, sound propagation, marine animal acoustic communication, and the potential effects of sound on hearing, behavior, and non-auditory systems. We refrain from extensive detail in describing areas of current knowledge here, but direct those interested in greater depth to previously published review texts on this issue (*e.g.*, Richardson *et al.*, 1995; NRC, 1994, 2000; 2003; 2005). As a general statement, we have a better understanding of the characteristics of various natural and anthropogenic sources of sound and how sounds travel (propagate) in water than we have about how marine mammals use, perceive, and are affected by sound.

<u>1. Sound Sources</u>

Sound is a common, if not defining, feature of the marine environment, originating from a variety of natural and anthropogenic sources. It is useful to distinguish between discrete, individually identifiable sound sources and the general background din (background noise) for which individual sources cannot be identified. The 2003 NRC report *Ocean Noise and Marine Mammals* argues for additional data to support the development of ocean sound 'budgets', identifying natural and anthropogenic sources of sound and their relative contribution to local ambient (background) noise conditions. The NRC (2003) report further highlights the need to monitor long-term trends and spatial variance in marine ambient (background) noise.

Natural sounds dominate background noise in the ocean in all frequency bands except those between about 10 Hz and 200 Hz, where sound from large vessels apparently dominates in many areas (Wenz, 1962). For instance, a considerable increase in background noise has been documented at relatively low frequencies (20-80 Hz) off the coast of California, the apparent cause of which is the increase in large vessel traffic during the 33 year analysis period (Andrew *et al.*, 2002; Wenz, 1969). Additionally, low frequency ambient (background) noise in relatively heavily traveled northern hemisphere ocean areas is generally higher than in the southern hemisphere (Cato, 1976). Given the elevation of low frequency background noise in certain areas, apparently as a result of anthropogenic input, it is reasonable to conclude the oceans have become noisier since the start of the industrial era. Developing greater understanding of the characteristics of sound sources, their distribution relative to the location and movements of marine animals, and spatial and temporal trends in marine background noise is clearly important for estimating potential impacts of anthropogenic sound on marine life.

Natural sources of sound in the oceans include wind, waves, precipitation, surf, lightning, animals, and other sources. Locally, earthquakes and shallow-water wind effects may dominate at frequencies below about 100 Hz, while wind, waves, and precipitation dominate above 200Hz. Many marine organisms produce sounds covering a broad of frequencies (<10 Hz to >150 kHz) (Wartzog and Ketten, 1999).

Anthropogenic sound in the oceans is generated by a variety of activities. Some activities produce acoustic signals for a specific purpose, while others emanate sound as an incidental byproduct. Human sources include: large commercial transport vessels; exploration, development, and production of offshore oil and gas (*e.g.*, airguns for seismic surveys, ships, drill rigs, and dynamic positioning thrusters); naval operations (*e.g.*, military/tactical sonars, communications devices, and explosives); fishing (*e.g.*, commercial/civilian sonars, acoustic deterrent and harassment devices); research (*e.g.*, airguns; sonars; telemetry, communication, navigation, and tomography sources); construction (*e.g.,* pile driving, dredging, and explosives); and others such as icebreaking, over-flying aircraft, and recreational boating. While we can generally characterize sound source levels, frequencies, spatial scale, signal duration, operational duration, and duty cycle, the acoustic characteristics of many sound sources are not sufficiently described in the scientific literature. With respect to the effects of sound on marine mammals, the most important characteristics of sounds to measure and the most appropriate means for averaging sounds over time and space also are not clear, but likely vary to some extent based on source and animal type.

The propagation of sound in water is highly complex and case-specific, but relatively well understood as a result of decades of dedicated research and development of predictive models. There is some variability between measured and modeled sound characteristics, which is likely due to errors in characterizing the ocean and seafloor environments (salinity, temperature, and bathymetry). Direct measurements of received sound characteristics at points distant from a source are optimal in estimating potential effects on marine life. Predictive propagation models, if sufficiently well developed and validated for analyses, can be used in the absence of empirical data.

2. Marine Mammals and Sound

Marine mammals comprise a diverse group of organisms that includes approximately 127 known species ranging from fully aquatic whales and dolphins to the semi-aquatic pinnipeds and polar bears. Marine mammals use sound to varying degrees for social interactions (primarily related to reproduction), foraging, predator avoidance, and spatial orientation. They have clearly evolved specialized sensory capabilities to take advantage of the physics of sound in water (Norris, 1969; Norris and Harvey, 1972).

Sound exposure can have a range of effects, ranging from none, to behavioral, to disturbance, to hearing effects and in extreme cases, mortality from various poorly understood mechanisms. Uncertainties about the effects of sound on marine life are driven by several fundamental problems. First, the lack of baseline natural history, physiological, and behavioral data for most marine animals makes it difficult to easily predict individual responses to sound. Second, there are fundamental, practical challenges inherent to studying marine mammal behavior in the wild such that some types of responses (even acute responses) may either be undetectable or require specialized monitoring capabilities. Third, even in cases where behavioral responses to sound have been documented, the mechanisms and implications of these changes are not always clear. Fourth, sample sizes in studies where behavioral changes are documented are often small, and the results are often specific to a particular location and scenario, making general conclusions difficult, given what is known about individual variation in certain fundamental characteristics.

From what is currently known, which is limited to a few individuals and extremely limited sample sizes, marine animals do not hear equally well at all frequencies. Eighty-three different species of cetaceans (whales, dolphins and porpoises) are recognized, and audiograms (i.e., graphs that plot how well a person or animal hears) have been developed for only 11 species, all of which are odontocetes (toothed whales) (Nachtigall *et al.*, 2000; Rice, 1998). The hearing of mysticetes (baleen whales) remains unmeasured, but anatomical analyses suggest they are low-frequency specialists (Wartzok and Ketten, 1999). Pinnipeds (seals, sea lions, and walrus) have considerable differences in aerial and underwater hearing sensitivity, based on the nine species tested, but do not hear sounds in air or water at frequencies as high as odontocete cetaceans hear in water (Schusterman *et al.*, 2000). A single study of manatee hearing suggests a fairly limited frequency bandwidth (Gerstein *et al.*, 1999). No published hearing data exist for sea otters or polar bears.

An understanding of normal behavior and the biological significance (*e.g.*, consequences for health, survival, and reproduction) of any resulting changes in behavior caused by sound exposure are critical to better answer questions regarding impacts. The behavior of marine mammals may vary by individual, population, species, age, sex, condition, context (motivation), and history (experience). There are few direct and well-controlled data concerning the behavioral effects of sound on marine mammals, making it difficult to predict exposure levels or other characteristics (e.g., frequency range, timing variation, repetition rates, changes in frequency, etc.) that will have specified effects in certain conditions. The limited systematic data are largely the result of controlled exposure experiments (CEEs), which provide the most direct means currently available to answer questions about the relationships between characteristics of sound exposure and changes in behavior of marine mammals (Richardson *et al.,* 1995; Miller *et al.,* 2000; Buck and Tyack; 2000; NRC, 2003).

Masking occurs when one sound reduces the receiver's ability to hear another sound. While masking is known to be a common, naturally occurring phenomenon, the ability of animals to compensate for the presence of masking noise is unknown, as is its potential biological significance. The extent to which various behavioral modifications are engaged to avoid masking of communication signals (*e.g.*, changing in frequency, loudness, duration, timing, or repetition rate of an animal's call) and the costs (*e.g.*, increased energy needed for sound production) of engaging in behaviors to overcome masking are also uncertain. Additionally, uncertainty about the effective nominal spatial range of sounds used by marine animals makes it difficult to estimate the significance of anthropogenic masking noise in many cases.

Over-stimulation from acoustic energy can result in a range of physiological effects. For example, excessive exposure to sound can cause hearing loss in mammals (Yost, 2000). The potential to produce temporary or permanent hearing loss, also known as temporary threshold shift (TTS) and permanent threshold shift (PTS), respectively, depends on the characteristics of the sound, exposure, and the animal receiving the sound. Generally, the higher the sound level and the longer the sound duration, the more likely TTS is to occur. While it seems reasonable to assume animals evolve behavioral responses to avoid exposure to sounds that might damage hearing, there is no empirical justification to date for concluding the sound exposure conditions causing behavioral disruption bear a consistent relationship to exposure conditions that trigger the onset of TTS.

Non-auditory effects (*e.g.*, stress, neurosensory effects, vestibular response, resonance, gas bubble growth, blast trauma) involve the interaction of sound with physiology other than the auditory system. Few controlled studies have measured the nervous, immune, or other systems before and after exposure to anthropogenic sound or other stressors. Moreover, the tools for studying stress in marine mammals are still limited. There is some limited data, but considerable uncertainty about the possible role of acoustically mediated gas bubble growth in marine mammals. Disagreement exists over the possible role of gas bubble growth in beaked whale strandings, largely based on different ideas about the origin of bubbles found in the tissues of beaked whales (Jepson *et al.*, 2003; Cox *et al.*, 2006; Fernandez *et al.*, 2005).

Population-level effects may result from the combined effects on individual members of a population over time (*e.g.,* the total number of individual deaths, decreased birth rates). Just as the collective effects of sound on individuals may produce population-level effects, so too the combined population-level effects within a species may have important consequences for that species' survival. The NRC (2005) states that, "…no scientific studies have conclusively demonstrated a link between exposure to sound and adverse effects on a marine mammal population." However, it is important to note that there is even less information available to assess population-level effects than exists to estimate individual responses to acoustic exposure. Furthermore, most population-level trends (whether positive or negative) would not be detectable until well after effects have begun to occur (Taylor, 1997). The NRC (2005) study attempts to address this issue by producing a conceptual model linking acoustic exposure stimuli to population-level effects. Insufficient data currently exist to apply the model. Clearly, additional information about individual responses, population status and trends, and relationship between behavior and vital rates (at the individual and population level) are necessary to understand population-level effects resulting from any anthropogenic factor, including sound.

B. Key Findings Regarding Management and Mitigation

Management will refer to the full process of assessing, evaluating, permitting or authorizing, mitigating, monitoring, and enforcing compliance for acoustic impacts on marine mammals from anthropogenic sound sources. The economic, social, and environmental costs and benefits of managing activities that may have acoustic impacts on marine mammals are relevant to developing long-term polices on acoustic impacts on marine mammals. Management of acoustic activities is currently accomplished under multiple Federal statutes, including the MMPA, ESA, National Environmental Policy Act (NEPA), Outer Continental Shelf Lands Act (OCSLA), and Coastal Zone Management Act (CZMA). Management systems integrate knowledge and research, risk assessment, permit and authorization processes, mitigation tools, and monitoring, evaluation, compliance and enforcement activities. The application of fully integrated management systems that bring together a combination of the tools at managers' disposal is likely to be the best way to maximize effective mitigation efforts.

1. Knowledge and Research

When managing activities in the marine environment, decision-makers in the regulated and the regulating agencies use the best available scientific information to implement the standards contained in applicable laws. These laws consider various species' needs, stakeholder interests, and societal values. However, even when using the best scientific information available, determining the precise impact of activities or mitigation measures can be difficult.

During the course of the Federal Advisory Committee's meetings, there was discussion of the terms "precautionary principle" and "precautionary approach" and their application by Federal agencies implementing conservation statutes in the face of uncertainty. There is no single agreed upon definition of either term. In light of those discussions, we are clarifying how the Services implement the conservation standards of the MMPA and ESA.[iii] The agencies use the best available science to assess the effects of activities on protected species and to develop appropriate mitigation conditions and mitigation measures. The best available scientific information standard does not require scientific certainty; rather the agencies assess the available data and apply their technical expertise to make judgments based on the scientific data in a manner consistent with the conservation purposes of the laws.[2] The agencies strive to improve species conservation and management by continually seeking to enhance and refine the best available science in order to reduce uncertainty. This is consistent with adaptive management techniques, which allow for periodic evaluation and adjustment.

Adaptive management has been suggested as a means to address the fact that management systems must allow for the incorporation of new information into the management system (*i.e.*, feedback). In adaptive management, decisions are made and reconsidered as new information is developed, providing a flexible approach to any management strategy. Managers incorporate periodic

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[2] For example, the Services' ESA section 7 analyses try to avoid concluding that actions have no detrimental effect on marine mammals or their ecosystems when, in fact, there is an effect (Type II error; see Cohen. 1987). This approach to error may lead to different conclusions than the more traditional, scientific approach to avoiding error, which seeks to avoid concluding that actions have an effect when, in fact, there is none (Type I error).

reevaluation of management goals, the effectiveness of management measures, and integrate new information into subsequent management decisions. Therefore, the type and level of protective measures prescribed through regulations may change as additional science reduces uncertainty.

In the present environment of scientific uncertainty, and given the difficulties in assessing impacts on marine mammals in the wild it is appropriate for managers to conservatively manage sound producing activities. Scientific research should continue to identify situations in which anthropogenic sound may have adverse effects. Research plays an important role in the management system as the primary means of carefully quantifying uncertainties and gaining other useful information for policy decisions. Most adaptive management strategies also encourage research to develop new information.

Additional resources are needed to better inform management decisions regarding chronic and acute sound, long- and short-term effects, cumulative and synergistic effects, and impacts on individuals and populations. Managers should have a knowledge base that identifies and describes:

- Marine mammals and their habitats,
- Threats to individuals and populations of marine mammals due to sound exposure, including case-specific potential mechanisms of disturbance, harm, or mortality,
- Sources of the threats (*i.e.*, sources of sound involved), and
- Methods of mitigating impacts.

2. Risk Assessment

Risk assessment is a critical decision-making tool for management, involving characterization of risks and appraisal of the probabilities that they pose a threat. Risk assessment tools and approaches range from presentations of qualitative information to more comprehensive quantitative analyses. Once the potential for adverse effects on marine mammals from acoustic sources (*i.e.*, a "hazard") has been hypothesized and a potential hazard identified, there are three basic steps in the assessment of the associated risk: (1) determination of exposure by identifying the distribution of marine mammals, their particular sensitivities to sound, the characteristics of the sound, and the marine mammals' overlap with sound sources across space and time (*i.e.*, "exposure assessment"); (2) determination of the range of possible responses by the marine mammals potentially receiving the signal (*i.e.*, "exposure-response assessment") to determine the consequences of the exposure; and (3) determination of the likelihood of a specific undesirable outcome from exposure to the sound (*i.e.*, "risk characterization") (Harwood, 2000). Risk assessments should include estimates of confidence and other measures for creating transparency; such measures provide support for decisions and allow risk assessments to be validated. Models with clear, explicit assumptions can be useful tools for assessing risk. The utility of models improves with validation in the field, and verification and reproducibility of results.

The determination of acceptable risk is the responsibility of Congress and the Federal and state agencies charged with implementing the relevant statutes. Decisions are usually subject to public review and input, and in several cases have been the subject of controversy in both the general public and the scientific community. Determining acceptable risk is complicated by the lack of understanding of the specific relationships between acoustic exposures and risk of impact, as well as the likely consequences of the outcomes. Federal agencies manage risk through mitigation and monitoring, which are incorporated into sound producing activities through the Services[3] authorization and permitting processes.

3. Permits and authorization processes

Due to a variety of factors, not all sound sources or sound-producing activities are currently managed or regulated to the same extent. Currently unaddressed activities include commercial shipping, recreational boating, whale watching (*e.g.*, powerboats), certain aquaculture activities (*e.g.*, acoustic alarms and powerboats), ice breaking, certain over-flying aircraft (*e.g.*, commercial airliners), terrestrial vehicle traffic, and certain military and research activities. Commercial fishing and its associated sound sources (including acoustic deterrent and harassment devices, ship or powerboat noise, and fish finders and echo sounders) are regulated separately under Section 118 of the MMPA. Commercial fishing operators are not subject to the permitting requirements for sound devices.

Compliance with "take" authorization and permitting requirements represents a substantial investment in time and money on the part of the applicants and agencies. Sound producers and researchers that apply for permits or authorizations to "take" marine mammals during the course of their activities are in need of timely, predictable, and cost-effective permitting and authorization processes that maintain current levels of protection for marine mammals under the current statutory regimes of the MMPA, ESA, and other Federal laws. Increasing application requests, public interest, and controversy is generating an increased burden on the Services to process the applications and comply with ESA and NEPA requirements. The Services' staff and resources for analyzing and processing these applications are limited and the current demand exceeds their capacity.

4. Mitigation

A range of mitigation and management techniques or approaches exist and are being implemented which can reduce the potential for adverse effects on marine mammals. Improving mitigation depends upon the ability to understand the effect that is to be mitigated. Mitigations are assumed to be beneficial. Efforts to measure effectiveness of these techniques and develop a better system are warranted.

There is not, and probably never will be, a single solution to designing and carrying out effective mitigation. Mitigation consists of a suite of tools designed to prevent, reduce, eliminate, or rectify the impacts of sound introduced into the environment. Mitigation tools currently available include:

- Operational procedures,
- Temporal, seasonal and geographic restrictions,
- Removal or modification of the sound source, and
- Training, education, and outreach.

[3] The Services refers to the U.S. Fish and Wildlife Service and the National Marine Fisheries Service who are responsible for implementing the provisions of the Marine Mammal Protection Act and the Endangered Species Act.

Mitigation tools are often used in combination and are not mutually exclusive. More detailed information about each tool, including its effectiveness and limitations can be found in Table 1 of the attached appendix. When considering mitigation strategies, managers begin with the ultimate goal of preventing adverse effects, but if that is not practicable, they modify their strategies to minimize impacts on marine mammals by reducing eliminating, or rectifying the effects of anthropogenic sound in the marine environment consistent with existing statutes.

The effectiveness of even commonly used mitigation measures (*e.g.*, ramp-up and safety zones) has generally not been systematically assessed, but may vary greatly from one case to another. Certain mitigation tools are inherently more effective than others. However, some of these may be impractical and may have the most significant cost or operational impacts on the sound-producing activities. While a number of mitigation tools have significant potential to reduce the impacts of anthropogenic noise on marine mammals they require focused research and development to determine effectiveness.

Marine mammal detection and observation methods are not mitigation tools in and of themselves, but they are important to the effective application and assessment of many mitigation activities. For example, detection of marine mammals using one of these tools may trigger mitigation such as shut down in safety zones or seasonal types of restrictions. Table 2 of the Appendix lists marine mammal detection and observation tools currently in use or in development.

5. Monitoring, Evaluation, Compliance, and Enforcement

Once a management action or plan has been implemented, it is necessary to appraise the outcomes of the management system as a whole as well as its various components (*i.e.*, to assess the extent to which specific and measurable goals are met). Such evaluations should examine both the effectiveness of the management and mitigation strategies applied (*e.g.,* through reporting any level of take during the activity and actual field sound propagation patterns) and the level of compliance with existing laws and regulations, including any mitigation requirements or other authorization conditions. Monitoring is a key element for the evaluation of both compliance and the effectiveness of management, and can provide useful information for the modification of management plans. Recipients of authorizations and permits who undertake the sound-producing activity are required to conduct monitoring and reporting. Detailed monitoring reports and observations must answer the key questions: was the mitigation carried out in full, if not, why not? and what marine mammal behaviors and responses occurred? If mitigation requirements are not fully carried out, the level of impact generated by a mitigated activity cannot be accurately determined. Monitoring may also be considered to help build the knowledge base used by decision-makers.

Monitoring, reporting, and evaluation are essential to assess the overall effectiveness of management activities. While mitigation effectiveness and compliance can be assessed through self-monitoring and self-reporting, these strategies may not be effective and could result in under-reporting, and inaccuracies, and depend on developing competencies. These concerns may be addressed by including an agency review and verification processes in a self-reporting system, or by including a mechanism for unannounced inspections. Self-reporting is an essential component of management despite potential shortcomings, especially in cases where activities occur at sea and the capacity to enforce regulations, permit conditions, or other requirements is limited. Additional resources and improvements in current monitoring and evaluation practices are needed.

Effective compliance strategies and enforcement programs are also necessary components of a management system but have received limited attention to date. They build and reinforce the credibility of mitigation efforts and the statutory and regulatory systems that support them. Compliance is meeting the requirements of the statutes (MMPA, ESA, NEPA, OCSLA, etc.), implementing regulations, and management programs. How well requirements are designed directly influences the level of compliance. A successful enforcement program depends upon creating requirements that are enforceable, monitoring compliance, and responding to violations. Both compliance and enforcement programs must be assessed for their effectiveness.

Improvements to any compliance program can result from developing best practices guidelines, developing and applying effective monitoring systems, implementing environmental management systems, and conducting and strengthening enforcement activities. In addition, focusing on the prevention of non-compliance can encourage improved compliance.

An improved management system should include innovative management approaches such as performance-based and adaptive management. Performance-based environmental management should offer: environmental performance standards or goals – to improve over the baseline; dissemination of performance data to the public – to assure verification; enhanced stakeholder involvement – to facilitate building trust; continuous improvement – to achieve better environmental outcomes; environmentally sustainable practices – to increase resource productivity; and operational flexibility – to implement adaptive management, to improve alignment of financial and environmental goals, and meet goals (The Aspen Institute, 2000). These programs are a way for regulators and sound producers to: establish a commitment to environmental management objectives; establish roles and responsibilities; ensure awareness, training, and competence; monitor, document, and assess procedures; track performance; and identify weaknesses in the management system, correct them and prevent their recurrence. Creative and proactive conservation strategies as part of longer-term, far-sighted management efforts could require less investment and provide additional and improved options for the regulated and regulatory communities and the environment. Non-regulatory management strategies can be used to supplement the management system in a variety of ways. For example, they encourage environmentally responsible action by informing those involved about the potential consequences of their actions and establishing incentives for reducing take of marine mammals

Adaptive management can be defined as "the cyclical process of systematically testing assumptions, generating learning by evaluating the results of such testing, and further revising and improving management practices" (Pomeroy *et al*., 2004). In practice, adaptive management typically means that decision makers establish clear goals, incorporate periodic reevaluation of these goals and the effectiveness of management measures, and integrate new information into subsequent management decisions. Most adaptive management strategies also encourage research to develop new information. To successfully implement adaptive management, monitoring and evaluation must occur for long enough to determine if the predicted objectives were achieved. MMPA and ESA currently provide an opportunity for feedback and adaptation. Provisions of NEPA allow for reevaluation of management regimes. The strength of the feedback systems could be improved by consistent and timely review and analysis of reports made to management agencies. It is crucial to recognize that adaptive management depends upon effective monitoring and reporting. The availability and quality of sufficient data to understand the conditions prior to onset of the activity vary widely.

C. International Efforts to Address the Potential Impact of Sound on Marine Mammals

1. Introduction

An interagency working group has been formed by the Department of State, Oceans Sub-Policy Coordinating Committee to develop and articulate U.S. positions on underwater sound, particularly in reference to its effects on living marine resources, for the use by U.S. officials in international fora. This working group has developed a position on the international regulation of the military use of active sonar. The Federal Caucus therefore defers to the interagency working group to develop specific recommendations on actions that should be taken at the international level.

2. Marine Mammal Commission International Workshop: Policy on Sound and Marine Mammals

An international policy workshop on sound and marine mammals was held 28-30 September 2004 in London, England, sponsored jointly by the U.S. Marine Mammal Commission and the U.K. Joint Nature Conservation Committee (JNCC). Over 100 participants from more than 20 countries attended. The 28 Advisory Committee members supported the idea of a Commission-sponsored international policy workshop and provided valuable advice in the early planning stages. The Commission and JNCC agreed in March 2004 to collaborate in drafting the agenda, identifying participants, convening the workshop, and producing a workshop report. The full Federal Advisory Committee has not seen the MMC report from the workshop as of the writing of this report. Therefore, this report does not reflect consensus opinion of the Committee or of the Federal members.

IV. KEY RECOMMENDATIONS AND DETERMINATIONS

A. Information and Research

A national research program should be put in place to research chronic and acute effects, long- and short-term effects, and cumulative and synergistic effects of sound on individuals and populations of marine mammals to inform management decisions. We support the concept of an interagency national research program to understand interactions between marine mammals and all sources of sound in the world's coastal and global oceans. A program such as the National Oceanographic Partnership Program (NOPP), established by Congress in 1997 and governed by the National Ocean

Research Leadership Council, is designed to enable multiple Federal agencies and private funders to jointly support research on issues of shared interest. This interagency program with a coordinating mechanism would support further funding diversification. The national research program would be based upon priorities determined by the participating community. Participants in this program should include NSF, Navy, NOAA, MMS, FWS, Marine Mammal Commission, etc. Resources would be needed to support this activity.

As described above, there are clear research needs in almost every relevant area regarding the effects of noise on marine mammals (i.e., sound sources and propagation, animal communication systems, and effects of noise on hearing and behavior). Research priorities should be based on the nature and extent of current information in various areas and issues that are apparently pressing. For instance, uncertainties regarding baseline animal life history, behavior, and effects of sounds are orders of magnitude greater than uncertainties regarding the characteristics of sound and sound propagation suggesting that they should be higher research priorities. Improving our knowledge of marine mammal population distribution and abundance is also important for management and a high priority [see e.g., NMFS (2004)]. These research areas will require sustained funding, representing a longer-term investment for the results to provide data that may be used in management decisions. Marine mammal stock assessment is an existing program of NMFS and FWS to meet a range of management needs. Efforts to improve stock assessments should be continued within the existing program, with input and participation from other interested agencies, rather than as part of the interagency national research program.

A detailed discussion and prioritization of research devoted to advancing understanding and management of anthropogenic noise impacts is provided in the Appendix of the Scientific Research Caucus statement and is not repeated here. In general, the Federal caucus concurs with the conclusions of colleagues in the research community with respect to research priorities, particularly regarding validation of mitigation measures and quantification of biological significance of behavioral reactions. Several additional priorities from the perspective of the Federal caucus are given below.

1) In addition to linking behavioral and physiological changes in behavior to individual vital rates, researchers must develop new techniques to measure and/or model the cumulative effects of acoustic exposure on individuals and ultimately marine ecosystems. This daunting task must consider not only discrete sound sources, but also their interaction with and contribution to chronic increases in background noise arising from human activities. We acknowledge that this will certainly be a lengthy process.

2) While intense discrete exposures may have a greater potential to cause greater individual harm, lower levels of chronic anthropogenic input in the oceans may have a greater potential to affect populations of marine animals as a consequence of masking. Research designed to quantify the significance of auditory masking at the individual and population level should be prioritized. Again, the difficulties inherent in and time required to accomplishing this are acknowledged to be great.

B. Management and Mitigation

Knowledge and Research

Management strategies will continue to use and develop "best available scientific information." The Federal agencies have determined that the national research program recommended above in Section IV.A. could substantially improve best available scientific information regarding baseline population conditions of, and the effects of sound on marine mammals. The agencies will use adaptive management to incorporate any new information as it becomes available through a research program and other means (e.g., public scoping, research, risk assessment, mitigation, and monitoring).

Risk assessment

Federal Agencies acknowledge the need for greater transparency in risk assessments. This includes making risk assessments available to the public, accounting for the difficulties in detecting the full range of potential impacts, acknowledging the effects of anthropogenic sound on marine mammals may not be detected, and including estimates of confidence and other measures.

Permits and authorization processes

Some sound producing activities are not managed for their potential adverse effects on marine mammals. This includes, but is not limited to, commercial shipping, recreational watercraft use, whale watching, and the development and use of acoustic harassment devices (AHDs and acoustic deterrent devices (ADDs)). The Federal agencies believe a comprehensive analysis that includes unaddressed sound sources is necessary to properly understand and manage the effects of sound on marine mammals.

Sound producers, and researchers in particular, that apply for permits or authorizations to "take" marine mammals during the course of their activities are in need of timely, predictable, and cost-effective permitting and authorization processes that maintain current levels of protection for marine mammals under the current statutory regimes of the MMPA, ESA, and other Federal laws. The Services have identified the following actions to address these needs. Some of these actions are already underway:

- Clarify guidelines for research funding entities and researchers
- Provide standard background documents, application information and references to reduce the cost and time of preparing applications;
- Develop mechanisms, where appropriate, to collectively process and issue permits and authorizations that are similar based on species, region or activity;
- Work with research funding entities and researchers to achieve better timing linkages among the process for authorization and permitting, securing funding, and scheduling research operations to minimize potential issues;

- Work to achieve a more comprehensive and coordinated approach to implementing both the MMPA and the ESA; and
- Identify innovative ways to meet regulatory requirements through reductions in potential impacts on marine mammals

Mitigation tools

There is not, and probably never will be, a single "silver bullet" solution to designing and carrying out effective mitigation. When considering mitigation strategies, managers begin with the ultimate goal of preventing adverse effects, but if that is not practicable, they modify their strategies to minimize impacts on marine mammals by reducing eliminating, or rectifying the effects of anthropogenic sound in the marine environment consistent with existing statutes.

Management agencies will continue to develop and evaluate the feasibility, applicability, and effectiveness of mitigation measures to address potential adverse effects from anthropogenic sounds on marine mammals.

The Services are working on a dialogue with the Coast Guard, US Navy, and other Federal agencies, and stakeholder groups, to identify and evaluate options to reduce sound production through development and application of quiet ship technologies where the reduction of sound production itself will not impede the ability of marine mammals to avoid oncoming vessels. Based on information received as a result of such a dialogue, the Federal agencies plan to expand these efforts to include working with naval architects and ship operators to review existing practices, develop educational programs for designers of recreational and commercial vessels about the potential impacts of anthropogenic sound, and explore the development of voluntary guidelines on operations, design, and construction of ships. As part of this process, the US Navy should actively contribute information related to sound reduction technologies as feasible.

Management agencies and relevant stakeholders should work together, where appropriate, to develop "best practice" guidelines, recognizing that a "one size fits all" approach is not practical. Those guidelines should utilize suites of mitigation tools and identify appropriate and feasible ways to apply them to different activities in order to prevent, reduce, eliminate, or rectify adverse effects from sound on marine mammals. Best-practice guidelines should provide a means to:

- Prevent adverse effects as a primary goal where practicable, (*e.g.,* through geographic, seasonal, and temporal restrictions, source modification, etc.);
- Minimize adverse effects where prevention is not practicable, (*e.g.,* through source or exposure reduction via operational procedures or engineering modification of sound sources or both); and
- Evaluate the effectiveness, practicality, feasibility, costs, and appropriateness of existing mitigation tools (including standardized pre- and post-activity monitoring and analyses), and develop new tools.

Monitoring, evaluation, compliance and enforcement

Management agencies intend to collaborate to develop standardized formats for the collection of monitoring data. These standardized systems should be rigorous enough to support the collection, aggregation, and analysis of scientific information. In conjunction, the Services will continue to develop and improve training and certification programs to ensure that observers are qualified to conduct effective monitoring, enabling data to be utilized.

As feasible, the Services will seek public and private partnerships to undertake an outreach program to educate sound producers and the general public, about the risks of anthropogenic sound to marine mammals and how adverse effects can be reduced or minimized. These partnerships should also encourage and explore means for stakeholder cooperation in compiling and sharing information on marine mammals

The Federal agencies will work to increase detection of strandings or mortalities at sea associated with sound-producing activities. The Services will strive to make their stranding investigations and other monitoring activities and assessments transparent and accessible to the public in a timely manner, recognizing that it takes time to collect and analyze full scientific information.

Sound producers should work with the management agencies to include a verification process in a self-reporting system, or include a mechanism for unannounced inspections.

Improvements to any compliance program can result from developing best practices guidelines, developing and applying effective monitoring systems, implementing environmental management systems, and conducting and strengthening enforcement activities. In addition, focusing on the prevention of non-compliance can encourage improved compliance. A compliance program should consist of well-designed requirements with clear objectives, sound implementation, and evaluation methods.

C. International Efforts to Reduce Impacts of Sound on Marine Mammals

Based on these actions and U.S. domestic policy, the Federal members of the Advisory Committee recommend the following:

- Encourage and participate in development of appropriate international mechanisms for collection and sharing of scientific information among governmental, inter-governmental, and non-governmental organizations.
- Encourage and participate in development of appropriate international mechanisms for collection and sharing of mitigation technologies and information on mitigation tools and effectiveness.

APPENDIX

Table 1. Summary of the mitigation tools currently in use or available for addressing impacts of anthropogenic sound on marine mammals. The tools are roughly categorized based on schemes laid out in Richardson *et al.* 1995 (pp. 417-424) and Barlow and Gisiner (in press). The order in which the tool types are presented here is not intended to indicate any preferential order for their use.

TOOL (WITH EXAMPLES)	DESCRIPTION
a. Operational Procedures (Marine Mammal Detection With Activity Modification, Aversive Alarms, etc.)	
1) Use of Sound (*e.g.*, Dry firing; Ramp-ups; Acoustic alarms)	Sound introduced at reduced levels prior to an activity (ramp-ups/soft-starts, dry firing), or between episodic activities with the intent to deter marine mammals from approaching a potentially damaging sound source (acoustic alarms). The effectiveness of dry firing and ramp-up has not been confirmed. Effectiveness depends on appropriately and accurately defining and maintaining a safety zone around the sound source. Moreover, ramp-ups are not always practical for military sonar as they would lead to loss of tactical advantage, although they may be useful for mitigation during some practice maneuvers or testing. In general, it is not clear whether acoustic alarms (ADDs and AHDs) could be used effectively and safely to reduce the impacts of anthropogenic sound.
2) Operational Modifications (*e.g.*, Vessel speed limits; Sonar or seismic airgun power limits)	Limits placed on specified aspects of a sound-producing activity's operations with the intent of reducing overall sound production. Some operational modifications have been successfully applied, but the use of such measures is not widespread, and their effectiveness has not been thoroughly tested. Signals deliberately introduced into the ocean to accomplish a specific goal (*e.g.*, seismic surveys and naval sonar) have operational characteristics that depend on that goal, and it may be difficult to modify those characteristics while still accomplishing the goal. Some operational modifications have been put in place to protect marine mammals from other anthropogenic impacts (*e.g.*, speed zones in manatee habitat to prevent collisions). The success of these measures depends on the context of their application.
3) Flight Restrictions	A specific type of operational restriction that merits separate mention because they are often overlooked in the protection of marine mammals. Rocket launches, helicopter flights, aerial surveys and other aircraft activities can be subject to a variety of requirements such as maintaining a minimum altitude and/or a maximum speed, or following geographic, seasonal or temporal restrictions. Issues related to the limitations, effectiveness, and potential applications of flight restrictions are similar to those related to other operational restrictions. Human safety is of primary concern when determining flight altitude and speed.

TOOL (WITH EXAMPLES)	**DESCRIPTION**
b. Temporal, Seasonal, and Geographic Restrictions (Habitat Avoidance, Routing and Positioning, etc.)	
1) Dynamic Management Areas (DMAs) (*e.g.*, Safety zones)	A temporary set of restrictions that come into action (or are "triggered") when certain conditions are met.[iv] They can be applied to a pre-specified geographical area, but are generally centered on the presence of an animal or their home. Safety zones (also called exclusion zones) are a particular kind of DMA, centered not on an animal, but instead around a sound source. A safety zone is a specified range from the source (generally based on a received sound pressure level) that must be free of marine mammals before an activity can commence (often referred to as determining an "all-clear") and/or must remain free of marine mammals during an activity. DMAs do afford some measure of protection for marine mammals and other target species, but their effectiveness is limited in two significant respects. Their effectiveness depends on one's ability to determine the position of animals in an area. Using these methods, it is unlikely that 100% of all marine mammals will be detected. Another issue related to DMAs is the size of a safety zone, due to difficulties determining both the predicted received levels of sound and safe exposure levels.
2) Shut Down or Stand Down	Typically combined with a safety zone and/or observers, this involves the suspension of an activity until the marine mammal has left the safety zone or normal behavior has been restored. Specific temporal restrictions related to the duration of suspension (*i.e.*, how long before the activity can resume) may vary based on detection of marine mammals (*e.g.*, siting conditions). Issues related to shut down and stand down are similar to those discussed on observers, passive and active acoustic monitoring, and Dynamic Management Areas. For example, application of shut down or stand down can have significant operational costs.
3) Seasonal Restrictions	Limits (including bans) on an activity during biologically important periods, such as during annual migrations or breeding seasons. The times associated with such restrictions may be fixed according to calendar dates, or associated with biological activity, such as animals' arrival at or departure from a particular location. Seasonal restrictions may be useful in mitigating impacts, but there are limitations to the application of this strategy. Seasonal restrictions should therefore include compensatory tools to account for seasonal fluctuations in biological behavior of the target species. In some cases, the flexible management framework required to apply biologically controlled seasonal restrictions can make them difficult to implement and thus unappealing to managers and the regulated communities.

TOOL (WITH EXAMPLES)	**DESCRIPTION**
4) Temporal Restrictions	Limiting an activity to specific times of the day or conditions, based on concerns about observer ability to detect marine mammals, biologically important periods of the day that might involve particularly sensitive behaviors, etc. May be tied to a safety zone, requiring that the zone be clear of all marine mammals prior to activity commencement or restarting (after a shut down or stand down of operations). While these restrictions can effectively reduce the impacts on species of interest during periods that they may be particularly sensitive, times that are important to one species may conflict with those important to another.
5) Year-Round Geographic Restrictions	Year-round spatial limits on an activity in a specified geographic region selected for various reasons, including that the area is biologically important habitat or the entire habitat of a particularly sensitive species, and that it contains geographic features that present a high likelihood of impacts occurring, etc. Restrictions in these areas may include limited access, moratorium on an/all anthropogenic sound activity, or rerouting. If application of a year-round geographic restriction excludes an activity from a specified region, it will prevent any impacts the sounds generated by that activity might have on marine mammals. However, it may have some of the most significant operational impacts on the sound-producing activities and therefore should not be undertaken lightly.
6) Geographical Selection	Differs from geographical restrictions in that it involves identifying low-risk areas and assigning them to be used for certain activities, instead of avoiding high-risk areas. Potential applications for geographical selection may need to be limited to those activities that are more flexible.
c. Removal or Modification of the Sound Source (Source Elimination and Equipment Design)	
1) Engineering or Mechanical Modifications (*e.g.*, Ship-quieting technologies; Receiver improvements; Signal-processing improvements; Source modifications)	Technological improvements or modifications to the design of equipment or techniques that may allow reductions in the intensity, or alter other relevant characteristics, of introduced sound while allowing intentionally produced signals to accomplish their intended purposes. Reducing the output of a source, or restricting its propagation in any significant way, may reduce its potential impacts but may also make the underlying activity less effective. The effectiveness of certain engineering or mechanical modifications also may be uncertain. To change the characteristics of a sound to make it less damaging, it is important to determine which characteristics are responsible for any given problem.[v]

TOOL **(WITH EXAMPLES)**	**DESCRIPTION**
2) Reduction in Activities	Reducing the amount of time during which, or space over which, a sound is produced. This may be achieved by increasing efficiency (*e.g.*, filling ship to capacity to reduce the number of trips), avoiding duplication of efforts (*e.g.*, companies or researchers share data or employ a common surveyor), using simulations, etc. However, there are logistical and legal problems that need to be addressed, with each case being different and thus requiring separate examination.
3) Sound Attenuation (*e.g.*, Sound screening)	Bubble curtains, blasting mats, dampening screens and similar devices and techniques used for limiting (attenuating) the amount of acoustic energy leaving a sound source. Primarily employed around stationary sources, such as pile drivers and explosions. Bubble curtains do not appear to eliminate all responses in marine mammals. Such measures can also produce relatively low-level, but constant, sound that could produce a masking effect for nearby marine mammals.[vi] Thus questions remain about the effectiveness of sound attenuation as a mitigation tool.
d. Training, Public Outreach, and Education	
1) Training, Public Outreach, and Education	Training and educating those involved in sound-producing activities (including the public) in various skills and techniques (*e.g.*, recognition of particularly sensitive species) or issues (*e.g.*, potential impacts of sound-producing activities on marine mammals).

Table 2. Summary of marine mammal detection and observation tools currently in use or in development. The order in which these tools are presented here is not intended to indicate any preferential order for their use.

Detection/Observation Method	Description
1) Marine Mammal Observers (*e.g.*, Shipboard surveys; Aerial surveys; Land-based surveys)	Individuals (ranging from marine mammal biologists and trained observers to crew members) who conduct visual surveys of marine mammals (*i.e.*, watching for their presence or behavior) for various reasons including, but not limited to: maintaining marine mammal-free safety zones; monitoring for avoidance or take behaviors; fulfilling information gathering conditions; and avoiding potentially fatal interactions. The limitations inherent in visual observation are well known to marine biologists. Sightings rates are affected by a variety of factors, such as light conditions, sea state and weather, how easily a species can be identified, marine mammal behavior and abundance, the level of the observers' experience, observer fatigue, the number of observers, and the frequency and duration of observations.
2) Observation Through Non-Acoustic Remote Sensing (*e.g.*, Forward-looking infrared radar - FLIR; Satellite imagery; Light detection and ranging – LIDAR; Satellite tagging and tracking)	Various indirect, technological methods of marine mammal detection and observation. Satellite tags can provide a full record of marine mammal positions and much other data throughout their dives, although this can only be transmitted to scientists under satellite coverage when the animals are at the surface. Non-acoustic remote sensing technologies may be affected by the weather or require mammals to be at or near the surface for detection. Additionally, not all remote sensing techniques allow real-time monitoring, and experience with tools that are effective for one species is not necessarily transferable to use with other marine mammal species.
3) Passive Acoustic Monitoring (PAM)	Use of hydrophones or other devices to determine if marine mammals are present by detecting vocalizations or particular sound-producing behaviors. PAM can be a viable component of an integrated mitigation, monitoring, and observation system, depending on the species for which the mitigation is intended. While current technology has limitations that must be considered in its application, PAM is an evolving technology with great promise.

Detection/Observation Method	Description
4) Active Acoustic Monitoring (AAM) (*e.g.*, "Whale-finding" sonar)	Use of sonar before and/or during operations to find and track marine mammals. Target identification remains a problem for AAM, possibly requiring multi-frequency systems to solve. Consequently, high detection rates are often accompanied by high rates of false detection, and, barring technological improvements, a reduction in false positives will go hand-in-hand with a reduced rate of correct detection.[vii] Additional research is needed on its efficacy and its effects.[viii] It should again be noted that, like PAM, this technique will not be a single stand-alone solution, but could play a role in an integrated detection system.

NOTES

[i] Public Law 108-7
[ii] MMPA 16 U.S.C. 1361 *et seq*.; ESA 16 U.S.C. 1531 *et seq*.
[iii] *e.g.*, MMPA 16 U.S.C. 1373(a), 1371(a)(5)(A); ESA 16 U.S.C. 1536(a)(2); see also Section 4(1) of the House of Representatives Conference Report No. 697, 96th Congress, Second Session, 12, (1979)
[iv] Russell 2001
[v] Barlow and Gisiner, in press
[vi] Erbe and Farmer 1998
[vii] Barlow and Gisiner, in press
[viii] Russell 2001; Barlow and Gisiner, in press

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Environmental Caucus Statement for

The Report of the Advisory Committee on Acoustic Impacts on Marine Mammals

to the

Marine Mammal Commission

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On Behalf of:

Humane Society of the United States (HSUS)
International Fund for Animal Welfare (IFAW)
Natural Resources Defense Council (NRDC)
Ocean Mammal Institute (OMI)
Whale and Dolphin Conservation Society (WDCS)

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The following statement reflects only the views of the individuals and organizations 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.

Statement C by submitted by Dolman, Green, Heskett, Reynolds, and Rose

Environmental Caucus Statement

On behalf of the undersigned conservation and animal welfare organizations and marine mammal scientists, we commend Congress and the Marine Mammal Commission for establishing a federal advisory committee to consider the impacts of proliferating undersea noise on marine mammals. While the process was ultimately unsuccessful in bridging the gap between conservationists and noise producers (*i.e.*, the Navy, the oil and gas industry, and noise-generating research scientists), we believe, as discussed in detail below, that the process yielded positive results in confirming (1) the critical importance of precautionary management under the Marine Mammal Protection Act, (2) the feasibility of a broad range of mitigation measures to reduce harm, (3) the need for independent, non-invasive research in priority areas, and (4) the wisdom of addressing this problem before the proliferation of intense anthropogenic noise sources becomes unmanageable.

Accordingly, we urge Congress to act now to address undersea noise pollution consistent with the following specific recommendations:

(1) Given the difficulties of assessing impacts on marine mammals in the wild, the vulnerable conservation status of many marine mammal populations, and the potential cumulative and synergistic effects of noise activities, it is essential that the wildlife agencies use precaution in managing ocean noise. Maintaining the integrity of the Marine Mammal Protection Act is critical to this effort, and Congress should reject legislative proposals that would weaken or introduce uncertainty into the Act's permitting provisions.

(2) Avoiding sensitive areas is probably the most effective means available of reducing the impacts of ocean noise and should become the backbone of management. The wildlife agencies should identify "hotspots," areas of biological importance where additional noise activity should be avoided, and "coldspots," areas presenting a lower risk of impact where some activities might be sited. Novel application of conservation tools such as designation of critical habitats, marine protected areas, and ocean zoning should be investigated as a means to protect marine mammals from anthropogenic noise.

(3) Congress should establish a national science program on ocean noise through the National Fish and Wildlife Foundation or similar institution, which would provide for the coordination, reliability, and independence of funding that are so strongly needed in this field. A substantial portion of any research budget should be dedicated to improving mitigation measures, such as engineering modifications, which hold considerable promise for the long-term management of ocean noise.

(4) In managing research, non-invasive studies that are as likely to yield conclusive results with less risk of harm to animals should be preferred over invasive research, such as controlled exposure experiments, that intentionally expose marine mammals to potentially harmful sound. Short-term studies on the effects of noise on marine mammals should proceed only if there is prior agreement between researchers and regulators as to which short-term reactions or effect sizes would constitute a "biologically significant" effect.

(5) Regulators should provide the public with better and more timely information about strandings and concurrent noise events. Stranding investigations and other monitoring activities and assessments by public agencies should be transparent and accessible to the public.

Introduction

Marine mammals, indeed most marine animals, are highly dependent on sound as their principal sense. Most species use sound for all aspects of their life, including reproduction, feeding, predator and hazard avoidance, communication, and navigation. Vision is only useful for tens of meters underwater, whereas sound can be heard for hundreds, even thousands of kilometers.

The efficiency with which sound travels underwater—five times faster than in air—means that the potential area impacted by even one noise source can be vast. For instance, the U.S. Navy's Low Frequency Active (SURTASS LFA) Sonar, used to detect submarines, could significantly affect marine life over hundreds of thousands of square kilometers (Navy 2001) and can be heard over a much greater area. Noise from a single seismic survey can flood through a region of almost 300,000 square kilometers, raising noise levels 100 times higher than normal, continuously for days at a time (IWC 2004). Seismic noise from eastern Canada measured 3,000 km away in the middle of the Atlantic was the loudest part of the background noise heard underwater (Nieukirk *et al.* 2004).

While other marine mammals are affected by noise, a series of beaked whale strandings first focused public attention on the impacts of undersea noise. The first published record that connected beaked whale strandings to military events dates back to 1991, when Simmonds and Lopez-Jurado (1991) reported that several beaked whale mass stranding events occurred together with naval activities between 1982 and 1989 in the Canary Islands. Since then, many more of these "acoustically-induced" strandings have come to light (*e.g.*, Frantzis 1998, NOAA and U. S. Navy 2001, Jepson *et al.* 2003), leading the International Whaling Commission's Scientific Committee to note that "there is now compelling evidence implicating military sonar as a direct impact on beaked whales in particular," and a U.S. Navy-commissioned report to state that "the evidence of sonar causation [of certain whale beachings] is, in our opinion, completely convincing" (Levine *et al.* 2004). More recently, cetacean species besides beaked whales have also been found to strand coincident with noise events.[1]

But strandings are not the only cause for concern. Underwater noise can prevent marine mammals and fish from hearing their prey or predators, from avoiding dangers, from navigating or orienting toward important habitat, from finding mates that are often widely dispersed, from staying in acoustic contact with their young or group members, and can cause them to leave important feeding and breeding habitat. Marine mammal calls can be drowned out or "masked" by noise. While some of these effects are not immediately lethal and may be harder to detect, they nevertheless can be as serious as outright mortality, causing animals to be so compromised as to threaten their survival or reproductive success.

[1] Cetaceans include whales, dolphins, and porpoises.

Anything that interferes with a marine mammal's ability to detect biologically important sounds could have a negative effect on the health of its population. The IWC's Scientific Committee noted that "repeated and persistent acoustic insults [over] a large area…should be considered enough to cause population level impacts" (IWC 2004). Population impacts are hard to detect in animals as difficult to study as marine mammals (only a handful of cetacean species have population estimates that are more precise than $\pm$ 40% (Whitehead *et al.* 2000)), but noise has been thought to contribute to several cetacean species' decline or lack of recovery (NMFS 2002; Weller *et al.* 2002).[2]

To understand fully how noise affects marine mammal populations, one must first know where the animals are and to what noise they are exposed. One must have a sufficiently good baseline understanding of "normality" to detect any changes in, for example, feeding rate. Then, one must know how a change in feeding rate translates into a change in, for example, birth rate, as this is an important measure of population health. Finally, one must be able to link these changes exclusively or primarily to noise, rather than other factors such as environmental conditions. And, most challenging, one must know how animals react to noise in all situations and states (*e.g.*, at depth, at rest, and during mating, feeding, and migration), bearing in mind that reactions vary depending on species, individuals, age, sex, prior experience, and other factors (Richardson and Würsig 1997), not to mention the characteristics of the noise source.

Despite data gaps, however, the scientific body of literature on noise impacts on marine mammals is growing, pointing consistently to cause for concern. Noise has killed and deafened marine animals (*e.g.*, Jepson *et al.* 2003, McCauley *et al.* 2003), caused them to move away from important breeding and feeding areas (*e.g.*, Bryant *et al.* 1984, Weller *et al.* 2002), and produced declines in fisheries' catch rates (*e.g.*, Engås *et al.* 1996, Skalski *et al.* 1992). And we know that many marine mammal species are keystone, or umbrella species—that is, they have a disproportionate effect on the ecosystem—and their protection requires that other related ecosystem components, such as their prey species, also be safeguarded. More generally, the various species that make up the marine ecosystem are more interrelated than those on land, which means that the potential for broad ecological effects ("domino effects") is greater than for terrestrial ecosystems (Frank *et al.* 2005, Shurin *et al.* 2002).

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[2] This contrasts with the claim in the NRC (2005) report that "no scientific studies have conclusively demonstrated a link between exposure to sound and adverse effects on a marine mammal population." This statement ignores:

1. The best information we have to date on noise-induced strandings, which indicates a serious, local population effect in the wake of the March 2000 Bahamas mass stranding, where a well-studied local population was either killed or displaced, failing to recover at least five years after the sonar event (Balcomb and Claridge 2001);
2. How difficult it is to discover population declines in all but a handful of cetacean species, since population estimates for most species are extremely imprecise (Whitehead *et al.* 2000);
3. How difficult it is to tie these population declines, should they be detectable, to noise;
4. That there has been no attempt to study the link between population declines and noise;
5. That most recognized cetacean population declines are not linked with any one effect. Rare examples of population declines known to be primarily caused by one effect are: the vaquita and by-catch; the Eastern Tropical Pacific dolphin declines and tuna nets; and Aleutian sea otters and orca predation (Perrin *et al.* 2002); and
6. That even contaminants known to be toxic and generally accepted as significant threats to marine mammals have not definitively produced marine mammal population declines, with the exception of sea otters and oil (Twiss and Reeves 1999); this is, at least partially, because population declines are hard to document, as noted earlier.

The threats marine mammals are confronted with, such as fisheries by-catch, habitat degradation, chemical pollution, whaling, vessel strikes, and global warming, likely do not occur in isolation. These threats may be cumulative (additive) or, indeed, synergistic (greater than the sum of their parts). We already know that human impacts on marine ecosystems such as over-fishing, eutrophication, climate change, and ultraviolet radiation interact to produce a magnified effect (Lotze and Worm 2002, Worm *et al.* 2002). Noise could similarly interact with marine mammal by-catch or ship collisions, preventing animals from sensing fishing gear or oncoming vessels or making them more vulnerable to injury, as evidence seems to indicate (Nowacek *et al.* 2005, Todd *et al.* 1996).

For all these reasons, scientists believe that the effects of undersea noise could be far-ranging and severe, and with ocean background noise levels doubling every decade for the last several decades in some areas (Andrew *et al.* 2002, IWC 2004), the problem of ocean noise will not diminish. This fact, combined with the slow reproductive rate of many whale species and the level of uncertainty in marine mammal science generally, necessitate precautionary management and protective mitigation measures to prevent or reduce harm today—*before* the proliferation of man-made noise sources in the world's oceans becomes intractable and its impacts irreversible.

Sources of Ocean Noise

There are numerous sources of natural and anthropogenic noise in the marine environment. They vary according to characteristics such as frequency (pitch), amplitude (loudness), duration, rise time (time required to reach maximum amplitude), directionality (the width of its broadcasted "beam"), duty cycle (percentage of time a sound is transmitted), and repetition rate. Natural noise sources include undersea earthquakes, volcanic eruptions, and lightning strikes on the water surface.

Anthropogenic underwater noise is principally the result of shipping, seismic exploration (undertaken by the oil and gas industry to find mineral deposits and by geophysicists to study the ocean floor), and naval sonar operations. Drilling, construction, oceanographic experiments, side-scanning (scientific) sonars, and acoustic harassment devices, among others, also contribute to noise levels.

Explosions can be as loud as undersea earthquakes, but are much higher in frequency and rise time and thus likely to be more dangerous to marine mammals. Airgun arrays used in seismic exploration are roughly as loud as volcanic eruptions, although there are many differences in their sound characteristics, making comparisons difficult. Naval sonars, at their highest output, are only somewhat quieter than the loudest airgun arrays. Individual ships, even supertankers, are not as loud as most airgun arrays or naval sonars; because of the number of ships, however, especially in the Northern Hemisphere, shipping contributes greatly to background noise levels. Sounds from seismic surveys, sonars, and other sources can produce reverberations or echoes that elevate noise levels for much longer than the actual duration of the sound.

It is unknown which characteristics of noise are most damaging to marine mammals, but some educated guesses can be made, based on the characteristics of the animals' own calls. For example, sound sources with higher amplitudes, mid-frequencies or low frequencies above 5 Hz, longer durations, rapid rise times, broad directionality (wide beams), and higher duty cycles (percentage of time actually transmitting) and repetition rates would probably be most problematic for marine mammals (Møhl 2004).

Although marine mammals can also produce very loud sounds, it is difficult to compare these with manmade noise since they vary in many of the above-mentioned characteristics. For instance, while a sperm whale click may run as loud as some naval sonars, its directionality is extremely narrow (Møhl 2004). Imagine a pencil- thin flashlight beam, compared, in the case of naval mid-frequency sonar, to a floodlight radiating light in virtually all directions. The chances of being exposed to the full power of a sperm whale click are comparatively slim.[3]

It is also invalid to compare anthropogenic to natural noise sources. Marine mammals are likely to have adapted over evolutionary time scales to some commonly encountered natural noise sources; they are unlikely to be similarly adapted to the relatively recent addition of anthropogenic noise. Especially for long-lived species, like whales, animals are probably unable to adapt at a pace similar to that of habitat change (Rabin and Greene 2002). While some natural and human-made sound sources share some acoustic characteristics, there is no evidence that marine mammals cannot detect the difference, especially regarding factors such as the context in which they occur.

Impacts of Noise Pollution on Marine Mammals

Cetacean Strandings

The National Marine Fisheries Service (NMFS) defines a stranding as a) a marine mammal dead on shore; or b) alive on shore and unable to return to the water, or c) in an unusual habitat (river or shallow water) and unable to return to its own habitat (*e.g.* deeper water) without assistance. Most of the strandings recorded by NMFS in its database of strandings involve pinnipeds (seals and sea lions). The reasons cetaceans strand are still largely unknown, but some strandings are the result of bio-toxins or disease. Although cetacean mass strandings (involving several animals) are uncommon, certain species, such as pilot whales or false killer whales, are comparatively frequent mass-stranders and were recorded doing so long before the industrial revolution.

Noise-related strandings. Recently, a new type of mass stranding began to emerge involving beaked whales, a species of whales that do not typically mass strand. Unusual aspects of these mass strandings have included: a) the involvement of beaked whales; b) several species stranded together; c) animals spread out over several tens of kilometers of coastline, yet stranded within several hours of each other—a so-called "atypical" stranding pattern; d) animals apparently disease-free, with food in their stomachs; e) some animals live-stranded; f) strandings very closely linked in space and time to a noise event; g) evidence of acoustic trauma discovered upon examination of the carcasses; and h) no other explanations available for the stranding. Not all of these strandings showed all of these

[3] Similarly, a sound source, like a bottlenose dolphin click, may be loud but extremely high in frequency (ultrasonic—above the human hearing range). It would be invalid to compare it to a single airgun, for example, even though it can be as loud, since the airgun is much lower in frequency, and lower frequencies travel much larger distances underwater. (Seismic surveys use an array of multiple airguns, which produce much louder noise levels than a single airgun.) Depth-sounder sonars, though moderately loud, are ultrasonic (generally over 50 kHz in frequency), and are directed downward in a very narrow beam; thus, their potential range of impact is very small.

characteristics, other than the involvement of beaked whales, the lack of disease, and the nearby noise event.

Noise was first implicated in these strandings because (1) no other threat could easily explain how, almost simultaneously, many whales could be affected over a large area, and (2) the locations and timing of individual whale strandings in a mass stranding event would often closely mirror the track of a noise-producing vessel. Finally, in the Bahamas stranding of 2000, the "smoking gun" of acoustic trauma was discovered. This consisted of hemorrhaging around the brain, in the inner ears, and in the acoustic fats (i.e., fats that are located in the head, including the jaw and "melon" or forehead of cetaceans, which are involved in sound transmission). These results led the U.S. Navy and the National Oceanic and Atmospheric Administration (NOAA) in their interim report (NOAA and U.S. Navy 2001) to conclude that "an acoustic or impulse injury…caused the animals to strand…and subsequently die…."

Exposure to military sonar was identified as the likely cause of a beaked whale stranding event in Greece in 1996, because of an "atypical" stranding pattern (Frantzis 1998). Similar events occurred in the Bahamas in 2000 (see above), Madeira in 2000 (Freitas 2004), and the Canary Islands in 2002 (Fernandez *et al.* 2005). Since 1960, more than 40 mass strandings including two or more Cuvier's beaked whales (*Ziphius cavirostris*) have been reported worldwide (See Table 1; Taylor *et al.*, 2004, Brownell *et al.* 2004), some at the same time and place as naval maneuvers and the use of active sonar (Frantzis 1998, NOAA 2001, Jepson *et al.* 2003, Brownell *et al.* 2004) or other noise sources, such as seismic surveys (Taylor *et al.* 2004; IWC 2004).

While the co-occurrence of two events (noise and strandings) does not necessary mean one caused the other, the probability that the two are not related grows smaller as more linked incidents are observed. This is because naval maneuvers and especially beaked whale mass strandings are comparatively rare events. The chance that two rare events will repeatedly occur together by coincidence is low. Additional strong evidence for the link between naval sonars and Cuvier's beaked whale mass strandings is provided by the fact that these strandings were reported in dramatically increased numbers after the early 1960's (Table 1), when much more powerful naval sonars began to be used (Friedman 1989).[4]

<u>Extent of the problem.</u> For a number of reasons, it is difficult to assess the magnitude of the problem, and the true extent of strandings associated with noise is likely underestimated. First, many strandings, let alone mortalities, will go undocumented, as will the associated noise events.

[4] Some of these strandings that occur together with a noise event are undisputed in their association with noise. Yet others are more controversial and are considered merely coincidental events by some stakeholders who require that the exact source of noise be determined (*e.g.*, that sonars were known to be operating, rather than just "naval maneuvers") and that evidence of acoustic trauma be shown in the whales. Such requirements raise the bar of "proof" or "causation" unacceptably high, since (1) information will always be lacking in trying to reconstruct past events, (2) most naval maneuvers do involve underwater noise of some kind, and sonars are often operating, and (3) while acoustic trauma provides very convincing evidence to link a stranding with noise, the lack of acoustic trauma should not be used to rule out such an association because whales could be near shore when they hear the noise and simply strand due to panic, dying only from the stranding with no other trauma evident.

Second, if animals can die at sea due to injuries sustained from a noise event (i.e., stranding is not the only reason they die), as scientists suspect (Fernandez 2005, IWC 2004), then detection is even more improbable. Whale carcasses are difficult to discover at sea, since they usually immediately sink, with the exception of right, bowhead, and sperm whales (Whitehead and Reeves 2005). While some may later float or strand, even in well-studied inshore populations of cetaceans, only a small proportion of carcasses are recovered (a total of 14 killer whale carcasses has been recovered out of 200 individuals known to have died along a well-populated coast, a 7% recovery rate) (John K.B. Ford, pers. comm.).

Third, no attempt has been made to correlate single strandings of beaked whales, as opposed to mass strandings, with acoustic activities. The fact that it has taken observers 40 years, during which mid-frequency sonar technology has been in wide use, to discover a link between naval sonars and beaked whale strandings underscores how easy it is to miss such impacts from human activities, even for such relatively obvious events as strandings.

Mechanism of injury. The mechanisms by which beaked whales are impacted by anthropogenic noise are not understood (Cox *et al.* in press). It is not clear whether the pathologies documented in the Bahamas, Madeira, and Canary Islands beaked whale stranding events are physiological or behavioral effects or some combination of the two. Beaked whales could be affected through: a) a behavioral response to noise that leads directly to stranding, such as swimming away from the noise into shallow water; b) a behavioral response such as ascending too rapidly from depth or staying too long at depth or at the surface, which leads to tissue damage (*e.g.*, because of decompression sickness or lack of oxygen); or c) a direct physiological response from noise exposure through, for example, non-auditory effects like gas bubble formation and growth, vertigo, or resonance (Cox *et al.* in review). Gas bubble formation associated at least in part with a behavioral response has been singled out as particularly plausible (Cox *et al.* in review).[5]

Bubble growth or decompression sickness plausibly explains the observed trauma, because the noise heard by the whales is likely not loud enough to cause permanent or even temporary hearing loss. By modeling the sound field and by knowing the distribution of Cuvier's whales in the area of the Bahamas, Hildebrand *et al.* (2004) determined that whales were exposed to relatively modest levels of noise, on average around 130 decibels (dB).[6] Bubble growth could theoretically be activated on exposure to sounds of 150 dB or below, and bubbles could grow significantly as the animal rises to the surface (Crum *et al.* 2005, Houser *et al.* 2001).

[5] In contrast to the necropsies conducted in the Bahamas stranding where only the heads were examined, in the Canary Islands stranding, pathologists examined the entire bodies of the whales. They found bubbles inside the blood vessels as well as hemorrhaging in the liver and other organs, features consistent with acute decompression sickness in humans.
[6] The decibel scale is like the Richter scale: it expresses force in logarithmic terms, rising in increasing orders of magnitude from a baseline value. Each ten-decibel rise along the scale corresponds to a ten-fold increase in intensity; thus, a sound measuring 130 dB is considered ten times more intense than a 120 dB sound, a sound of 140 dB is 100 times more intense, and a sound of 150 dB is 1,000 times more intense. Throughout this statement, decibel levels are calculated to a reference pressure of 1 microPascals (µPa), the standard for water-borne sounds. In general, peak pressures are given for impulsive sounds, like those produced by airgun arrays, while, for other types of noise, a special average of pressures known as the root-mean-square is provided.

For this to happen, however, tissues would have to be supersaturated with nitrogen, which is in fact the case, especially for deep-diving marine mammals (Houser *et al.* 2001, Ridgway and Howard 1979). Deep-diving whales, such as beaked whales and sperm whales, would then theoretically be at greatest risk of injury from bubble growth. Contrary to conventional wisdom, which has long held that deep-diving cetaceans somehow avoid "bends"-like symptoms, recent anatomical studies of sperm whales and other species show that *in vivo* bubble formation is indeed possible in cetaceans other than beaked whales (Jepson *et al.* 2003, Jepson *et al.* 2005), and may even be chronic in sperm whales (Moore and Early 2004).

Population-level impact. As previously mentioned, the population consequences of acoustically-induced strandings are unclear. The conservation status of most beaked whales is listed as "data deficient" (IUCN 2004). These animals tend to be notoriously elusive and hard to study. The few long-term studies of beaked whale populations that exist indicate that these animals are found in small local populations that are resident year-round (Wimmer and Whitehead 2004; Balcomb and Claridge 2001). Cuvier's beaked whales also show a high degree of genetic isolation among oceanic, and in some cases, regional populations (Dalebout *et al.* in press).

For species with this kind of population structuring, transient and localized acoustic impacts could have prolonged and serious consequences. In the case of the Bahamas 2000 event, the only stranding event for which baseline survey data are available, only one of the Cuvier's beaked whales that were photo-identified over a nine-year period before the strandings has since been resighted and only about eight new individuals have re-populated the area in the five years since the stranding (Balcomb and Claridge 2001, K. Balcomb, pers. comm.).

This indicates that the affected local population of Cuvier's beaked whales may have been isolated from a larger population, implying that a population-level effect may have resulted, directly or indirectly, from the brief sonar transit (Balcomb and Claridge 2001, IWC 2004). Most, if not all, of the local population of the species may have been killed or, at minimum, displaced from its former habitat. For species like beaked whales whose rates of increase are low, even relatively small effects may cause population declines (Whitehead *et al.* 2000).

Non-beaked whale strandings. While beaked whales seem particularly vulnerable to the effects of noise, other cetaceans also have been involved in noise-induced strandings. Some species, such as minke whales (Bahamas 2000) and pygmy sperm whales (Canary Is. 1988), are known to have stranded concurrently with beaked whales; others, such as long-finned pilot whales and dwarf sperm whales (N. Carolina 2005), melon-headed whales (Hawaii 2004), harbor porpoises (Haro Strait 2003), and humpback whales (Brazil 2002) have stranded in noise-related events that did not involve beaked whales at all (Table 2). In the case of the Brazilian humpbacks, the anomaly was not an overall increase in stranding rates, but an increase in the number of adult humpbacks that stranded, relative to juveniles.[7]

[7] Such a change in relative rates provides better evidence of an effect, because it addresses standardizing "effort," or the problem of whether simply more people are looking for stranded animals. Since it is equally easy to find a stranded adult or juvenile, the factor of effort could not explain the relative differences in stranding rates.

It is not known which other species could be vulnerable to noise-induced strandings. NMFS is currently investigating whether the pilot whales, minke whale, and dwarf sperm whales that stranded in North Carolina in January 2005 had traumas consistent with acoustic impacts. As mentioned earlier, some species of cetaceans, such as pilot whales, regularly mass strand for a variety of reasons. If these same species also occasionally strand due to noise events, such a connection would be easy to miss and their susceptibility to noise-related injury and mortality may be underestimated.

Relative to the North Carolina stranding, it should be noted that NMFS did not provide any report on the cause or other details until January 2006, one year after the event (Kaufman 2006). Similarly, there has been no final report of the Bahamas 2000 stranding, over four years after the interim report and almost six years after the stranding event.

Table 1. Mass Strandings of Beaked Whales
(Brownell *et al.* 2004, Espinosa *et al.* 2005, Frantzis 2004, IWC 2004, Moore and Stafford 2005)

Year	**Location**	**Species (numbers)** [Zc= Cuvier's, Me= Gervais', Md=Blainville's beaked whales]	**Associated activity, when available**
1914	New York, United States	Zc (2)	
1960	Sagami Bay, Japan	Zc (2)	US Fleet
1963	Gulf of Genoa, Italy	Zc (15+)	Naval maneuvers
1963	Sagami Bay, Japan	Zc (8-10)	US Fleet
1964	Sagami Bay, Japan	Zc (2)	US Fleet
1965	Puerto Rico	Zc (5)	
1966	Ligurian Sea, Italy	Zc (3)	Naval maneuvers
1967	Sagami Bay, Japan	Zc (2)	US Fleet
1968	Bahamas	Zc (4)	
1974	Corsica	Zc (3), Striped dolphin (1)	Naval patrol
1974	Lesser Antilles	Zc (4)	Naval explosion
1975	Lesser Antilles	Zc (3)	
1978	Sagami Bay, Japan	Zc (9)	US Fleet
1978	Suruga Bay, Japan	Zc (4)	US Fleet
1979	Sagami Bay, Japan	Zc (13)	US Fleet
1980	Bahamas	Zc (3)	
1981	Bermuda	Zc (4)	
1981	Alaska, United States	Zc (2)	
1983	Galapagos	Zc (6)	
1985	Canary Islands	Zc (12+), Me (1)	Naval maneuvers

Year	**Location**	**Species (numbers)** [Zc= Cuvier's, Me= Gervais', Md=Blainville's beaked whales]	**Associated activity, when available**
1986	Canary Islands	Zc (5), Me (1), beaked whale spp. (1)	
1987	Canary Islands	Me (3)	
1987	Italy	Zc (2)	
1987	Suruga Bay, Japan	Zc (2)	US Fleet
1987	Canary Islands	Zc (2)	
1988	Canary Islands	Zc (3), bottlenose whale (a beaked whale) (1), pygmy sperm whale (2)	Naval maneuvers
1989	Sagami Bay, Japan	Zc (3)	US Fleet
1989	Canary Islands	Zc (15+), Me (3), Md (2)	Naval maneuvers
1990	Suruga Bay, Japan	Zc (6)	US Fleet
1991	Canary Islands	Zc (2)	Naval maneuvers
1991	Lesser Antilles	Zc (4)	
1993	Taiwan	Zc (2)	
1994	Taiwan	Zc (2)	
1996	Greece	Zc (12)	Naval LFAS trials
1997	Greece	Zc (3)	
1997	Greece	Zc (9+)	Naval maneuvers
1998	Puerto Rico	Zc (5)	
1999	Virgin Islands	Zc (4)	Naval maneuvers
2000	Bahamas	Zc (9), Md (3), beaked whale spp. (2), minke whale (2), Atlantic spotted dolphin (1)	Naval mid-frequency sonar
2000	Galapagos	Zc (3)	Seismic research
2000	Madeira	Zc (3)	Naval mid-frequency sonar
2001	Solomon Islands	Zc (2)	
2002	Canary Islands	Zc (9), Me (1), Md (1), beaked whale spp. (3)	Naval mid-frequency sonar
2002	Mexico	Zc (2)	Seismic research
2004	Canary Islands	Zc (4)	Naval maneuvers

Table 2. Associated Mass Strandings Involving Species Other Than Beaked Whales
(Engel *et al.* 2004; Martin *et al.* 2004; NOAA and U.S. Navy 2001; NMFS 2005; Navy 2004b)

Year	Location	Species (numbers)	Associated activity (when available)
1988	Canary Islands	Pygmy sperm whale (2), Zc (3), bottlenose whale (1)	Naval maneuvers
2000	Bahamas	Minke whale (2), *Balaenoptera* sp. (2), Atlantic spotted dolphin (1), Zc. (9), Md. (3), Ziphiid sp. (2)	Naval mid-frequency sonar
2002	Brazil	Humpback whale (8)	Seismic exploration
2003	Washington, United States	Harbor porpoise (14), Dall's porpoise (1)	Naval mid-frequency sonar
2004	Hawaii, United States	Melon-headed whale (~200)	Naval mid-frequency sonar
2005	North Carolina, United States	Long-finned pilot whale (34), dwarf sperm whale (2), minke whale (1)	Naval maneuvers; investigation pending

Other Impacts of Noise on Marine Mammals
Temporary or permanent hearing loss. There is currently a great deal of focus on temporary (TTS or Temporary Threshold Shift) or permanent (PTS or Permanent Threshold Shift) hearing loss when assessing the impacts of noise on marine mammals. Certainly, such physiological effects are of great concern. Even a temporary loss in hearing, lasting from minutes to days, can be fatal or injurious to animals in the wild, if it means missing detection of a predator or other significant hazard.
TTS and PTS are more easily modeled and predicted than other impacts, especially behavioral ones. But since only TTS has ever been measured in only a handful of captive marine mammals (it is unethical and illegal to purposely induce PTS), questionable extrapolations have often been used from study animals (and other mammals) to marine mammals in general. In fact, it is unknown at this point whether the vertebrate auditory system is the most sensitive to noise exposure, and, as a result, it may not be the best indicator for noise impacts. Depending on the frequency and other characteristics of the noise source, it could be that skin sensations or reverberations or resonance in air sacs, for instance, could actually cause more of an impact on a marine mammal than any direct effect on its ears.

As is demonstrated with the beaked whale stranding in the Bahamas, a narrow focus on TTS and PTS will not provide a complete picture of potential harm. Although these whales received noise levels well below those understood to cause TTS or PTS in most cetaceans, they sustained damage to their inner ears, most likely as a result of indirect behavioral or non-auditory effects. Thus, the most severe acoustic impacts on marine mammals recorded to date were the result of exposures too low to induce TTS, according to current predictive models.

Arguments have been made that if an animal is relatively insensitive to a sound, that sound (or sounds with similar characteristics) must not be important for its survival. This does not necessarily follow since an animal only needs to be as sensitive to a stimulus as demanded by the usual tasks it faces (Stearns and Hoekstra 2000). An animal's sensitivity to a particular sound type may therefore not be the best indicator of that sound's importance for the animal's survival (Ryan *et al.* 1990).

The fact that marine mammals can make loud sounds is sometimes used as proof that they are adapted to hearing loud sounds and thus immune from acoustic damage. This is an incorrect conclusion, since (1) animals' ears are protected from the sounds they themselves produce and (2) animals generally space themselves such that they do not expose each other to loud sounds, except perhaps when behaving aggressively, intentionally causing damage. The human voice is also loud enough to cause hearing damage in other humans, if yelling or singing occurs at a close distance from the ear over hours, yet this is socially unacceptable.

Masking. Masking refers to the interfering or obscuring effects of noise, limiting animals from hearing important signals. Certain low-frequency whale sounds like blue and fin whale calls can be heard over hundreds or thousands of kilometers, and are presumably used to attract widely spread-out mates (Croll *et al.* 2002). While some stakeholders argue that a call's ability to be heard over large distances does not mean it is actually used to communicate with distant whales, animals would not be expected to make calls louder than necessary to achieve their function (Stearns and Hoekstra 2000). In the case of loud, low frequency whale calls, the function may not be to have one's call merely detected, but to advertise such features as quality and fitness to prospective mates (Croll *et al.* 2002).

It is necessary, therefore, to know the function of a call before we can hope to evaluate the significance of masking. Since this is difficult to do for most cetacean calls, it is precautionary to assume that the effect masking noise will have on most calls is negative. In birds, for instance, there are indications that masking can reduce the information content of calls (Leonard and Horn 2005).

It should also be assumed that it is advantageous for marine mammals to hear the sometimes very faint sounds of their prey or predators, mates, and of navigation cues. Faint acoustic cues from distant sound sources may indeed be important for navigation and orientation (*e.g.*, Tyack and Clark 2000). On migration, bowhead whales appear to take evasive action around ice floes well ahead of being able to detect them visually (Ellison *et al.* 1987; George *et al.* 1989).

Noise does not need to be the same frequency as the signal of interest to mask it. At low and very high frequencies, a noise can mask a much wider range of frequencies (Richardson *et al.* 1995). To some degree, marine mammals may be able to overcome the effects of masking, especially of natural noise, by using filtering techniques or directional hearing. However, such techniques could also mean that marine mammals can "pick out" certain noise sources (ones they find alarming, for instance) from background noise and thus be affected by them at levels quieter than background noise. This could extend a noise source's range of potential impact considerably.

The long-term consequences of continuous exposure to increasing background noise levels in the ocean, especially on auditory development in the young, are unknown. Infant rats reared in even moderately elevated levels of background noise showed delays in brain development (Chang and Merzenich 2003).

Noise impacts on calls, behavior, distribution, and stress of marine mammals. Changes in critical marine mammal behaviors in response to noise have repeatedly been documented. For example, pilot, sperm, and killer whales and bottlenose dolphins have shown changes in call rates when exposed to low and mid-frequency noise sources, including sounds from boats (Bowles *et al.* 1994, Buckstaff 2004, Foote *et al.* 2004, Rendell and Gordon 1999). Humpback mating song length increased in response to low frequency sonar, perhaps in an effort to compensate for the interference (Miller *et al.* 2000). Gray whales were displaced for more than five years from one of their breeding lagoons when exposed to industrial sounds, returning only several years after the activities stopped (Jones *et al.* 1994). Killer whales and harbor porpoises moved locations over seasons or years to avoid loud acoustic harassment devices (Morton and Symonds 2002, Olesiuk *et al.* 2002).

Critically endangered western gray whales off Sakhalin Island, Russia, were displaced by seismic surveys from a primary feeding area, and returned only days after seismic activity ceased (IWC 2004). This displacement was statistically significant, occurring only during the six weeks of seismic surveys, compared with the three weeks pre- and three weeks post-seismic conditions (Weller *et al.* 2002). Behavioral reactions, including changes in whale swim speeds, orientations, and breathing patterns, occurred at this same site at received levels of 139 dB. It was hypothesized that such changes could indicate decreased foraging success (ISRP 2005, Weller *et al.* 2002). Two different research teams and data from several years showed beluga whales typically take evasive action to icebreakers at distances from 35-50 km, at the point where they can probably just detect them. They travel up to 80 km from the ship track and generally remain away for one to two days (Finley *et al.* 1990; Cosens and Dueck 1993).

Such responses can vary widely depending on behavioral state. For instance, bowhead whales avoided seismic airgun noise at received levels of 120-130 dB during their fall migration, but at received levels of 158-170 dB (roughly 10,000 times more intense) when feeding in the summer (Richardson *et al.* 1999; Richardson *et al.* 1995). Another study found that humpback cows and calves in key habitat showed avoidance of seismic airguns at 140-143 dB, much lower than migrating gray whales (McCauley *et al.* 2000).

Indications of increased stress and a weakened immune system following noise broadcasts have also been observed in marine mammals (Romano *et al.* 2004). Chronic stress can inhibit the immune system, as well as otherwise compromise the health of animals, which could have repercussions for the health of populations. Particularly in light of recent research, which shows that the stress and change in behavior patterns associated with avoiding predators has as much or more impact on prey populations as actual predation (Luttbeg and Kerby 2005), such sub-lethal impacts may be extremely important. These "frightening" vs. "consuming" effects of predators are even more pronounced in aquatic, compared with terrestrial, systems (Luttbeg and Kerby 2005).

The same may be true for noise impacts. Simply through the stress of behavioral changes induced to avoid noise, animals may be facing population-level impacts analogous to being killed outright by noise.

<u>Cautionary notes on behavioral impacts and stress.</u> The biological significance (*e.g.*, consequences for health, survival, or reproduction) of behavioral responses to noise is difficult to determine. Long-

term studies, however, have more successfully related disturbance reactions to population consequences (Bejder 2005). The approach currently used to predict long-term, cumulative impacts is to study how animals respond to short-term exposures to noise and predict how this may impact the population based on the temporal and spatial scale of the noise.

This approach is flawed as short-term reactions may be minor, yet still produce population-level impacts, as has been demonstrated in dolphins (Bejder 2005) and caribou (Harrington and Veitch 1992). Humpback whales exposed to explosions showed little or no behavioral reaction to the noise (they were not displaced nor did they change their overall movements), yet subsequently displayed an unusual pattern of greater fatal entanglement in fishing gear, possibly due to hearing impairment causing a decreased ability to detect the nets (Todd *et al.* 1996). Had these whales not blundered into nets in an unusual pattern, this serious impact never would have been detected.

Just because marine mammals remain near noise does not mean they are not affected by it. Animals may be strongly motivated to stay in an area in order to feed or mate, even to the point of damaging their hearing. Sea lions will sometimes remain in a prime feeding area in the presence of noise loud enough to harm their hearing (NMFS 1996).

Even when responses to noise are detected in marine mammals, these may not be a reliable indicator of the impact on the population. Indeed, disturbance studies on some species show that the weaker the behavioral response, the more serious the impact on the population. The individuals with lower energy reserves or no alternative habitat cannot afford to flee repeatedly from disturbance but must remain and continue feeding (Gill *et al.* 2001, Stillman and Goss-Custard 2002). Thus, just because animals do not react in an observable or obvious manner does not mean they are not seriously impacted.
When repeatedly exposed to the same type of noise, animals may habituate or "get used to" to that particular noise over time. Unfortunately, unless all individuals are known and tracked, what appears to be habituation may in fact be the most sensitive individuals permanently leaving and the least sensitive staying (Bejder 2005). This is another reason why in-depth long-term studies are needed to clarify the full picture.

<u>*Impacts of Noise on Other Marine Life*</u>
Although public attention has focused on the effects of undersea noise on marine mammals, an increasing amount of scientific research has established impacts on a broad range of marine species throughout the ocean ecosystem, including fish, invertebrates, and sea turtles.

<u>Fish and catch rates.</u> Fish use sound for practically all aspects of their life, including the perception of their environment, mating, communication, and predator avoidance (Popper 2003). Settling reef fish larvae also use sound to orient toward and select reefs (Simpson *et al.* 2005). An accumulating body of evidence establishes the risks to fish and their eggs from exposure to too much noise.

Seismic airguns have been shown to severely damage fish ears, possibly permanently, at distances of 500 m to several kilometers from seismic surveys (McCauley *et al.* 2003). Ears showed no recovery

58 days after exposure to seismic airguns, when the fish were sacrificed. Enger (1981) observed structural damage to the inner ear of cod with intense noise exposure.

Temporary hearing loss (TTS) has been measured in several fish species. Scholik and Yan (2002) found TTS in the fathead minnow after only 2 hrs of exposure to boat noise. Smith *et al.* (2004) showed significant TTS and a short-term stress response in goldfish after only 10 min of noise (160-170 dB). After 21 days of noise exposure, it took the goldfish 14 days to recover their hearing. Goldfish and catfish subjected to white noise (158 dB) for 12 and 24 hrs showed a significant loss in hearing sensitivity, also taking 14 days to recover their hearing in all but one frequency, which did not recover (Amoser and Ladich 2003). Exposure duration had no influence on hearing loss in this case. Masking in cod (Buerkle 1969, Hawkins and Chapman 1975) and goldfish (Fay *et al.* 1978) has also been demonstrated.

Reduced catch rates of 40-80% and fewer fish near seismic surveys have been reported in species such as cod, haddock, rockfish, herring, and blue whiting (Dalen and Knutsen 1987, Engås *et al.* 1996, Løkkeborg 1991, Skalski *et al.* 1992, Slotte *et al.* 2004). These effects can last 5 days or more after exposure, at distances of more than 30 km from a seismic survey and over a monitoring area of 4000 square kilometers. European sea bass exposed to a seismic survey for 6 or 72 hrs showed increases in stress hormones (Santulli *et al.* 1999).

Strong behavioral reactions have been observed in fish due to noise. Day-to-night movements of fish were changed near airguns (Wardle *et al.* 2001). Fish also showed reactions like dropping to deeper depths, becoming motionless, becoming more active, or forming a compact school (Dalen and Knutsen 1987, McCauley *et al.* 2000, Pearson *et al.* 1992, Santulli *et al.* 1999; Skalski *et al.* 1992, Slotte *et al.* 2004). Brown trout, whiting, and bass subjected to low-frequency tones below 180 dB in a pool showed ruptured swim bladders and hemorrhaged eyes, and mortality rates of up to 60% in some cases, 24 hrs after sound exposure (Turnpenny *et al.* 1994).

Noise can also be lethal to embryonic fish. In two estuarine fish species raised in tanks, the viability of eggs and the resulting larvae, as well as growth rate, was significantly reduced in noisy compared to quiet tanks (Banner and Hyatt 1973), and several studies have demonstrated significant mortality in eggs, larvae, and fry exposed to airgun noise (*e.g.*, Booman *et al.* 1996, Dalen and Knutsen 1987, Kostyuchenko 1973).

<u>Invertebrates.</u> Nine giant squid mass stranded, some of them live, coincident with geophysical surveys in 2001 and 2003 in Spain (Guerra *et al.* 2004). The squid all had internal injuries, some of them massive.

A peer-reviewed study of snow crabs under seismic noise conditions showed bruised organs and abnormal ovaries, along with hemorrhaging, leg loss, delayed embryo development, smaller larvae, sediments in their gills and other structures, and changes consistent with a stress response, as compared with control animals (DFO 2004). Sound exposure in tanks may cause physiological changes in brown shrimp that increase mortality and reduce reproduction. A modest increase in continuous background noise caused an increase in metabolic rate leading to significant reduction in growth and reproduction over three months (Lagardère 1982, Régnault and Lagardère 1983).

Sea turtles. Captive loggerhead and green sea turtles have been observed to start swimming in response to sound exposure (Bartol *et al.* 1999, Lenhardt 1994, O'Hara and Wilcox 1990). Loggerheads exposed to low-frequency sound responded by swimming towards the surface at the onset (Lenhardt 1994). Sea turtles increased their swimming in response to an approaching airgun at received levels of approximately 166 dB and showed an avoidance response at 175 dB (McCauley *et al.* 2000).

Management and Mitigation of Ocean Noise

The nation's leading instrument for the conservation of whales, dolphins, porpoises, and other marine mammal species is the Marine Mammal Protection Act (MMPA). All noise-producing activities within U.S. waters, and those conducted by U.S. citizens and vessels on the high seas, fall within the MMPA's scope, but for various reasons some noise producers have not sought authorizations from the wildlife agencies for their noise production. Activities that remain unregulated or only partly regulated include commercial shipping, recreational boating, whale watching (*e.g.*, powerboats), certain aquaculture activities (*e.g.*, acoustic alarms and powerboats), ice breaking, certain over-flying aircraft (*e.g.*, commercial airliners), terrestrial vehicle traffic, some oil and gas exploration and production activities, and certain military and research activities. In general, more work is needed to meaningfully apply the MMPA to the problem of ocean noise.

Several efforts have been made in the past to establish particular noise levels that would trigger management action. Prior to 1994, NMFS used a "120 dB criterion" as a level above which potentially harmful acoustic effects may occur. This level was based on two series of field studies (Ljungblad *et al.* 1988; Malme *et al.* 1983, 1984; Richardson and Malme 1993; Richardson *et al.* 1985, 1986, 1990), which determined that gray and bowhead whales showed consistent avoidance of continuous industrial noise at *average* received levels of 120 dB. Since this degree of consistency between species and field studies is very rare in marine mammal science, the 120 dB criterion was deemed reliable at the time. Since then, allowable noise levels have increased, in some cases to around 180 dB, based on very limited data from a few individuals of a few species, even as research on other impacts and other species suggests caution.

Meanwhile, Congress has amended the MMPA's definition of harassment, which establishes the baseline for regulatory concern, for military readiness and some research activities. To meet the new threshold, an activity would have to disrupt marine mammal behavioral patterns, such as breeding or nursing, to the point where they are "abandoned or significantly altered." Although the new language may seem innocuous, it poses serious problems for regulation. In many cases, the term "significantly altered" has not been scientifically defined, and some projects could evade the Act's requirements by relying on its inherent uncertainty. When a panel of researchers floated similar language a few years earlier, the Marine Mammal Commission testified that it would threaten "the precautionary burden of proof that has been the hallmark of the Marine Mammal Protection Act since its inception in 1972."[8] Ironically, a change in the definition was not needed: for almost five years, the wildlife agencies have been applying a standard that explicitly excludes *de minimus* changes in behavior[9]—the rationale that was used to justify the change.

Due to the inherent uncertainties associated with acoustic impacts on marine mammals, and the potential for harm to occur before it is detected, the noise issue has been highlighted for the application of precaution in management (*e.g.*, Mayer and Simmonds 1996). As a rule, environmental science rarely gives conclusive evidence of causality, particularly within the timeframes where irreversible population and ecosystem-level effects may occur (Ludwig *et al.* 1993). This is certainly the case for marine mammals, given the threatened status of many species and the exceptional difficulty of measuring the impacts of human activities on marine mammal populations in the wild (*e.g.*, Thompson and Mayer 1996). While additional research to understand and reduce the impacts of ocean noise is important, it may not give us answers for decades. Precautionary mitigation is needed in the meantime.

Best Practices for Mitigating or Preventing Noise Impacts on Marine Mammals

A variety of tools are available that can reduce the exposure of marine mammals to harmful noise. These tools may be broken down into three major categories: operational procedures; temporal, seasonal and geographic restrictions; and removal or modification of the sound source. Mitigation tools are often used in combination and are not mutually exclusive.

Unfortunately, the mitigation measures most commonly prescribed in the United States are extremely limited. The use of "safety zones," for example, requires a crew to scan for whales and other species near the source and to temporarily shut down or reduce power if animals are spotted within a prescribed distance. Safety zones do help reduce some species' risk of exposure to the highest levels of sound, but are hampered by consistently low detection rates in monitoring particularly for some species and under conditions of poor visibility (high winds, night, fog, etc.). For deep-diving beaked whales, visual detection by marine mammal observers is ineffective, with an average detection rate of 1-2% of animals under typical mitigation survey conditions (Barlow and Gisiner, in press). Furthermore, the small, one- or two-kilometer disc around the sound source that constitutes the typical safety zone does little for marine mammals at the population level, which is generally much more important.

Research is needed to improve or evaluate various mitigation tools (Moscrop and Swift 1999), but several methods are available now that should be used immediately to curb the effects of anthropogenic underwater noise on marine mammals and their habitats. Given the uncertainty in determining how noise impacts marine mammals, reducing overall noise levels (the "acoustic footprint") in the marine environment should be a high priority.

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[8] House Resources Committee, Subcommittee on Fisheries Conservation, Wildlife and Oceans, Oversight Hearing on the Marine Mammal Protection Act, 107th Cong., 1st Sess. 277-78 (Oct. 11, 2001).

[9] *E.g.*, 67 Fed. Reg. 46712, 46762-63 (July 16, 2002) (Final Rule for SURTASS LFA system).

Seasonal and geographic exclusions. Geographic areas or regions that are biologically important for marine mammals (i.e., breeding, feeding, and calving grounds and migratory habitats) should be placed off-limits to noise-producing activities on a seasonal or year-round basis. This tool is likely to be highly effective, and the last few years have seen it applied internationally. In November 2004, for example, Spanish authorities reacted to a series of whale mortalities in the Canary Islands by announcing a moratorium on the military use of active sonar in waters around the islands of Lanzarote and Fuerteventura out to a distance of 50 km.[10] Meanwhile, the Marine Mammal Protection Zone in the Great Australian Bight has been placed off limits to oil and gas exploration and, seasonally, to vessel traffic (Australia 2005).

Designating and enforcing marine reserves can be an extremely effective tool for protecting marine mammals and other marine life from noise-producing activities. Similar to wildlife refuges on land, commercial activity, such as oil and gas exploration and extraction and other habitat-altering activities, is off-limits in marine reserves. In 2004, the Scientific Committee of the International Whaling Commission recommended that ocean zoning and similar tools be investigated as a means to protect marine mammals from anthropogenic noise (IWC 2004). Requiring ship to route away from biologically important marine mammal habitats is another method for reducing sound levels, and this mitigation has the added benefit of reducing the risk of ship collisions with large whales.

Source Modification. Lowering noise levels or removing them altogether are possible options through engineering modification of the sound source and the use of alternative technologies.

- The ocean fleet of the future can and should be a greener one with the design and construction of quieter commercial ships. For instance, propellers can be designed to limit cavitation, the collapse of tiny air bubbles that is the source of much shipping noise; hulls can be designed to absorb mechanical energy by positioning hull equipment on sound absorbing mounts; and much of the mechanical noise from ships can be minimized by good engine maintenance (NMFS 2005). All of the above alterations would generally increase efficiency, decrease fuel usage, and reduce engine repairs at the same time, while providing quieter, more comfortable living conditions for humans onboard. Much of this technology has already been developed for military and research applications.

- A number of engineering solutions have been proposed for high-energy seismic surveys used by the oil-and-gas industry. As an alternative to airguns, the current standard for offshore exploration, a quieter marine vibrator has been developed with significantly less energy above 100 Hz (Deffenbauch 2002). Other alternatives that have been proposed include a mobile sea floor source with trawled surface receivers; and a highly sensitive optical fiber hydrophone, which has already been developed by Australian scientists. In addition, the British government and others have called for the development of “suppressor” devices to reduce an airgun’s higher frequency output, a by-product that serves no commercial purpose.

[10] Resolución 79/2004, 102 Boletín Oficial del Estado 16643-45; Statement of Bono Martinez, Senior Defense Minister of Spain (statement made to the Spanish Parliament on 3 Nov. 2004).

- Efforts are being made to modify military sonar systems for detecting enemy submarines in near shore waters. The Dutch and Norwegian navies are currently experimenting with techniques to modify the characteristics of some of their active sonars, to identify an alternative that would prove less harmful to beaked whales (Lok 2004). In the United States, an expert panel commissioned by the Office of Naval Research advised the Navy to explore the use of complex waveforms that would retain Doppler sensitivity but produce lower peak amplitudes (Levine 2004). It is our understanding that a number of engineering solutions are currently being explored, at least by third-party firms.

Government and private investment in research and development of promising quieting technologies like these is essential if progress is to be made in preventing acoustic impacts on marine species.

Reduction in Noise-Producing Activities. Some reduction in activity might be achieved by increasing efficiency. Examples include avoiding duplication of seismic surveys by having companies share data or employ a common surveyor; by maximizing the coverage of seismic survey lines to reduce the number of passes; by using simulators in naval exercises; and by attempting to fill every cargo ship to capacity for every journey to reduce the number of trips.

Monitoring. Monitoring and reporting are integral parts of management in that it helps determine the effectiveness of management actions. Monitoring of marine mammals can be done before, during, and after noise activity to determine the impact of the noise. However, such research will be of limited usefulness unless there is a good prior baseline of previously well-studied animals with which to compare. In general, it is necessary to improve marine mammal monitoring both to facilitate the use of tools such as “safety zones” and geographical exclusions and to increase the level of detection of strandings, mortalities at sea, and fish kills associated with noise-producing activities.

One particularly promising technology is *Passive Acoustic Monitoring (PAM)*. PAM uses hydrophones or remote autonomous recording devices (ARDs) to listen for sounds made by whales and dolphins and to identify, track, and survey species within a defined area of the ocean. While not a mitigation tool in and of itself, it can be an effective method for detecting the presence of marine mammals within an area that may be impacted by noise (JNCC 2004). Detection may consequently trigger safety zones, seasonal restrictions, or other mitigation requirements. One of the most promising uses of PAM is to monitor noise levels within marine mammal habitats by setting up autonomous recording devices to monitor noise levels continuously. Such networks can provide important management information over time about the presence and distribution of marine mammals, about the sources and levels of man-made noise occurring in important marine habitats, and about how such noise impacts marine mammals (*e.g.*, affects their vocalizations).

International Approaches to Managing Ocean Noise

By its very nature, ocean noise transcends political boundaries. Intense noise can propagate across entire ocean basins (*e.g.*, Bowles *et al.* 1994), relying on the efficiency of water as a conductor of sound, and some marine mammals and other species migrate over many hundreds of miles. For these reasons, international institutions have begun to recognize that noise is a form of pollution requiring international regulation.

The 1982 United Nations Convention on the Law of the Sea (UNCLOS) defines "pollution" to include harmful "energy" and, thus, consistent with the general rule of treaty interpretation set forth in the Vienna Convention on the Law of Treaties, would be interpreted to encompass underwater sound within its mandates.[11] This definition is significant because UNCLOS provides the international legal framework for nearly all ocean uses and its definition of marine pollution has been incorporated into instruments governing a number of other global and regional institutions. Here, we summarize relevant statements and actions by some of the international bodies currently addressing ocean noise as a threat to marine ecosystems.

Agreement on the Conservation of Cetaceans of the Black and Mediterranean Sea and Atlantic Contiguous Area (ACCOBAMS). ACCOBAMS is a regional agreement established under the auspices of the 1979 Convention on the Conservation of Migratory Species of Wild Animals (CMS, also known as the Bonn Convention). The Parties to the agreement have urged, among other things, that the use of anthropogenic sound be avoided in marine mammal habitat, and that any use of anthropogenic sound in or near areas believed to be the habitat of Cuvier's beaked whales be undertaken only with special caution and transparency.[12]

Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS). ASCOBANS is a regional agreement that aims to promote cooperation among the Parties for the protection of all odontocete species (except the sperm whale) in the agreement area. ASCOBANS has begun to address undersea noise pollution in its Conservation and Management Plan, which is annexed to the Agreement. This Annex sets forth mandatory conservation measures to be applied to cetaceans, including "the prevention of . . . significant disturbance, especially of an acoustic nature."[13] In 2003, the Parties of ASCOBANS passed a resolution requesting parties to take steps to reduce the impact of noise on cetaceans from seismic surveys, military activities, shipping vessels, acoustic harassment devices and other acoustic disturbances.[14]

Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR). The 1992 OSPAR Convention is the current instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic. The OSPAR Commission has recognized "noise disturbance" as among the potentially harmful effects of human activities for

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[11] Vienna Convention on the Law of Treaties, May 23, 1969, Art. 31, 1155 U.N.T.S. 311; see H.M. Dotinga and A.G. Oude Elferink, Acoustic Pollution in the Oceans: The Search for Legal Standards, 31 Ocean Development and International Law 151, 158 (2000). The group that initially drafted the definition added the term "energy" apparently to ensure that thermal pollution would be included; however, under the Vienna Convention, such drafting material is considered a "supplementary" means of interpretation, of recourse only where the general rule leaves a provision ambiguous or obscure or leads to a result that is manifestly unreasonable or absurd.

[12] ACCOBAMS, *Assessment and Impact Assessment of Man-Made Noise*, ACCOBAMS Res. 2.16 (2004).

[13] Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas of 17 Mar. 1992 (entered into force 29 Mar. 1994), Annex, para. 1(d).

[14] ASCOBANS, *Effects of Noise and of Vessels*, ASCOBANS Res. 4.5 (2003).

several species of whale and has noted the need to further assess pollution from undersea noise "raised by offshore activities."[15]

European Parliament: In 2004, the European Parliament passed a resolution that called, *inter alia*, (1) for the European Union and its Member States to adopt a moratorium on the deployment of high-intensity active naval sonars until a global assessment of their cumulative environmental impact has been completed; (2) on the Member States to immediately restrict the use of high-intensity active naval sonars in waters falling under their jurisdiction; and (3) for the European Commission and the Member States to set up a multinational task force to develop international agreements regulating sound levels in the world's oceans, with the goal of limiting the adverse impact of anthropogenic sound on marine mammals and fish.[16]

International Maritime Organization (IMO). The IMO administers the International Convention for the Prevention of Pollution from Ships of 1973, as amended by Protocol of 1978 (MARPOL), and has recognized noise as a hazard to the marine environment. Although measures limiting sound emissions from ships could not be adopted under MARPOL as currently written, the IMO has nonetheless listed shipping noise as an appropriate target of the "particularly sensitive sea areas" that it helps designate.[17]

International Whaling Commission (IWC). The IWC is an intergovernmental organization established in 1946 under the International Convention for the Regulation of Whaling (ICRW). In 2004, the IWC Scientific Committee held a symposium on the impact of anthropogenic noise on cetacean populations, concluding that "[t]here [is] now compelling evidence implicating anthropogenic sound as a potential threat to marine mammals. This threat is manifested at both regional and ocean-scale levels that could impact populations of animals" (IWC 2004). Based on this review, the Scientific Committee recommended integrating and coordinating international research projects to study and describe acoustic impacts; including anthropogenic noise assessments and noise exposure standards within the framework of both national and international ocean conservation plans; supporting multinational programs to monitor ocean noise; and developing basin, regional and local-scale noise budgets (IWC 2004).

IUCN-World Conservation Union (IUCN). Founded in 1948, the IUCN is a non-governmental organization made up of about 1000 members from some 140 countries, including 77 States, 114 government agencies, and more than 800 NGOs. It has recognized that anthropogenic ocean noise is a form of pollution (comprised of energy) that may have adverse effects on the marine ecosystem and has requested that the reduction of anthropogenic ocean noise around the world be promoted, that governments work through the U.N. "to develop mechanisms for the control of undersea

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[15] OSPAR Commission, Case Reports for the Initial List of Threatened and/or Declining Species and Habitats in the OSPAR Maritime Area at 91 (2004); OSPAR Commission*, Guidelines for the Management of Marine Protected Areas in the OSPAR Maritime Area*, OSPAR Doc. 2003-18 (2003), Table 2.

[16] European Parliament, *European Parliament Resolution on the Environmental Effects of High-Intensity Active Naval Sonars*, E.P. Res. B6-0018/2004 (October 21, 2004), para. 2.

[17] IMO, Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas, Res. A.927(22), para. 2.2 and Res. A.720(17), Annex, para. 1.2.2 and 1.2.11.

noise," and that support for, and conduct and application of, further research on the effects and mitigation of anthropogenic noise on marine species at the highest standards of science and public credibility be encouraged.[18]

The Role of Research

To date, acoustics research has focused primarily on understanding the effects of undersea noise on marine mammals. While such research is undoubtedly worthwhile, it will be difficult to gain even moderately complete or full insight into such impacts within the foreseeable future. Moreover, despite results from past research that indicate marine mammals are being negatively impacted by noise exposure, greater protection has not in fact been afforded to these species. Given what is at stake for marine animals, it is vital that any large-scale research program on undersea noise commit a substantial portion of its budget, at the outset, to developing and improving the mitigation tools discussed in this statement.

Among the priorities for research:

1. Research should be directed toward mitigation and the development of more effective mitigation tools, such as improving Passive Acoustic Monitoring, or engineering modifications or alternatives to make noise sources safer for marine mammals (*e.g.*, quieter, shorter duration, more directional, eliminating unnecessary frequencies).
2. Baseline research to determine where the greatest concentrations of marine mammals and indeed, marine life, occur in the oceans is vital in order to protect these areas to the greatest degree possible. Conversely, areas that represent "deserts" for marine life and could be suitable for some noise-producing activities should be identified.
3. More and better retrospective analyses of past stranding data should be conducted, using suitable controls. To do this most effectively, noise events worldwide, including naval maneuvers, should be disclosed and documented. Stranding networks should be improved worldwide, and data consolidated, while stranding protocols to better detect acoustic injuries should be established.
4. Long-term, systematic observations of known individual marine mammals in the wild provide the most in-depth information on population-level impacts. Individuals should be studied in different noise conditions using ongoing noise-producing activities so as to gain insight into the impacts of noise on marine mammals in a less invasive way without adding more noise to the environment.
5. Research is needed on ecological effects, both on prey species and on marine mammal population dynamics. The cumulative and synergistic effects of noise, together with other environmental stressors (IWC 2004), should be examined.
6. Stress hormones (*e.g.*, in feces) should be studied from marine mammals in noisy and quiet areas.
7. Hearing in more easily studied marine mammals, such as pinnipeds, should be examined in high-noise areas compared with suitable controls.

[18] IUCN, *Undersea Noise Pollution*, World Conservation Congress Res. 3-053 (2004).

It is important to recognize that noise is one of several serious threats currently facing marine mammals, and resources to ameliorate it must not take away from those allocated to deal with other threats as well. Accomplishing any meaningful research on ocean noise further requires that we address two significant issues: conflict of interest and animal welfare ethics.

Conflicts of Interest in Marine Mammal Research

Conflicts of interest are "a set of conditions in which professional judgment concerning a primary interest (such as a patient's welfare or the validity of research) tends to be unduly influenced by a secondary interest (such as financial gain)" (Thompson 1993). This problem arises in the present context because of the overwhelming funding dominance of the U.S. Navy, sponsoring 70% of all marine mammal noise research in the U.S. and 50% of all such research worldwide (Navy 2004a). This funding percentage has grown dramatically since the 1980's, when Defense Department (mainly Navy) funding for all marine mammal research was around 5-20% in the United States (Waring 1994). As a National Research Council panel on ocean noise (NRC 2000) observed, "Sponsors of research need to be aware that studies funded and led by one special interest are vulnerable to concerns about conflict of interest. For example, research on the effects of smoking funded by [the U.S. National Institute of Health] is likely to be perceived to be more objective than research conducted by the tobacco industry."

The constant pressure researchers experience to secure funding to support their work produces significant financial conflicts of interest, as many researchers would not want to offend or risk losing funding sources by publishing results adverse to the interests of those sources. The importance of Navy funding has resulted in scientists being reluctant to speak out against U.S. Navy activities for fear that it could affect their future research funding (Whitehead and Weilgart 1995). Indeed, there is evidence the U.S. Navy considered that Navy-funded scientists had obligations to the Navy in their public comments on controversial noise-related conservation issues (Dalton 2006, Weilgart *et al.* 2005). Maintaining confidence in ocean noise research, both inside and outside the scientific community, is vital to its future support.

Some believe that ethical guidelines would solve the conflict of interest problem, but changing the funding structure of marine mammal science will be more effective at safeguarding the credibility of the field. The more independent research on noise impacts is from its sponsors (including non-governmental advocacy organizations), the more credible it will be with all stakeholders. An independent fund, with contributions from all potential sources, could be administered by an independent committee that meaningfully represents all major stakeholders and has the authority to establish priorities for the research, commission it, and recommend regulations. Secondarily, funding diversification can help reduce conflicts of interest between funding organizations and marine mammal researchers.

One model for achieving funding diversification and independence is the National Whale Conservation Fund administered by the National Fish and Wildlife Foundation (NFWF). Through legislation, a targeted fund could be established at NFWF for research into noise impacts on marine mammals and other species, and into the mitigation and management of these effects. NFWF has the advantage of providing a mechanism for accepting government and private funds as well as maximizing the independence of funding decisions from noise producing sponsors. Research proposals would be sought and grants for research and education would be disbursed through a competitive program. The grant process would be administered in cooperation with a council of advisors that could include representatives of the Department of Commerce, the Marine Mammal Commission, sound producers, non-governmental conservation or wildlife protection organizations, and the scientific community.

Advisory Boards and expert panels can perform formal peer reviews of scientific results, but they must include meaningful stakeholder participation to be effective in increasing funding transparency and independence. Panels should provide fair and balanced appointments, public participation, disclosure of potential conflicts of interest, and transparency of process.
The wildlife agencies also must be vigilant to avoid bias and political interference, as a 2005 survey of agency staff indicated (UCS 2005).

Animal Welfare Ethics
Controlled exposure experiments (CEEs) involve the use of controlled doses of noise directed at animals in the wild for the purposes of assessing their behavioral or physiological responses. Because CEEs purposely expose marine mammals to noise without knowing which levels cause harm, pain, stress, or even death, they raise ethical considerations and are controversial. Also, they unintentionally expose many more animals and species than can be observed and studied.

While it is desirable that all scientific experiments be well-designed, this is especially true for experiments that can place animals at risk, such as CEEs. The standards for such research must be higher than for more benign research, and experiments must be designed with the greatest power to detect real effects and provide convincing results. In this regard, it is important that the limitations of such research be clearly acknowledged. For example, there are currently insufficient baseline data to quantify the effects of sound exposure. To determine long-term effects, long-term research is required, yet it is difficult and impractical to carry out a controlled experiment over larger scales of space (tens of kilometers) and time (many months). It is also difficult to find controls that mimic the experimental setting in all respects, except for the addition of sound, and to eliminate confounding factors such as location, season, and oceanographic conditions. For these and other reasons, the interpretation of the results of CEEs may be open to question and their value may be limited. Alternatives to CEEs include systematic observations of animals in different noise conditions using ongoing sound-producing activities.
One way to rapidly test hearing is to measure the *auditory brainstem response (ABR)* of animals by monitoring brainwave patterns from the skin surface. Some researchers are interested in testing live stranded wild marine mammals, in order to establish basic audiograms for the many species for which data are lacking, but as stranded animals are under great stress, this new technique raises ethical questions.

Some of the organizations co-authoring this statement do not endorse the use of CEEs or ABRs as a matter of policy, but recognize that such experiments are likely to go forward. Precautionary guidelines should be developed for both research approaches. Such guidelines should ensure the protection of wildlife, guarantee the utility of CEEs for conservation, and reduce exposures to the minimum needed to achieve results.

Conclusion

Undersea noise is a serious threat, although it is not possible to ascertain the scope of the problem at this time. Because of the limitations of marine mammal science, precaution is called for in the regulation of noise to adequately protect marine mammals. Immediate and effective mitigation measures, such as geographic exclusion zones, must be implemented to distance marine mammals from noise sources. Efforts must be made to reduce the "acoustic footprint" of human activities in general.

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Report of the

Energy Producers Caucus

Statement for

The Report of the Federal Advisory Committee on Acoustic Impacts on Marine Mammals

to the

Marine Mammal Commission

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

INTRODUCTION

In 2003 Congress directed the Marine Mammal Commission (MMC) to examine acoustic "threats" to marine mammals, and develop means of reducing those threats while "maintaining the oceans as a global highway of international commerce."

The MMC formed a 28-member Advisory Committee on Acoustic Impacts on Marine Mammals (Advisory Committee). The Committee comprises representatives of state and federal agencies involved with natural resource management (9 members) and with national defense (2); private and public marine research organizations (7); commercial sound producers (4); and environmental non-governmental organizations (NGOs) (6).

This report is submitted to the Marine Mammal Commission by the Energy Producers Caucus of the Advisory Committee. This caucus comprises three members: G. C. Gill, President of the International Association of Geophysical Contractors; James P. Ray, Ph.D.,[2] President of Oceanic Environmental Solutions, LLC; and Bruce A. Tackett, Manager of Legislative and Regulatory Issues for ExxonMobil Biomedical Sciences, Inc. The Energy Producers Caucus represents entities involved in exploration for and production of offshore oil and natural gas.

This document describes the opinions and concerns of the Energy Producers Caucus on the issues presented to the Federal Advisory Committee. Although a final consensus report (100% agreement) among all 28 members of the Advisory Committee could not be reached, it is important to note:

The Energy Producers Caucus supports the reports submitted by the Federal Representatives Caucus and the Scientific Research Caucus.

Given the broad scope of the reports submitted by the above-mentioned caucuses, and given that the Federal Advisory Committee Report will be prepared and submitted by the Marine Mammal Commission, the Energy Producers Caucus statement will focus on energy industry issues, and will identify those areas in particular where we wish to provide context, clarity or emphasis of our support for the recommendations of the aforementioned caucuses, or where we might have differing opinions. It is important to note that there is significant agreement among the positions and recommendations of the Energy Producers Caucus, the Federal Representatives Caucus, and the Scientific Research Caucus.

More than 23% of oil and 30% of natural gas produced in the United States comes from energy resources located beneath the ocean floor. The impact of supply disruptions, such as caused by the recent hurricanes, Katrina and Rita, on Gulf of Mexico production, and the resulting impact on U.S. fuel supply and prices, were a sharp reminder of the importance of U.S. offshore oil and natural gas supplies. It also made clear that the U.S. needs to develop offshore oil and natural gas resources in areas beyond the Gulf of Mexico. As worldwide energy demand continues to increase, it is vital to U.S. economic, energy security, and

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national defense interests that our offshore areas continue to play their vital role in meeting this nation's growing energy needs.
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A significant percentage of known offshore resources is depleted through production each year. Our dependence on foreign oil presents economic and national security risks. These energy-related risks can be reduced through conservation, switching to non-oil energy sources, and increasing production here in America. New resources must be discovered every year to replace those being depleted through consumption.

Offshore oil and natural gas exploration requires the use of seismic surveys, which use compressed air to create sound waves (acoustic energy) that when reflected back to the surface can be analyzed by computers and used to assist in defining geologic structures beneath the ocean floor. Seismic surveys are temporary and localized in nature. In conducting seismic surveys, airgun arrays create impulsive sounds of ultra-short duration. These sounds are directed downward, and have very low frequency. In fact, more than 90% of acoustic energy created by today's airguns is below 300 Hz. Seismic information is used by geologists and geophysicists to assess the location and size of potential oil and natural gas deposits, which often lay several miles beneath the ocean floor. This approach bolsters the efficiency of exploration by increasing the probability of finding commercial quantities of oil or natural gas. There is no currently available practical replacement technology.

Seismic surveys are short term events that provide important environmental benefits. First, they reveal which areas are *not* worthy prospects. Second, they reduce the number of wells required to locate and precisely delineate oil and natural gas resources. And third, they reduce the number of wells required to produce the resources that are discovered. Fewer wells means less environmental impact

Analysis of seismic data also improves efficiency of offshore production operations by helping engineers and geologists determine ways to maximize production from existing wells. Without the use of seismic surveys, it would not be possible to develop this nation's extensive offshore oil and natural gas resources. These resources keep our economy going strong, create jobs and help reduce dependence on foreign energy. Oil and natural gas production in America enhances our energy security and is vital to our national defense.

OCEAN SOUNDS AND MARINE MAMMALS

Throughout history, the Earth's oceans have served mankind in many important ways. Oceans are a major source of food. They are the world's primary venue for commercial trade transportation, with more than 90% of global trade being sea-borne. As noted above, much of our oil and natural gas comes from beneath the sea floor. In addition, oceans provide recreation for swimming, surfing, boating, sport fishing, ocean cruises, whale watching and sightseeing. Finally, oceans are a critical component of national defense.

Among the oceans' inhabitants are marine mammals. These animals include whales, dolphins and porpoises (collectively known as cetaceans); seals, sea lions and walruses (collectively known as pinnipeds); and sea otters, manatees, sea cows and polar bears.

Marine mammals use sound for a variety of important functions, which can include navigation, location of prey, avoidance of danger, and communication. But all marine mammals do not hear all ocean sounds. Just as our family dogs hear sounds (such as a high-frequency dog whistle) that humans and some other mammals do not, not all whales hear the same sounds. Hearing sensitivity in whales varies by species and within species. That is why sound produced by sonar signals may affect, for example, beaked whales in some unique circumstances, but not other whales. Thus, all sounds occurring in oceans are not heard by all marine mammals. More important, all sounds heard by marine mammals do not necessarily pose risks to those animals. As a result, generalized statements of concern over increases in ambient (not frequency-specific) sound misconstrue and overstate the risks associated with "sound."

There is both natural and human-generated (anthropogenic) sound in the ocean. The incidence of anthropogenic sound has increased since the start of the industrial revolution in the mid-19th century. Common sources of anthropogenic sound at sea include commercial and recreation vessels, sonar operations, seismic surveys (e.g., oil and gas, academic research, etc.), dredging and coastal construction. Natural sound sources include earthquakes, waves, wind, rainfall, cracking ice, underwater volcanoes, and vocalizations and other sounds made by fish, invertebrates, and marine mammals. The volume of underwater sound – whether natural or anthropogenic – ranges from subtle to loud. Oceans are noisy places without humans.

GROWING BODY OF RESEARCH

While there remains a need for additional research on marine mammals and how anthropogenic sound may affect them, there is much known today that was not well understood a decade or more ago. Extensive research has been completed during the past several years, and the information summarized in the Federal Research Caucus Report and the Scientific Research Caucus Report is indicative of the breadth and depth of these research findings.

None of the growing body of scientific research has identified circumstances in which human-generated sound – including seismic – has adversely affected marine mammals at the population level. Consequently, based on all of the available scientific information, it appears to be indisputable that there is not a "crisis" involving marine mammals and anthropogenic sound.

Since 1994, the National Research Council (NRC) has conducted four detailed reviews that have examined varying facets of how anthropogenic sound may affect marine mammals. These NRC studies represent the most thorough and accurate summaries of the state of knowledge and understanding of the issue of marine mammals and anthropogenic sound. (Note: The terms *noise* and *sound* are not synonymous, and the NRC reports use both terms. Sound is an all-encompassing term referring to any acoustic energy. Noise is a subset of sound, referring to sound unwanted by the entity that hears it. The opposite of noise is a signal: a sound containing useful or desired information. Thus, any individual sound may be a signal to some and noise to others. Throughout this document we use the neutral term *sound*.)

For more than a quarter-century, the energy industry has been a leader in sponsoring and conducting research in the field of anthropogenic sound and its potential effects on marine mammals. This industry effort is being significantly expanded with plans for a 3-5 year global research program with a budget projected in excess of $20 million, and commencing in 2006. The energy industry is expanding its research effort because it recognizes that while much has been learned about marine mammals and anthropogenic sound, some gaps remain in our knowledge base. In addition to this new effort, there are numerous individual company projects underway, or planned for the near future. Hence, the Energy Producers Caucus strongly supports the need for additional scientific investigation on marine sound and associated effects on marine mammals, at both the individual and population level.

The weight of the evidence from peer reviewed research completed to date argues strongly against any need for immediate or emergency action to limit or otherwise control anthropogenic sound in oceans. The reality is that the existing science does not lead to a conclusion that human-generated sound has – or is – adversely affecting marine mammals at the population level. Indeed, there is evidence of marine mammal populations *increasing* significantly in some locations where anthropogenic sound levels have also increased. For example, the population of eastern gray whales migrating along the California coast has increased so dramatically that the species has been removed from the U.S. Government's Endangered Species List. This population increase occurred during a time when anthropogenic sound along the California coast also increased significantly. We observed that some seek to oversimplify the sound issue and use a handful of stranding reports for which no causative factors have been conclusively identified as the basis to jump to a conclusion of significant global harm. We believe that this is counterproductive to serious work and inquiry into the issue by marine mammal scientists who focus on science rather than advocacy.

With respect specifically to seismic surveys, there are no scientifically-valid data indicating that seismic activity results in either: 1) physical injury to marine mammals; or 2) adverse impacts upon the viability and reproduction of marine mammal populations.

KEY AREAS OF SIMILAR VIEWS

During the nearly two years of work by the Advisory Committee, it became clear that there were many areas and issues where there were similar views. Due to the complexity of the issues and diversity of views, and because the Advisory Committee defined consensus as requiring 100% agreement, it proved impossible to achieve full agreement on language. Upon review of the Federal Caucus and the Scientific Research Caucus reports, we believe that there is noteworthy similarity of views in many areas. Based on this assessment, we have endorsed those two caucus reports. The readers of this report should refer to the specific caucus reports, or individual submittals, for the specific views of those other caucuses. The views of the Energy Producers Caucus are as follows:

1. The absence of any "environmental crisis" relating to anthropogenic sound and marine mammals; and the need for public policy decisions to weigh known anthropogenic threats to marine mammals (e.g., fishing by-catch) when considering how best to reduce man's threats to these animals;
2. The need for additional science-based research;

3. The need to focus on mitigating adverse effects at the *population* level (e.g., focusing mitigation on key factors such as adult survival and reproduction), although subpopulation or individual factors should not be ignored;
4. The need to rely on risk assessment as the key tool in evaluating when, where and how mitigation measures may be appropriate and best applied; and
5. The need to employ a "balanced protective approach" in managing competing interests and mitigating anthropogenic sound.

KEY AREAS OF DISAGREEMENT

During the Advisory Committee's many meetings, a range of viewpoints was expressed on a variety of issues. On many of these issues there were differing opinions from the different members and caucuses. The following represent the views and issues of key importance to the Energy Producers Caucus. They will serve as a focal point for comparison with the positions of other members and/or caucuses of the FACA committee.

1. Context of potential threat

While it is not unreasonable to speculate that anthropogenic sound in oceans could pose a potential threat to certain marine mammals in certain circumstances, such potential risk should be evaluated against other factors. For example, *fishing by-catch* (marine mammals becoming entangled in nets and related fishing equipment) represents a far more serious threat to marine mammal populations than does anthropogenic sound. In fact, by-catch is estimated by researchers and environmental NGOs to cause the deaths of somewhere between 300,000 to 500,000 marine mammals annually[3]. These numbers are several orders of magnitude greater than any science-based estimate of potential threats caused by anthropogenic sound. With respect to marine mammals and anthropogenic sound, any notion that "the sky is falling" (no matter how strongly such a view is advocated) is scientifically unsupportable.

2. Current state of knowledge

Much research has been completed during the past several years, including four scientifically rigorous reviews conducted in 1994, 2002, 2003 and 2005 by the National Research Council. These studies have not been able to conclude that there is any connection between anthropogenic sound and population level effects. More science-based research is needed before mitigation measures which would limit access to vital oil and natural gas resources are considered.

3. Integrity of research

Significant measures are in place to manage bias and the perception of bias through existing legal and ethical requirements for preserving research integrity. Single-entity funding for mission-critical research is fundamental to the operations of many anthropogenic sound producers, and the peer review process, along with advisory boards and expert panels, helps ensure research integrity. It is recognized that mission-specific research is important, and has its place in marine mammal research. It is highly desirable to have diversity in the

[3] These data are not yet published in the peer reviewed literature. But the estimates developed by federal agencies, environmental NGOs (e.g., World Wildlife Fund), and the International Whaling Commission all are consistent with the estimates quoted above.

sources of research funding. Diversity of funding sources brings broader expertise to bear, different perspectives, and helps leverage the costs of expensive programs. It also helps decrease the concern over sponsor-based bias in research programs. The best way to ensure that research is not manipulated is to strongly encourage research from a variety of perspectives and interests, *not* to restrict the volume of research. A long-held principle of the scientific method is the need for competition of ideas and testing of hypotheses. Those who seek to limit research would be better served to undertake research themselves and to transparently peer review it, consistent with the Data Quality Act.

4. Precautionary approach to management, risk assessment, mitigation, and research permitting

There is no practical or legal basis for the use of a "precautionary approach" in mitigating the incidence of anthropogenic sound in oceans. Neither the United States nor the international community agrees on a uniform definition or practice of "precautionary approach." No agreement exists on such vital concepts as types of risks or levels of scientific uncertainty that should trigger "precaution." In fact, substantial debate continues both as to the scope of a "precautionary approach" and its status in international law. Current definitions vary widely as to when activity should be allowed to proceed and how protective measures should be developed.

Decisions about caution should consider risks to both marine mammals and impacts on other ocean resources and ocean users. The U.S. regulatory agencies already incorporate the concept of caution in their execution of the various environmental laws that relate to marine mammals. They are essentially using a "balanced protective approach" that takes into account numerous other factors, including levels of risk and levels of uncertainty. Their mandate is to be conservative based on the levels of risk perceived.

5. Need for coordinated international action

Any consideration of issues related to anthropogenic sound in the international context requires a review of national security interests, trade freedoms and treaties, and commercial considerations. As one example, military use of sonar is critical to U.S. national defense. Indeed, the national security interests of many nations require that their naval forces employ active sonar. It is unreasonable to assume that the U.S. or any other nation would agree to subjugate its national defense or energy interests to international guidelines or mechanisms relating to marine mammals and anthropogenic sound. The U.S. should encourage cooperation on international research programs, joint database archives, and information sharing.

KEY FINDINGS AND CONCLUSIONS OF ENERGY PRODUCERS CAUCUS

After nearly two years of participation as Advisory Committee members, the Energy Producers Caucus has reached the following key conclusions regarding marine mammals and the potential impact on them of anthropogenic sound:

1. We agree with the conclusion of the NRC report (2005) that there is no information that leads to a conclusion that anthropogenic sound causes population-level adverse effects on marine mammals. Other factors affect marine mammals by several orders of magnitude more than the potential effects of human-generated sound. For example, anthropogenic sound appears to be closely linked to only four marine mammal stranding incidents (fewer than 100 animals total over several years). This is a very small number considering that experts have noted that on average there have been 3,700 whales that strand annually in the U.S., or more than 30,000 over a decade. In addition, to put strandings into context, researchers estimate that 300,000 to 500,000 marine mammals are killed *annually* as a consequence of commercial fishing by-catch. In June, 2005, the Scientific Committee of the International Whaling Commission estimated that *"…nearly 1,000 cetaceans die every day in fishing gear, the leading threat to the survival of the world's 80-plus species of whales, dolphins and porpoises."* The World Wildlife Fund, an environmental non-governmental organization, reports that *"Unintentional death of whales and dolphins in fishing gear is pushing some cetacean species to the brink of extinction."*

2. Any assessment of threats from anthropogenic sound must not occur in a vacuum. As in all other areas, U.S. government resources to assess and address anthropogenic sound are not limitless. Therefore, in establishing priorities and allocating resources, policy makers must assess risks and benefits and consider all relevant factors in making balanced decisions. Hence, anthropogenic sound must be evaluated in the context of other anthropogenic threats to marine mammals, such as fishing by-catch, ocean pollution, habitat degradation, harmful algal blooms, whaling, vessel/whale collisions, and whale watching. Any biologically-significant adverse effects caused by anthropogenic sound must be examined in the context of other known causes of marine mammal disruption and mortality. And perhaps most important, research, management and mitigation activities must be focused on the most likely areas for potential risks of *adverse effects* of sound, not simply on sound itself.

3. In evaluating risks and benefits, it is crucial to distinguish between risks to marine mammal *populations* rather than minor behavioral effects on *individuals*. As the NRC 2000 and 2005 reports note, *"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."* This distinction is critical because federal agency regulators must make decisions that are practicable and balanced when choosing appropriate levels of protection. To take the position that no individual marine mammal can ever be affected by anthropogenic sound is to effectively decree that all human activity in the oceans cease.

4. There is no "one-size-fits-all" solution to designing and carrying out effective mitigation. A wide range of circumstances involving marine mammal populations, geography, seasons, ocean conditions, and sources of anthropogenic sound necessitates wide flexibility in implementing mitigation. Certain mitigation tools are inherently more effective than others. But some may be impractical or unwarranted, and some may have unreasonable costs and operational impacts.

5. Management and mitigation programs should be science-based and reflect assessments of risks and benefits in the face of uncertainties. Such assessments should be the primary tool in determining which management measures may be appropriate. Based upon our understanding of the risks, we believe that current management systems are effective, recognizing that future improvements may be warranted. In particular, permitting systems need to be streamlined, and adaptive management practices should be used to reflect changing circumstances and enhanced knowledge.

6. Considering what is known about the small numbers of whales adversely impacted by sound, current mitigation measures appear to be more than adequate to protect the viability and reproduction of marine mammal populations. Specific monitoring and mitigation activities, however, should be determined by a risk-assessment. As described above, scientific evidence does not indicate that anthropogenic sounds adversely affect the viability and reproduction of marine mammal populations.

7. There is substantial inconsistency in the current management of sound-producing activities. Management should be extended to unaddressed and currently unregulated sources and activities that have significant potential to produce adverse effects. Examples include dredging, construction, aircraft noise, whale watching industry, commercial shipping, and recreational boating.

8. An adequate long-term research investment is needed. This is the key to providing decision-makers reliable scientific information regarding anthropogenic sound sources, marine mammal populations, risks of adverse effects of sound exposure, and new means of mitigating risks. Adequate funding must be available to all relevant federal agencies for their permitting and authorization divisions.

9. Federal agencies, which have been at the forefront of marine mammal protection and research on a worldwide basis, could enhance their leadership by taking several steps. These include:

- Improving permitting certainty and timeliness for both researchers and sound producers.
- Conducting necessary marine mammal research, including population studies, biological response studies, and life history studies, which comprise the core information base required by the agencies to adequately manage the resources that they are mandated to regulate. With more complete information, the agencies could conduct better risk assessments and make improved, scientifically-based regulatory decisions.
- Improving permitting processes, which over the past decade have been imperiled by litigation whose sole intent appears to be to prevent all permitting.
- Developing mechanisms to collectively process and issue permits and authorizations that are similar, based on species, region or activity.
- Creating a standardized and centralized database to make collected information useful to researchers, sound producers and others.

10. Policies are needed that balance protection with risks and benefits in the face of uncertainty. As noted, properly focused scientific research should provide knowledge that will help inform a reasonable path forward. Judgments about the nature and effects of sound in the marine environment require the use of the various risk assessment methods (qualitative, quantitative and comparative risk assessment) to help ensure that real problems and real solutions -- not hyperbole and weak associations -- are addressed. There are uncertainties in our understanding of marine mammals and how anthropogenic sound may affect them. There is a variety of tools (including models and statistical analyses) that can help identify and manage uncertainty rather than over-react to it. Based upon the risks that have been identified, and the observations and available data on mitigation measures, we think that available mitigation tools are appropriate. It is important in the future to conduct related research that assesses the effectiveness of different mitigation methods. However, if warranted by new research findings, current mitigation measures can be adjusted through an adaptive management system, as recommended by the Advisory Committee's Federal Representatives Caucus. Used together, these tools can inform decisions about uncertainty rather than relying on generalized but unsubstantiated statements of fear, demanding imprudent action.

11. Marine mammals have been stranding themselves for thousands of years, long before man-made sound became prevalent. Strandings of a wide range of marine mammals have been noted over a long period of time. The historical records show strandings long before man was introducing significant sound into the oceans. Some examples include: 1) the philosopher Aristotle (350 B.C.) reported dolphin strandings (Aristotle, *Historia Animalia*, Book IX, Ch. 48 [translated by D'Arcy Wentworth Thompson]). The National Oceanic and Atmospheric Administration has reported that strandings "…were common in Cape Cod during the 17th century."

There are many hypotheses on the stranding issue, including lunar cycles, geomagnetic lines crossing landsfalls at sudden angles, microbubbles in the surf after storms absorbing animal navigation signals, shallow slope environments' inability to reflect navigation signals, sun spots, and general animal health (e.g., nematode infections in middle ear), etc.

While there have been no scientifically documented strandings caused by seismic operations, some evidence suggests that mid-frequency sonar may in unique circumstances have been a factor in a small number of strandings. In the case of four strandings of beaked whales occurring since 1996, evidence suggests that nearby naval sonar operations may have played a role. The other beaked whale strandings reported do not have a clear scientifically-based causal link to mid-frequency sonar operations.

Improvements in research methods and evaluations of stranded animals, and tracking of strandings, especially for beaked whales, are needed. Of key importance is reducing response time conducting stranding evaluations.

12. A "balanced protective approach" is the appropriate way for managers to make decisions in the face of scientific uncertainty. Such uncertainty has led some to raise the concept of the *precautionary approach* in managing sound-producing activities. *Precautionary approach* is a concept not defined uniformly across domestic and international laws and regulations. In fact, the term does not appear in the National Environmental Policy Act, Marine Mammal Protection Act, or Endangered Species Act. The Energy Producers Caucus believes these laws require a balanced protective approach that recognizes multiple uses of the environment while protecting ocean resources, and balancing environmental, economic, and scientific interests. Regulatory agencies routinely use a balanced protective approach in making management decisions and establishing permit parameters. The Energy Producers Caucus supports continued use of this science and risk assessment-based approach to management and mitigation.

13. Regulatory agencies should avoid layering caution and more caution on conservative judgments and assumptions. As regulators consider their management of this issue, they will have the opportunity to apply caution and conservative judgments to their management process. Without transparency and documenting where these judgments are inserted, it is easy to lose sight of a result of layering caution upon caution upon caution. Regulators should not be repeatedly inserting caution intended to mitigate risk into their judgments and assumptions. Rather, they should be as accurate as possible, using the mandated federal data quality standards. If warranted, regulators should make any judgments as to the application of caution in the management process only one time, and it should be fully documented.

14. "Universal international guidelines" that regulate anthropogenic sound would compromise national sovereignty generally and specifically U.S. interests regarding national defense, commercial trade, energy production and economic development. While individual nations may develop domestic policies and regulations to address sound in the marine environment, neither marine mammals nor sound are constrained by legal or political boundaries. With the exception of shipping (which occurs across oceans), most anthropogenic sound occurs near the coastline of individual countries, which are free to impose regulations.

The U.S. continues to be the world leader in conducting research on issues relating to anthropogenic sound in the oceans and the potential effects of such sound on marine mammals at the population level. Scientifically-vetted information that satisfies federal requirements for data quality can and should be used in U.S. regulatory decisions and shared with other countries.

Specifically for shipping activities in international waters, both inter-governmental and international non-governmental bodies may help address adverse effects of sound in the marine environment.

15. New technologies and research method development is crucial to advancing marine mammal science. Many of the key basic biological questions regarding marine mammal distribution, migration, feeding, and response characteristics can only be determined through the use of new technologies. Continued development and use of such techniques as satellite tagging and controlled exposure experiments should be encouraged.

RECOMMENDATIONS TO CONGRESS AND FEDERAL AGENCIES

The Energy Producers Caucus respectfully offers Congress and the agencies the following recommendations:

1. The appropriate federal agencies should complete an integrated assessment of the status of marine mammal species and populations and the potential impacts of anthropogenic sound at the population level. This should include a risk assessment that considers *all* factors, including sound, with the potential to affect marine mammal reproduction and survival. This risk assessment should drive the allocation of limited federal resources to various agency programs. Such integrated, risk-based decision-making will ensure that funding is directed to the most critical areas and is programmed over multiple years. This assessment should focus on significant rather than minor impacts.

2. Federal agencies should be given guidance concerning how to balance management of the multitude of activities which produce anthropogenic sound in oceans. While marine mammals are an important resource, their protection from population level-risks associated with anthropogenic sound cannot occur in a vacuum. In developing management and mitigation programs directed at marine mammals, other critically-important uses of the oceans (particularly national defense, energy production and commercial trade) must also be considered.

3. The appropriate agencies should expand and improve their use of risk-based and science-based assessments in development of their management and mitigation regimes.

4. An interagency task force should be established to improve the cross-boundary coordination of federal marine mammal activities.

5. Agencies should be given guidance to improve permitting certainty and timeliness for both researchers and sound producers. Mechanisms are needed to collectively process and issue permits and authorizations that are similar, based on species, region or activity. Another useful step would be the creation of a standardized and centralized database to make information collected widely available in a useful and consistent format to researchers, producers and others.

6. Congress should require that the agencies, as they perform their duties to manage marine mammals, take into consideration the vital importance to the nation of continuing to find and produce new offshore energy resources. With 25% of domestic oil production and 30% of domestic natural gas production coming from offshore areas, it is imperative that U.S. energy producers continue to have access to these resource-rich areas.

7. Congress should provide adequate funding so that designated agencies will have adequate resources to carry out their mandates efficiently, and so that key scientific information can be gathered on marine mammal biology and life history. The lack of personnel and adequate funding for NEPA compliance documents seriously hampers the Agencies' ability to process permits in a timely fashion. In addition, extra delays can be caused by concerns over potential lawsuits. Also, focused research on marine mammal populations and biology is not only needed as it relates to the anthropogenic sound issue, but more important, for the proper management of marine mammal resources, taking into consideration all other potential outside effects on these animals. The Energy Producers Caucus strongly supports the need for increased federal funding of marine mammal research. The level of funding should reflect a risk-assessment of the level of risk posed by sound to marine mammals, a seriatim ranking of other risks to marine mammals, and consideration of other funding pressures. We have no specific recommendation as to the amount of federal funding required.

8. The Energy Producers Caucus does not completely endorse the recommended levels of funding proposed by the Scientific Research Caucus. There are two major concerns: 1) a concern that the risks associated with the issue, and competing budget pressures may not justify spending $150,000,000 to $200,000,000 over 10 years (e.g., could we save many more marine mammals by reducing fishing by-catch impacts?); and, 2) are there adequate numbers of top quality scientists to effectively spend the level of funds identified above?;

9. As Congress considers the scheduled reauthorization of the MMPA and ESA, it should streamline and simplify the current statutory and regulatory structure for protection of marine mammals. In its present state the current statutory and regulatory structure is overly complex, contains gaps and sends conflicting signals. As such, it invites litigation and diversion of administrative resources that could otherwise be directed to benefit research and management of programs for the benefit of marine mammal populations. The current scheme brings some activities under regulatory scrutiny, but leaves others wholly or significantly outside management.

CONCLUSIONS

In addition to the inherent ecological value of the world's oceans, mankind uses the world's oceans for a range of important activities, including harvesting food, producing energy, transporting goods in global trade, and protecting national security. Marine mammals that live in oceans are magnificent animals that deserve protection from human activities that pose a substantial risk to harming marine mammal populations. Such activities may include pollution, habitat degradation and – most noteworthy – fishing by-catch, which itself has an enormous negative impact on marine mammals.

While the possibility exists that anthropogenic sound could, under certain circumstances, affect marine mammals (and may or may not be biologically significant) in localized areas at the individual level, existing scientific research does not support the view that human-generated sound is harming marine mammal populations. More research is needed to better understand marine mammal populations and how human-generated sound affects them.

While such research is underway, federal agencies involved in marine mammal protection should continue their conservative balanced protective approach in managing and mitigating adverse effects of anthropogenic sound. *All* factors that may affect marine mammal population viability and reproduction – not just anthropogenic sound – must be considered when evaluating the potential impacts of any individual factor. To do otherwise would be to engage in "advocacy science" rather than legitimate science.

Commercial Shipping Industry Representative Statement for

The Report of the Advisory Committee on Acoustic Impacts on Marine Mammals

to the

Marine Mammal Commission

Submitted by Committee Member:

Kathy J. Metcalf
Director, Maritime Affairs
Chamber of Shipping of America

Submission Date: 1 February 2006

The following statement reflects only the views of the individuals and organizations 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.

CHAMBER OF SHIPPING OF AMERICA
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Mr. David Cottingham
Executive Director
Marine Mammal Commission
4340 East-West Highway
Room 905
Bethesda, MD 20814

Advisory Committee on Impacts of Anthropogenic Sound on Marine Mammals Commercial Shipping Industry Representative Report and Comments

Dear Mr. Cottingham:

This document is forwarded to you in accordance with the Process Summary provisions as proposed by the Marine Mammal Commission, consistent with the Committee's Operating Procedures, as presented at our last plenary meeting held on September 20-21, 2005 in Bethesda, MD.

Let me first begin by expressing my deep appreciation for being given the opportunity to serve on the Federal Advisory Committee with such a distinguished group of individuals with expertise far beyond what I could have ever imagined. While this significant issue we were charged with addressing rightly so has its origins in the scientific community, bringing together such a diverse group of scientists, policy makers and non-governmental organizations is truly a credit to you and the Marine Mammal Commission and your collective intent to address this issue and its possible solutions head-on, in a transparent fashion and providing the opportunity for all constituencies to input into this very complex process addressing an even more complex issue. While I am disappointed that we were not able to reach consensus on a report to the Commission, I am confident that the information collected and issues debated during this process may yet still lead to progress on addressing the issue of marine mammals and noise in an environmentally protective and economically viable manner.

(1) These comments I provide to you today are solely with respect to the issue of sound generated by commercial shipping and what I believe to be the prudent way forward to assure that the issue is addressed in a manner which takes into account the need to preserve our oceans' precious marine resources while at the same time preserving their use as global highways of maritime commerce. As you may recall from the many long hours the committee met, on several occasions, one sound producer or another attempted to redirect the spotlight from their sound producing operations to those of another sound producer. I did not at that time and will not now participate in this type of finger pointing exercise.

Quite simply, the first point I wish to make on behalf of the commercial shipping industry is that any sound producer that is conducting activities that negatively impact marine mammals must be willing to further investigate those activities with a focus on the specific origins and characteristics of those sounds and possible mitigation methods.

(2) While it is overly simplistic to state the obvious, it is critical that the nature and extent of any particular sound source's impact be identified before any mitigation strategies can be identified. We all know how difficult that discussion can be and how even more difficult the process can be when trying to reach some agreement on the appropriate course of action taking into account the significant gaps in information needed versus that which is available, dealing with scientific uncertainty and assessing the impacts of various mitigation strategies on a wide variety of marine mammals, in a hydrographically diverse world. It is no surprise to anyone that the commercial maritime industry is not expert in the fields of marine biology or acoustics. What the industry is expert in is transporting the world's trade in a safe and environmentally protective manner and our approach to the issue of impacts of commercial shipping noise on marine mammals takes and will continue to take that most serious of commitments to heart.

(3) We support the submission by the scientific research caucus entitled "Scientific Research Caucus, Statement for the Report of the Advisory Committee on Acoustic Impacts on Marine Mammals to the Marine Mammal Commission" dated 3 January 2006. This submission supports our position that a great deal of information that we need in order to make intelligent decisions is simply not yet available and a national research program is necessary to begin to fill these critical gaps in knowledge. We also fully support utilization of the 5-stage risk assessment process as the proper framework for guiding our thought processes from hazard identification through risk management.

(4) Specific to the generation of sound by commercial shipping, we emphasize text found in the above referenced submission at page 13, which reads in relevant part, "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 the 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**." (emphasis added)

(5) Acknowledging this lack of evidence of adverse impact, we support the recommendation of the scientific research caucus that studies should be conducted that measure the effects of low frequency shipping noise on baleen whales. In fact, we would take one step further and urge that the United States take a leadership role in appropriate international fora which may oversee the conduct of this type of research at an international level. As I stated many times during our many hours of committee deliberations, neither sound nor whales respect neat jurisdictional boundaries. Based on the long ranges low frequency sound is

transmitted and the global nature of commercial shipping, a local or even national program to assess impacts simply will not provide the entire picture necessary to assess the impacts of sound generated by commercial shipping on marine mammals and identify potential mitigation strategies.

(6) We are not however, suggesting that sound producers, including those of us that make up the commercial shipping industry, sit idly by waiting for all the necessary scientific data to be assembled. During this critical period in which impacts of sound on marine mammals are assessed, sound producers should begin to examine possible mitigation strategies which may be employed if, and when, the adverse impacts on marine mammals are both characterized and quantified.

(7) In the case of the shipping industry, ship quieting technologies have been and continue to be identified which focus on methods to reduce sound from normal ship operations for reasons other than impacts on marine mammals e.g. military purposes, reduction of sound levels in ships' living spaces for crew and passenger comfort and safety, and machinery operational and maintenance benefits from reduced vibration. In addition, design and construction techniques developed to reduce propeller cavitation, the single largest contributor of ship generated noise in the low frequency ranges of concern for marine mammals, are continually being refined to improve the fuel efficiency of today's modern marine propulsion systems.

(8) In order to fully address the issues associated with sound generated from commercial shipping, expertise from naval architects and ship engineers must necessarily be injected into these discussions to adequately examine a vessel as an individual point source. In order to adequately examine sound from commercial vessels as a collective source of ambient noise in the oceans, global experts on ship routing and maritime trade must also be integrated into the discussions in order to examine and identify maritime traffic densities throughout the world.

(9) Finally, only a very small percentage of the commercial shipping industry is even aware that sound generated incidental to the normal operation of commercial vessels may even be a problem for marine mammals. This necessitates an aggressive education and outreach campaign designed to reach all the necessary experts (ship owners, naval architects, design engineers, ship routing specialists) so that the general nature of the problem is made known and its potential impacts and possible mitigation measures may begin to be identified.

(10) This is not to suggest that we support immediate mandates that all ships or even new ships employ ship-quieting technologies. It is to say however, that the commercial shipping industry as a whole must begin to think about this issue and possible solutions, if adverse impacts are found to result from ship generated sound. Furthermore, we do support the continuing review and voluntary implementation of cavitation reduction technologies on new ship construction since not only do these technologies result in better fuel efficiency

for the vessels on which they are installed, but also have the additional benefit of reducing low frequency sound from normal ship operations.

(11) In the items directly above, we have outlined in very general terms the steps we believe are justified for addressing the issue of sound generated from commercial shipping. However, an equally important question is how does this initiative get started and by whom? Clearly the scientific issues must be addressed by the scientific community, hopefully at the international level. However, we believe the commercial shipping issues outlined above are ideally addressed by the International Maritime Organization (IMO), a subsidiary body of the United Nations. The purposes of the Organization, as summarized by Article 1(a) of the IMO Convention, are "to provide machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships". Today, IMO's membership stands at 166 member states and a number of intergovernmental and non-governmental organizations that provide broad expertise in all matters maritime. Within these 166 member states, stand the world's maritime powers as defined both in terms of trade volume and vessels registered under the flags of particular countries. In short, all the global players necessary to address this global issue are active participants at IMO and as such the interests of flag states, port states and coastal states alike are well represented.

(12) Therefore, we strongly support that the United States take a leadership role in bringing this issue to the International Maritime Organization. While we would certainly defer to those that are more expert in diplomatic relations and strategies, our suggestion for a first step would be for the United States to submit an information paper on this issue with as much information as practical to assure that the IMO membership is fully informed on this issue. This submission must necessarily touch on the scientific aspects of marine mammals and sound as well as the information gaps that exist relative to defining the nature and extent of the problem relative to all sound sources. The submission must also include a more focused discussion on the possible impacts of sound generated from commercial shipping, identification of possible mitigation strategies and urge further discussion of this issue at the international level, both at IMO and in any other appropriate international scientific body. Utilizing the collective expertise within the IMO community, will enable critical discussions to occur and foster a better understanding of the role that commercial shipping may play in future sound mitigation efforts.

Respectfully submitted,

Kathy J. Metcalf
Director, Maritime Affairs

Scientific Research Caucus Statement for

The Report of the Advisory Committee on Acoustic Impacts on Marine Mammals

to the

Marine Mammal Commission

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SCIENTIFIC RESEARCH CAUCUS STATEMENT

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 Caucus 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.

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.

STATEMENT OF THE ISSUE

> "The basic goal of marine mammal conservation is to prevent human activities from harming marine mammal populations." (NRC, 2005)

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 by-catch 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, however, 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.

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 exposure 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.

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):

> 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.

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.

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.

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 devoted 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 (http://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.

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 database 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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California Coastal Commission Statement for

The Report of the Advisory Committee on Acoustic Impacts on Marine Mammals

to the

Marine Mammal Commission

Submitted by Committee Member:

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Submission Date: 19 December 2005

The following statement reflects only the views of the individuals and organizations 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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The California Coastal Commission appreciates the opportunity to have had a representative on the Federal Advisory Committee on Acoustic Impacts on Marine Mammals. The California Coastal Commission is charged with overseeing the coastal zone of the State of California and protecting its valuable coastal resources, including marine mammals. The coastal and marine ecosystems of this State represent both an important economic interest and a vital spiritual one. The coastal and marine ecosystems and marine life within this State's sovereign waters and beyond support important commercial activities, including fishing and tourism. California residents and tourists alike enjoy the benefits and solace that comes from being able to see and appreciate the beauty and wonder of nature. Marine mammals represent a critically important part of this and play a special role in our society and as such deserve our protection.

The California Coastal Commission's regulatory authority over state waters and beyond into federal waters comes through both the California Coastal Act and the federal Coastal Zone Management Act (CZMA). It is within the coastal waters of the states that U.S. strandings occur. It is thus critically important that the states have a say in what happens relative to this issue.

It is with that in mind that the California Coastal Commission is submitting this statement to the Marine Mammal Commission. It is unfortunate that consensus was not reached among the Advisory Committee members so that one comprehensive document could be submitted to Congress and we have not attempted to craft one. Instead we have commented only on those issues that were listed as disagreements at the final Plenary session.

Introduction

Anthropogenic noise is a recognized, but largely unregulated, form of ocean pollution that can deafen, disturb, injure, and kill marine life.[1] Many species of marine mammals are known to be highly sensitive to sound and rely upon sound to navigate, find food, locate mates, avoid predators, and communicate with one another. A combination of noise sources, including shipping, oil and gas exploration and production, dredging, construction, and military activities, has resulted in dramatic increases in noise levels throughout the oceans. Over the last ten years, a growing body of evidence has shown that some forms of ocean noise can kill, injure, and deafen whales and other marine mammals.[2] In particular, a sequence of marine mammal strandings and mortalities has been linked to exposure to mid-frequency sonar.[3] There is also evidence that some affected animals do not strand but die at sea. This has increased public concern about the effects of anthropogenic noise on marine mammals, which has been acknowledged in a variety of domestic and international fora.

Marine mammals have evolved over millions of years and rely on sound for vital life functions and have specialized sensory capabilities to take advantage of the physics of sound in the ocean. Anthropogenic noise in the oceans has increased since the start of the industrial revolution and increases in ambient noise levels,[4] as well as individual sound sources, can cause adverse effects, the extent and type of which are not well understood. Military technology and scientific research using low frequency active acoustics attempting to cover large distances have specifically targeted the ecological sound niches that low frequency specialist whales have evolved to rely on, necessarily competing with those marine mammal species. Peer-reviewed scientific literature indicates that marine mammals are affected by exposure to anthropogenic noise in a variety of ways that can be harmful or even lethal. However, there are significant gaps in information available to understand and manage these effects. This is particularly the case because marine mammals are extremely difficult to study and the marine environment is extraordinarily complex and dynamic. In addition, this is a relatively new field of concern and the amount of research undertaken to date has been limited in scope and duration.

Much of the information needed to understand the impacts of noise on populations and individuals will remain unknown for decades, if not longer. In the face of much uncertainty, the California Coastal Commission and other agencies must make decisions about proposed activities. Given the current data gaps and the uncertainties in information available about impacts of sound on the marine environment, and the potential for harm to occur before it is detected, it is appropriate for managers to apply precaution when allowing necessary activities to proceed. The current statutes presume that a precautionary approach should be taken and place the burden of proof on the applicant proposing the action. This is necessary because scientific certainty is difficult to obtain on most issues but will be particularly elusive in this field. Because many of these species reproduce very slowly, requiring scientific certainty before taking protective measures could very well result in their extinction.

While much remains to be learned about marine mammals and their responses to noise, one method of determining if there is a correlation between intense noise events (sonar and seismic) would be to be able to have more accurate information about strandings coincident with noise events. However, stranding teams are not necessarily available to cover all areas where strandings occur and funds for quick, accurate, and unbiased review of strandings are insufficient. In addition, knowledge of military activities is not always available. As a result, only publicized mass strandings are reviewed to see if they are coincident with naval or other sound-producing activities. Additionally, there has been no attempt to look at single strandings to see if there may have been sound-producing activities in the area. There also is no standardized form for reporting the results of necropsies and the public is frequently not allowed to observe necropsies or have access to the data for long periods of time (e.g., 2005 North Carolina stranding event). A more coordinated and complete analysis of all stranding data should be conducted.

While anthropogenic noise is only one of many serious threats facing marine mammals, such as fisheries by-catch, habitat degradation, ocean pollution, whaling, vessel strikes, global warming, and others, it is too early in our investigations to know where this issue sits in a relative sense. Most likely the answer will depend upon the species and a more complete knowledge of both cumulative and synergistic effects of noise. Long-term cumulative impacts to populations and synergistic effects that may heighten the impacts of other threats may turn out to be the greatest impact of noise on marine mammal populations. However, the indications are that this threat is significant enough to require efforts to reduce its potential impacts and should be taken seriously.

Extent of the Problem

How significant is the threat and what is the relative importance of sound?

There has been an attempt by some to downplay the significance of sound as a threat, particularly as it compares to other threats. However, it is impossible to say at this stage of our knowledge what the relative importance is. Underwater noise can prevent marine mammals from hearing their prey or predators, from avoiding dangers, from navigating or orienting toward important habitat, from finding mates, from contact with their young, and can cause them to leave important feeding and breeding habitat.[5] Those who state that anthropogenic noise only affects a few individuals or who insist on an irrefutable burden of proof are looking at this from a very narrow perspective, i.e., considering only known atypical mass strandings where the existence of a sound source was known as a measure of the impact and requiring that there be physical evidence of trauma. This ignores that:

1) The majority of strandings likely go unreported, particularly in remote areas;
2) Mortalities that occur away from the coast are very difficult to detect since most whale carcasses sink immediately;[6]
3) Knowledge of whether or not a sound source may be present during known strandings may not be available;
4) Strandings of single whales where there is no other known cause of the stranding are not reviewed for a possible connection to sound;[7]
5) There may be cumulative and synergistic effects on individuals and populations that are difficult, if not impossible, to determine;
6) There may be significant impacts to a variety of biologically necessary functions;
7) Strandings are not the only possible impact of sound; and
8) Limiting the inclusion of strandings to those where there is proof of a cause and effect is inaccurate and misleading.

The significance of the impacts may vary with the species. Some species are more threatened by ship strikes, other by by-catch, and still others, such as beaked whales, by noise. We also know that human impacts on marine ecosystems interact to produce a magnified effect of other threats. There is no reason to believe that it is different with noise. Thus noise could, for instance, affect the ability of marine mammals to sense fishing gear or create stress that magnifies the impacts of pollution.

In conclusion, the impact of anthropogenic noise on marine mammals cannot be looked at in a simplistic way by only comparing the known number of mass strandings proven to be connected to sound to the total number of strandings, including those for which there is no explanation. The body of scientific literature on noise impacts on marine mammals is growing, pointing almost uniformly to a cause for concern. While the relative significance of this threat is yet to be determined, it is clear, even at this stage, that this threat should not be taken lightly.

Impact on populations

Impacts of noise on populations, even non-lethal impacts, can severely affect species survival. However, population impacts are difficult to detect, particularly where there is insufficient information about the population size and structure. Where the impacts are the result of long-term cumulative exposure, scientific observation and conclusions are particularly elusive but noise is believed to have contributed to the decline of several species of whales or their failure to recover.[8] The NRC statement that "no scientific studies have conclusively demonstrated a link between exposure to sound and adverse effects on a marine mammal population" [1] is misleading at best, because there are also no scientific studies that conclusively demonstrate that there have been no effects on any marine mammal population. In other words, there is simply not sufficient information to make that conclusory statement. In addition, it ignores the information on noise-induced strandings of a well-studied local population of beaked whales that was either killed or did not return even five years after the sonar event believed to have caused the stranding.[9] That local population impact, on a species about which we know little of the population numbers or structure, cannot be ignored as a possible population impact.

Additionally, the NRC conclusion ignores that:

1) in all but a few cetacean species our population estimates are too imprecise to be able to detect population declines;[10]
2) there have been no studies that have attempted to study population declines due to noise;
3) if we were able to detect a population decline, it would be difficult if not impossible to tie it to noise;
4) where we do know of population declines, most cannot be linked to one primary cause;[11] and
5) in instances where we have reason to believe there can be major impacts, such as in the case of known toxins, even those that accumulate in the tissues of marine mammals, it has not been possible to prove they are a cause of marine mammal decline.[12]

In conclusion, marine mammal population declines are difficult to document especially without accurate baseline population counts to start with. However, what we have learned in the very short time that attention has focused on these issues is that we have seriously underestimated the effects of noise on marine mammals. This indicates that the effects of anthropogenic noise could be far-ranging and severe and should not be discounted.

Degree of scientific uncertainty and the use of extrapolation

In the last few decades, knowledge of marine mammal biology has increased yet many aspects of marine mammal behavior, physiology, populations, and ecology remain unknown. An understanding of normal behavior and the biological significance of any resulting changes in behavior caused by sound exposure are critical to better answer questions regarding impacts. Unfortunately, much of the understanding of normal behavior required to answer these questions is unknown at this time.

1 NRC 2005. Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects. National Academy Press Washington, D.C. 96 pp.

At this time there is still a significant amount of uncertainty about how marine mammals hear, how they use sound, and the impacts of noise on them. In fact, the data gaps are so substantial that it is difficult to draw any definitive conclusions on this subject, other than to state that there is a high degree of probability that sound may impact marine mammals in significant ways necessitating the use of precaution.

Listed below are just some of the areas where it is generally agreed that there is uncertainty:

- Eighty-three different species of cetaceans are currently recognized, and audiograms have been developed for only 11 species, all of which are odontocetes.
- The hearing of mysticete whales remains unmeasured.
- Uncertainty regarding the specific uses of sound by marine mammals (e.g., extent, context) makes it difficult to detect or interpret changes in behaviors associated with sound.
- We know relatively little about the extent of marine mammals' use of sound from natural sources (for navigation, prey detection, predator avoidance, or other uses).
- There is uncertainty about how marine mammals use sound to communicate or carry out other functions.
- The ranges and circumstances of effective communication using sound are also unclear.
- There is limited information available on what constitutes normal behavior for many species.
- There is a lack of baseline behavioral data making it difficult to assess the impact of sound or determine what would constitute a biologically significant disturbance.
- There is uncertainty about whether an animal hears the same types of sounds that it produces, and therefore whether it is appropriate to estimate an animal's audiogram by examining its sound production.
- There is uncertainty about whether or not sounds to which animals are relatively insensitive are still important to their survival.
- There is uncertainty about the pathways by which sound travels to the inner ear and about other mechanisms for hearing in marine mammals.
- There is uncertainty about the onset of auditory trauma in marine mammals, including which types and levels of sound exposures will induce trauma in which species.
- There are limited experimental data on TTS (temporary threshold shift) in marine mammals, and no experimental data on PTS (permanent threshold shift, i.e., deafness).
- It is uncertain whether increased sound levels in the oceans could cause auditory developmental problems for young marine mammals.
- We do not know whether marine mammals have natural mechanisms to protect their hearing. If they do have protective mechanisms, they may not work in the same way as in the ears of terrestrial mammals. If marine mammals do have protective mechanisms, we do not know whether or how they might fatigue.
- There is uncertainty about whether the auditory systems of mysticetes may be more likely than those of odontocetes to be affected by low- to mid-frequency sounds because mysticetes' vocalizations consist of these same frequencies.

- While masking is known to be a common, naturally occurring phenomenon, there is uncertainty about the specific conditions under which, and the extent to which, it occurs in marine mammals, and when it is significant.
- The full range of options available to marine mammals to overcome masking is not known.
- There is uncertainty about the potential of general, non-directional ambient noise to cause masking, which results from a lack of information about ambient noise levels.
- Uncertainties exist about baseline feeding rates and hunting success, mate-searching behavior, and predator avoidance affecting scientists' understanding of whether masking is likely to adversely affect the survival or reproductive success of an individual or population.
- Direct effects of masking are difficult to demonstrate in the field.
- The prevalence of non-auditory physiological sound effects (e.g., stress, neurosensory effects, effects on balance, tissue damage from acoustic resonance, gas bubble growth in tissues and blood and blast-trauma injury) in marine mammals and the relative vulnerability of different species to such effects are uncertain.
- Little is known about how sound might induce stress in marine mammals.
- There have been no studies to date specifically investigating these stresses in marine mammals.
- There is uncertainty about the possible role of acoustic resonance in beaked whale strandings associated with sound exposure.
- The relationship of sound characteristics to gas bubble growth is unclear.
- Disagreement currently exists over the possible role of gas bubble growth in beaked whale strandings.
- It is unclear what, if any, specialized adaptations deep diving marine mammals may have evolved to avoid decompression-type effects during their routine diving behaviors.
- The biological significance (e.g., consequences for health, survival, reproduction) of behavioral responses to sound is largely unknown.
- The long-term, cumulative impacts of sound exposure on behavior are also unknown, making it more difficult to determine the significance of observed behavioral changes over time.
- Little is known about the extent to which marine mammals can or do adapt their behavior to changes in anthropogenic sound.
- It is also uncertain how most marine mammal species may respond behaviorally to long-term increases in background noise levels.
- The characteristics of sound that trigger a behavioral reaction are often unknown.
- There are few direct data concerning the behavioral effects of sound on marine mammals.

Uncertainties about the effects of sound on marine mammals are driven by several fundamental problems. First, the lack of baseline behavioral data for most marine mammals makes it difficult to measure and interpret behavioral responses to sound. Second, there are fundamental, practical challenges inherent to studying marine mammal behavior in the wild such that some types of responses (even acute responses) are difficult to detect with currently available monitoring capabilities. Third, even in cases where behavioral responses to sound have been documented, the mechanisms and implications of these changes are not always clear. Fourth, sample sizes in studies where behavioral changes are documented are often small, and the results are often specific to a particular location and scenario, making general conclusions difficult. In addition, even where behavioral changes are documented, interpreting the effects that are detected is extremely difficult, at best.

While the above is not meant to imply that we do not know anything about these issues, it highlights the significant gaps in our current understanding. We do not even know what the hearing range is for most cetaceans (only 11 out of the 83 known species), and we have no measurements on mysticetes at all. Most of what is known about the hearing range of these species comes from studies with one or a few individuals belonging to these 11 species. Extrapolation of these few data points is then used to determine the hearing range of the entire species. We know that there are great variations in the hearing ability and range of individuals within a species, and thus any extrapolation within the same species should include the probability of error and set possible bounds. To then use the extrapolated data to extrapolate again between species where there are no direct observations or experimental data is scientifically inaccurate and can only lead to erroneous conclusions. While extrapolation is a valid scientific tool, extrapolations must be used with great care and underlying assumptions must be clearly stated. More confidence is placed in extrapolations where comparisons are made between more closely related species or where sample size is larger. Use of extrapolations in this field at this early stage of our knowledge is justifiably controversial. Extrapolation increases in validity as the body of knowledge and extent of data increase in robustness. Until such time as there are a greater number of data points, i.e., individuals measured, including those that are not captive, the risks of drawing the wrong conclusions that could lead to serious management decision errors is too great to justify.

The degree of uncertainty that exists in this newly emerging field of science should not be used as a justification for postponing action to prevent environmental degradation. The potential for harm to occur before it is detected necessitates the use of a precautionary approach to the review and permitting of activities that involve the intentional production of anthropogenic sound.

Relationship Between Stranding and Sound

Level of relationship: cause/effect, correlated, associated

Much has been made of the need to assess the relationship between strandings and sound by defining whether or not the relationship is a coincidence, association, or is correlated or related by cause and effect. Some stakeholders believe that to fully understand the nature of any relationship (e.g., coincidence or correlation) of an acoustic event with a stranding, scientists need, at a minimum, good information on:

- The sound sources involved and the propagation of energy from those sources;
- The animals' physiological and metabolic status and injuries;
- The animals' potential causes of death based on necropsy findings;

- The spatial and temporal correspondence between the sound sources and the animals; and
- The stranding pattern (e.g., atypical strandings having two or more animals stranded over several hours spread over kilometers of coast, rather than at the same time and location; or strandings involving more than one species).

In practice, it is rare to have such complete information and requiring this level of information sets the standard at an unachievable level. Information available to draw conclusions about the causes of stranding events is limited, making it difficult to assess the relationship between strandings and sound. Requiring the determination of whether a stranding is related to sound by cause/effect, correlation, association, or coincidence as a prerequisite to listing it in a table of strandings is inappropriate and artificially narrows the list of strandings that may involve noise. When events, particularly ones that are rare, occur together repeatedly, data from such events can be used to determine a relationship between the two and should not be overlooked, even if a particular individual event cannot be proven to be correlated.

Number of relevant stranding or mortality events

Current understanding of the connection between sound and strandings has not advanced to the point where the relationship between sound exposure and mortality can be understood in terms of physiological, behavioral, and population-level responses, making it difficult to assess the magnitude of impacts. Recent attention directed towards marine mammal strandings and sound, and particularly the potential impacts of sound on beaked whales, argues for the need to highlight this topic.

The National Marine Fisheries Service (NMFS) maintains a database of marine mammal strandings in the U.S.[13] Some conclude the database indicates that the effects of noise are relatively insignificant when considering the number of strandings known to be caused by anthropogenic noise. However, it is extremely misleading to use the figures from this database. The vast majority of the strandings in the database involve pinnipeds (seals and sea lions) not cetaceans, and to date no strandings of pinnipeds have been linked to noise. In addition, most of these are strandings of one or two individuals where noise is not even considered a possible cause, and therefore no attempt was made to look at the relationship between the stranding and noise. Because 60% of the strandings cannot be explained by any known cause[14], it is also possible that a percentage of these could be sound-related and that for others sound was a contributing factor.

Anthropogenic sound has only recently emerged as a probable cause of some marine mammal strandings and, prior to the early 1990s, was not even looked at as a possible cause of strandings. In 1998, exposure to military sonar was postulated as the cause of a beaked whale stranding event in Greece in 1996.[15] Similar events have occurred in the Bahamas Islands in 2000, Madeira in 2002 and the Canary Islands in 2002.[16] Mass strandings of Cuvier's beaked whales are considered to be highly unusual. Since the early 1960s, when the Navy's mid-frequency tactical sonar was first deployed and the use of arrays began, more than 40 mass strandings of Cuvier's beaked whales have been reported worldwide, some together with naval maneuvers and the use of active sonar or other noise sources such as seismic surveys. Some of these strandings that occur together with a noise event are undisputed in their association with noise. In other cases stakeholders consider them to be coincidental events. These stakeholders require that the exact source and level of noise be determined and also require evidence of the physiological condition of the animals, potential causes of death based on necropsy findings, the presence of a qualified biologist to document both the stranding and the noise event and the spatial and temporal correspondence between the sound source and the animals. Such information may be useful in determining a cause and effect relationship but is seldom available and raises the bar of proof to a level usually unattainable. It should not be necessary to prove a cause and effect, e.g., through a known mechanism, to be convinced that some strandings are linked with sonar. This is the manner in which the relationship between smoking and cancer and other diseases was elucidated. It is therefore necessary to include a very complete list of strandings, particularly of mass strandings, and all known possible sound sources operating in the area at the time, to enable a more accurate analysis of the potential connection between noise and strandings whether or not a cause and effect can be conclusively proved.

It is interesting to note that that a double standard is being used. These same stakeholders reject the use of extrapolation to determine received levels in a stranding, even with relatively good propagation models that are available, yet they accept extrapolation relative to hearing from a single odontocete to a mysticete.

The magnitude of the problem of acoustically-induced strandings remains unknown, but there are concerns that the number of these strandings identified may underestimate the number of animals affected. In general, an analysis of stranding data may underestimate the number of strandings related to sound events because: a) a substantial number of strandings, and especially mortalities at sea, may go undetected or undocumented; and b) a substantial proportion of any associated sound events may go undocumented (e.g., because of the absence of a standardized reporting system). Stranding detection is affected by factors such as their proximity to relatively populated areas (i.e., whether humans are likely to observe them). Animals that die at sea are seldom detected. The documentation of strandings depends on reporting efforts (e.g., by local stranding response networks) and the availability of qualified personnel to conduct necropsies or other analysis. In addition, the question of possible underestimation of acoustically-induced strandings is a particular concern for species other than beaked whales that may strand more regularly due to other causes. In these latter species, a connection to sound exposure may go undetected and their susceptibility to sound-related injury and mortality may be underestimated.

While much remains to be learned about marine mammals and their responses to noise, having more accurate information about strandings that occur coincident with noise events would help us determine if there is a correlation between the two. However, stranding teams are not necessarily available to cover all areas where strandings occur and funds for quick, accurate, and unbiased review of strandings are insufficient. In addition, knowledge of military activities is not always available and may be classified. As a result, only publicized mass strandings are reviewed to see if they are coincident with naval or other sound-producing activities and there has been no attempt to correlate single strandings of whales with noise events. There is also no standardized form for reporting the results of necropsies and the public is frequently not allowed to observe necropsies, or have access to the data for long periods of time (e.g., North Carolina stranding), making the conclusions subject to suspicion by members of the public, particularly when public members are barred from observing while Navy-sponsored scientists conduct the necropsies (e.g., Haro Strait[17]).

It has taken 40 years to notice the connection between naval sonar and mass strandings of beaked whales, even though this is one of the most obvious connections. This underscores how easy it is to miss the connections between noise and a variety of impacts on marine mammals. Some stakeholders have attempted to limit the listing of strandings to the four events where there is very good evidence of the connection between strandings and anthropogenic noise. This paints a very deceptive picture of what may be happening. It is of particular importance that we not limit the list of strandings that may have a connection to sound sources. A complete list is necessary to more fully understand the magnitude of the problem and allow for an analysis to determine whether a statistical correlation of the relationship between noise and strandings exists. We have therefore included a more complete list of strandings (Table 1).

Table 1. Mass Strandings of Beaked Whales[18]
(Brownell et al. 2004; ICES 2005)

Year	Location	Species (numbers)	Associated activity, when available
1914	New York, U.S.	Zc (2)	
1960	Sagami Bay, Japan	Zc (2)	US Fleet
1963	Gulf of Genoa, Italy	Zc (15+)	Naval maneuvers
1963	Sagami Bay, Japan	Zc (8-10)	US Fleet
1964	Sagami Bay, Japan	Zc (2)	US Fleet
1965	Puerto Rico	Zc (5)	
1966	Ligurian Sea, Italy	Zc (3)	Naval maneuvers
1967	Sagami Bay, Japan	Zc (2)	US Fleet
1968	Bahamas	Zc (4)	
1974	Corsica	Zc (3), striped dolphin (1)	Naval patrol
1974	Lesser Antilles	Zc (4)	Naval explosion
1975	Lesser Antilles	Zc (3)	
1978	Sagami Bay, Japan	Zc (9)	US Fleet
1978	Suruga Bay, Japan	Zc (4)	US Fleet
1979	Sagami Bay, Japan	Zc (13)	US Fleet
1980	Bahamas	Zc (3)	
1981	Bermuda	Zc (4)	
1981	Alaska, United States	Zc (2)	
1983	Galapagos	Zc (6)	
1985	Canary Islands	Zc (12+), Me (1)	Naval maneuvers
1986	Canary Islands	Zc (5), Me (1), *Ziphiid* sp. (1)	
1987	Canary Islands	Me (3)	
1987	Italy	Zc (2)	
1967	Suruga Bay, Japan	Zc (2)	
1987	Canary Islands	Zc (2)	
1988	Canary Islands	Zc (3), bottlenose whale (1), pygmy sperm whale (2)	Naval maneuvers
1989	Sagami Bay, Japan	Zc (3)	US Fleet
1989	Canary Islands	Zc (15+), Me (3), Md (2)	Naval maneuvers
1990	Suruga Bay, Japan	Zc (6)	US Fleet
1991	Canary Islands	Zc (2)	Naval maneuvers
1991	Lesser Antilles	Zc (4)	
1993	Taiwan	Zc (2)	
1994	Taiwan	Zc (2)	

Year	Location	Species (numbers)	Associated activity, when available
1996	Greece	Zc (12)	Naval LFAS trials
1997	Greece	Zc (3)	
1997	Greece	Zc (9+)	Naval maneuvers
1998	Puerto Rico	Zc (5)	
1999	Virgin Islands	Zc (4)	Naval maneuvers
2000	Bahamas	Zc (9), Md (3), *Ziphiid* sp. (2), minke whale (2), *Balaenoptera* sp. (2), Atlantic spotted dolphin (1)	Naval mid-frequency sonar
2000	Galapagos	Zc (3)	Seismic research
2000	Madeira	Zc (3)	Naval mid-frequency sonar
2001	Solomon Islands	Zc (2)	
2002	Canary Islands	Zc (9), Me (1), Md (1), beaked whale spp. (3)	Naval mid-frequency sonar
2002	Mexico	Zc (2)	Seismic research
2004	Canary Islands	Zc (4)	Naval maneuvers

Zc=*Ziphius cavirostris* (Cuvier's beaked whale); Md=*Mesoplodon densirostris* (Blainville's beaked whale); Me=*Mesoplodon europaeus* (Gervais' beaked whale)

Range of species involved: beaked whales, other?

While marine mammal species other than beaked whales have been involved in mass strandings associated with anthropogenic sound, the connection is more readily apparent with beaked whales, in part because beaked whales are not known to regularly mass strand due to other causes (e.g., disease). In comparison with beaked whales, other species of cetaceans such as pilot whales mass strand more regularly, and these events are often attributed to causes other than anthropogenic sound exposure. Because beaked whale mass strandings are so rare, these strandings are likely to lead to questions about their possible causes. However, while the connection is more obvious in the case of beaked whales, other cetaceans have also been involved in strandings associated with anthropogenic noise. Minke whales, (Bahamas 2000), pygmy sperm whales (Canary Islands 1988), and bottlenose whales (Canary Islands 1988) have stranded concurrent with beaked whales. In other instances, melon-headed whales (Hawaii 2004), harbor porpoises (Haro Strait 2003[17]), and humpback whales (Brazil 2002) have stranded in events that did not involve beaked whales. In addition to these, NMFS is still investigating whether the pilot whales, minke whales, and dwarf sperm whales that stranded in North Carolina (January 2005) had traumas consistent with acoustic impacts. It should be noted that NMFS has not provided any report on the North Carolina incident, which occurred over ten months ago, and has not provided a final report on the Bahamas 2000 stranding almost five years after the event. This limits the ability to draw any conclusions about these events and the involvement of species other than beaked whales.

Table 2. Associated Mass Strandings Involving Species Other Than Beaked Whales[19]
(Engel et al. 2004; Martin et al. 2004; NOAA and U.S. Navy 2001; NMFS 2005; Tomaszeski 2004)

Year	Location	Species (numbers)	Associated activity (when available)
1988	Canary Islands	Pygmy sperm whale (2), Zc (3), bottlenose whale (1)	Naval maneuvers
2000	Bahamas	Minke whale (2), *Balaenoptera* sp. (2), Atlantic spotted dolphin (1), Zc. (9), Md. (3), Ziphiid sp. (2)	Naval mid-frequency sonar
2002	Brazil	Humpback whale (8)	Seismic exploration
2003	Washington, United States	Harbor porpoise (14), Dall's porpoise (1)	Naval mid-frequency sonar
2004	Hawaii, United States	Melon-headed whale (~200)	Naval mid-frequency sonar
2005	North Carolina, United States	Long-finned pilot whale (34), dwarf sperm whale (2), minke whale (1)	Naval maneuvers; investigation pending

Range of sound sources involved: sonar, airguns

Much has been made of the impact of Naval sonar, particularly mid-frequency sonar, and the connection to strandings, particularly of beaked whales. That there is a connection is clear.[20] Whether or not there is a connection to the strandings of other species is still a matter of disagreement, although for those non-beaked whale species stranding alongside beaked whales during a noise event, it would be hard to believe that there is no connection. It is unnecessary to dwell on this type of sound source as being the only one having impacts on marine mammals.

Other sources of sound, particularly seismic and shipping, should be of equal concern. Seismic surveys use sound that can travel across entire ocean basins. A single seismic survey in the northwest Atlantic was found to flood an area almost 100,000 square miles with one hundred fold greater than ambient noise levels, persisting so as to be nearly continuous for days.[21] This form of intense underwater sound has been used for many years but has only recently undergone any scrutiny as to its possible impacts on marine mammals. Scripps Institution of Oceanography scientific research to study deep ocean temperatures to assist global climate change models (i.e., Acoustic Thermometry of Ocean Climate (ATOC) was specifically intended to be both transoceanic and operational over decades. The U.S. Navy's Low Frequency Active Sonar (LFA) is intended to ensonify an underwater area of several million km^2 at greater than ambient levels.[22]

In 2004, the International Whaling Commission's Scientific Committee concluded that increased sound from seismic surveys was "cause for serious concern."[23] Its conclusion was based on a substantial and growing body of evidence that shows that seismic pulses can kill, injure, and disturb a wide variety of marine animals, including whales, fish, and squid. Impacts range from strandings, to temporary or permanent hearing loss and abandonment of habitat and disruption of vital behaviors like mating and feeding. The IWC Scientific Committee expressed great concern about the effects of seismic surveys on blue, fin, and other endangered large whales,[24] particularly in their critical habitats, and some scientists have asserted that the persistent use of seismic surveys in areas known to contain large whales in significant numbers should be considered sufficient to cause population-level impacts.[25] The State of California (State Lands Commission) banned further high-energy seismic surveys within its waters until such time as a programmatic Environmental Impact Report is completed, due to concerns about the impact of seismic surveys on fish eggs and larvae.[26]

In 2002, in the Gulf of California, Mexico, two beaked whales (*Ziphius cavirostris*) were found to have stranded coincident with geophysical surveys that were being conducted in the area.[27] That same year, the stranding rate of adult humpback whales was unusually high compared with that of juvenile humpbacks along Brazil's Abrolhos Banks, where oil and gas surveys were conducted.[28] Studies suggest that substantial numbers of western Pacific gray whales, a population that is considered critically endangered, were displaced from important feeding grounds in response to seismic surveys off Russia's Sakhalin Island.[29] Other marine mammal species known to be affected by airgun arrays include sperm whales, whose distribution in the northern Gulf of Mexico has been observed to change in response to seismic operations;[30] bowhead whales, which have been shown to avoid survey vessels to a distance of more than twenty kilometers while migrating off the Alaskan coast;[31] harbor porpoises, which have been seen to engage in dramatic avoidance responses at significant distances from an array[32], and all small odontocetes in U.K. waters where sighting rates (combined) are significantly higher when air gun arrays are not shooting.[33]

Until sufficient stranding teams are in place to report, monitor and correlate possible strandings that might be associated with the use of seismic surveys and until there is a long-term study on the possible cumulative and synergistic effects on populations it will not be possible to have an accurate picture of the extent of the problem, and it will remain a major concern.

While Navy sonar and seismic surveys are the most obvious and easily recognizable as causing direct adverse impacts to marine mammals, the effects of shipping also rise to the level of significance. Shipping, however, unlike sonar and seismic noise, is not a single source of noise that can be as easily studied. Shipping is diffuse and spread throughout the world's oceans, raising the ambient levels of sound. Shipping noise creates the same frequencies used by many marine species, including baleen whales.[34] The most probable impacts of shipping relate to the masking of biologically meaningful sounds, and to chronic and sublethal effects including disruptions to breeding, migration patterns, and communication. In addition, shipping noise may create stress that could contribute to a variety of synergistic impacts that affect the longevity of individuals and have possible long-term population impacts.

Other sources of anthropogenic sound in the oceans that are of significant concern include underwater explosives, anti-predator devices (e.g., acoustic harassment devices (or AHDs)) and whale watching boats. Whale watching boats have been linked to possible population-level impacts and are of particular concern because they are specifically directed at whales.[35]

Mechanisms of injury: auditory, behavioral, non-auditory

There is currently considerable scientific debate about the mechanisms of injuries sustained by marine mammals that lead to strandings. While this is of obvious scientific interest and importance, it should not be considered important relative to the regulatory agencies' decisions regarding the management of sound-producing activities. Knowledge of the mechanisms of injury could result in a better understanding of how to mitigate for these lethal impacts. Until this knowledge gap is filled, agencies must make decisions about allowing these activities to proceed. Regardless of how the injuries take place, the fact that sound sources cause them, affecting not only individuals but also possibly populations, must be factored into agencies' decisions about permitting and management.

Recommendations:

1) Provide funding to have sufficient stranding teams available to review and obtain information on strandings in a timely manner.
2) Increase the level of monitoring to detect strandings or mortalities at sea associated with noise events.
3) Develop a standardized form for the reporting of data from strandings, including consistent necropsy examinations to detect acoustically-related injuries.
4) Allow for a limited number of members of the public to be present during necropsies to increase the transparency of the process.
5) Require reporting of any activities involving sound in areas where there was a stranding, including date, time, and location of the activity.

Effectiveness of Current Management/Mitigation

What are the best practices?

Many sound-producing activities serve important social, economic, or other purposes, and effective management of their effects is therefore essential, particularly when prevention of adverse effects is not practicable. Addressing human-caused acoustic impacts on marine mammals through a comprehensive and transparent management system should be a high priority, and potential and known adverse effects associated with anthropogenic sound should be minimized in the marine environment. Scientists have not conclusively identified all situations in which anthropogenic sound will have adverse effects, but a range of mitigation and management techniques or approaches currently exist, that, if implemented, may reduce potential adverse effects.

The components of systems for managing the effects of sound on marine mammals include knowledge and research, risk assessment, permit and authorization processes, mitigation tools and monitoring, evaluation, enforcement, and compliance activities. Mitigation consists of a suite of tools designed to prevent, reduce, eliminate, or rectify the impacts of sound introduced into the environment. When considering the application of mitigation strategies, managers begin with the ultimate goal of preventing adverse effects (e.g., through source removal or exclusion zones). If that prevention is not practicable, they modify their strategies to minimize impacts on marine mammals (e.g., through source or exposure reduction) consistent with existing statutes. It is important to note that sound-producing activities may not be allowed to proceed in cases where mitigation is inadequate or impossible and the potential adverse effects warrant such action.

The application of fully integrated mitigation systems that bring together an appropriate combination of the tools at managers' disposal is likely to be the best way to maximize effective mitigation efforts. There is not, and probably never will be, a single "silver bullet" solution to designing and carrying out effective mitigation. The effectiveness of source removal is obvious but the effectiveness of other commonly used mitigation measures (e.g., ramp-up and safety zones) has generally not been systematically assessed, and may vary greatly form one case to another. Certain mitigation tools, such as exclusion zones, are inherently effective. However, under certain circumstances, some of these may be impractical for the sound-producers. Mitigation tools currently available include:

- Operational procedures (such as ramp-ups and speed limits);
- Temporal, seasonal, and geographic restrictions; and
- Removal or modification of the sound sources (such as ship-quieting technologies and reductions in sound-producing activities).

Fundamentally, the primary goal of any management system must be to reduce or eliminate the intensity, and thus the potential for negative impacts, of noise sources by either not undertaking these activities to begin with, or through modifications to those activities (including the use of alternative, quieter technologies), and geographic and seasonal restrictions or exclusions.

Mitigation strategies that have the greatest potential for reducing risks to marine mammals include, as a matter of priority, reduction of source levels or source removal. Moreover, reducing overall sound levels is a general premise of mitigation, and should be a goal of any management system attempting to prevent adverse effects on marine mammals, and in so doing, pursuing targeted mitigation of discrete noise-producing activities. To this end, we highlight several proactive mitigation tools that we believe are the most effective and should be improved upon and employed expeditiously for managing the impacts of human-generated noise on marine mammals and their habitats.

Seasonal and geographic exclusions: Geographic areas or regions that are biologically important for marine mammals (i.e. breeding, feeding, calving and migratory habitats) should be off-limits to noise-producing activities on a seasonal or permanent basis. This tool is the most effective in preventing harmful effects of noise on marine mammals by excluding noise-producing activities from critical habitats during important biological activity.

Marine reserves. Designating and enforcing marine reserves can be an extremely effective tool for protecting marine mammals and other marine life from noise-producing activities. Commercial activity, such as oil and gas exploration and extraction and other habitat-altering activities, should be off limits in marine reserves.

Source removal, reduction and modification. Where forms of marine habitat protection such as marine reserves and seasonal restrictions are not possible, lowering noise levels or removing them altogether are possible options through the use of alternative technologies.

The above tools are inherently the most effective at reducing or eliminating the impacts to marine mammals, but there are also practical limitations on their use and they may not always be "practicable" under current statutes. The use of safety zones with adequate monitoring is the next best level of protection that can and should be used.

Safety zones. Safety zones are centered around a sound source, rather than an animal. A safety zone is a specified distance from the source (generally based on an estimated received sound pressure level) that must be free of marine mammals before an activity can commence and/or must remain free of marine mammals during an activity.

The sizes of safety zones are typically determined using a variety of information, including prior observations of marine mammal impacts, sound propagation models, sound source information, real-time acoustic measurements, and consideration of other mitigation measures employed.

There are several limitations on the effectiveness of safety zones, including our lack of scientific knowledge about what levels of sound may be safe for a particular marine mammals species and thus the appropriate "received level" that is required to be set. In addition there are significant limitations on the ability to detect marine mammals prior to their entering the safety zone.

Safety zones are generally used in conjunction with marine mammal observers. These observers are individuals ranging from marine mammal biologists and trained observers to crewmembers who conduct visual surveys of marine mammals (i.e., watching for their presence or behavior) for various reasons including maintenance of marine mammal–free safety zones.

The limitations inherent in visual observations are well known. A variety of factors affect sighting rates. Effective visual observations are also generally limited to hours of daylight. Visual detection is also limited because it can only be achieved at or very near the water's surface. Sighting rates in good conditions are much higher for species that spend more time at the surface, or for those that are more visible when they breathe. However, many cryptic species that spend very little time at the surface (e.g., deep diving beaked whales) are difficult to detect even under ideal conditions.

The limitations of using marine mammal observers to enforce a safety zone can be offset through the use of Passive Acoustic Monitoring (PAM), especially for some deep diving species, if they vocalize. There are some technical limitations to PAM; for example, stationary hydrophones or Acoustic Recording Devices (ARDs) are not particularly useful for monitoring a highly mobile sound source unless there is a bottom array covering the area. Using these methods together, it is still unlikely that 100% of all marine mammals will be detected.

While there are no known mitigation techniques that guarantee elimination of potential and known impacts — other than denying an activity or creating seasonal and geographic exclusion zones — management and regulatory agencies must deal with the need for requests for permits for sound-producing activities. They must therefore, consistent with current statutes, look to all possible mitigation tools to reduce the impact to the level of least practicable adverse impact.

Recommendations for Management and Mitigation:

1) The management agencies should identify, and implement immediately, mitigation measures that are effective for noise-producing activities (e.g., source reduction and removal; geographic and seasonal restrictions) while a sustained national research program that includes systematic study of the effectiveness of mitigation tools is being developed.
2) The agencies should work with the U.S. Navy, air gun users (including scientists, geophysical contractors, and oil and gas companies), and the shipping industry to prioritize and ensure the development and use of quieter technologies, and other source reduction tools or methods. In addition, management should be extended to unaddressed sources and activities that have the potential to produce adverse effects (including, but not limited to, commercial shipping, recreational watercraft use, whale watching, and the development and use of AHD (Acoustic Harassment Devices, e.g., sounds to keep mammals away from fishing areas), and ADD (Acoustic Deterrent Devices, e.g., use of sound to keep mammals from entangling in fishing nets).
3) The National Marine Fisheries Service and the U.S. Fish and Wildlife Service (the Services) should examine novel applications of conservation tools such as designation of critical habitats, marine protected areas and ocean zoning to protect populations from chronic or episodic anthropogenic noise.
4) The Services should develop standardized and transparent systems and formats for the collection of monitoring data to be able to systematically take advantage of appropriate opportunities to collect data that can be used for statistical analysis, and facilitate the review, aggregation, and publication of data and results of those analyses.
5) The Services should establish training and certification programs to ensure that observers are qualified to conduct effective monitoring, enabling data to be utilized effectively.

Cost-effectiveness and practicality/practicability

Current statutes authorize the Services to issue permits for taking marine mammals that meet specific requirements, and to authorize small incidental takings of small numbers of marine mammals for activities "within a certain geographical region… during periods of not more than five consecutive years…" provided (1) that "the total of such taking… will have a negligible impact on such species or stock" and (2) that the agency "prescribes regulations setting forth… permissible methods of taking… effecting the least practicable adverse impact" on marine mammals. The MMPA has been working relatively well and there is no reason to believe it needs changing. The current statutes do not include cost or cost-effectiveness as a consideration in the application of mitigation to reduce the impact to the least practicable adverse impact. NMFS must provide meaningful protections for species regardless of the resulting economic costs. In addition, while some military exemptions may be warranted, broad-scale and unneeded military exemptions from the MMPA are not appropriate. This is critically important because the purpose of these statutes is to protect and preserve these species. To include cost and cost-effectiveness as considerations in the protection of species would undermine those protections and complicate the statutes to the point where requiring mitigations would become almost impossible. Protections provided for under the MMPA, NEPA, and ESA would become meaningless. There is no definition of what is meant by "cost-effective" and, as has been stated under the Mitigation Best Practices Section above, no mitigations to date have been studied for their effectiveness. To determine if a mitigation is "cost effective" would first require a determination of the mitigation's effectiveness relative to potential and known impacts to the species. It is clear that at this point there are huge data gaps and high uncertainty in all aspects of this field. It would first require a series of long-term studies to better understand marine mammals and to look at the impacts of noise along with a determination of the mitigation's ability to reduce that impact. While we highly recommend that such studies be conducted, the results and ability to interpret them are decades away. In the meantime, decision-makers cannot be stripped of the only mechanisms they have at their disposal to reduce the potential and known impacts of anthropogenic sound on marine mammals.

Assignment of burden of proof: sound producers vs. regulators

The current regulatory system, NEPA (National Environmental Policy Act), MMPA (Marine Mammal Protection Act), ESA (Endangered Species Act), and CZMA (Coastal Zone Management Act), requires that the impacts of activities affecting marine mammals be reduced to the least practicable adverse impact and sets the burden of proof for determining what those impacts are with the sound producer.[2] This is essential to retain. Given the scientific uncertainty surrounding this issue, the difficulty in studying marine mammals, our expectation that the data gaps will not be filled perhaps for decades, and the likelihood that scientific certainty can be achieved in the near future, or ever, is very remote, the need to have those proposing an activity show that their activity can be mitigated to reduce the potential for impact is essential. If agencies are required to prove that a sound-producing activity causes harm before requiring reasonable protection through mitigation, no mitigations will be able to be required and serious and/or irreparable harm to these important species could occur.

Precautionary approach—addressing the uncertainty

Given the level of uncertainty, the data gaps, and the serious – even lethal – potential effects of sound on marine mammals, precaution is necessary to protect and conserve these species that have a special place and role in nature and in our culture. While there is no clear-cut, agreed upon definition of precaution or the precautionary approach, some level of precaution is appropriate, given the difficulty of studying marine mammals in the wild, our lack of knowledge of marine mammal populations, and the potential for harm to occur before it is detected. The current regulatory system, through provisions in NEPA, MMPA, and ESA, incorporates precaution. Scientific uncertainty should not be used as a justification for postponing action to protect these species. Failure to take a precautionary approach until scientific certainty is achieved, which may never be possible, and attempting to shift the current burden of proof from the applicant to the agencies, could result in direct population effects, leading to the extinction of some species.

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[2] Under the ESA, the take (harm/harassment) of listed species is strictly prohibited and consultation is required under the regulations whenever a federal activity/permit "may affect" a listed species. Following consultation, "take" may be authorized only where the agency/applicant can "insure" that the authorized action "is not likely to jeopardize" the survival of the species or adversely modify its critical habitat. "Any person who wants to be shielded from Section 9 liability for a take by an exemption or take permit "shall have the burden of proving that the exemption or permit is applicable has been granted". Taken together this puts the burden on anyone who wants to undertake an activity that could affect a listed species. The MMPA has language that similarly applies.

The California Coastal Commission believes that protecting marine mammals, which it considers to be coastal resources, is important to this State. As such the Coastal Commission applies precaution in its decision-making process in two ways. Under the CZMA, precaution is applied to mean that given uncertainties that might impact coastal resources the applicant is required to mitigate possible impacts to the maximum extent practicable and to monitor for impacts. Under the Coastal Act, if there is uncertainty the Coastal Commission takes the position that the applicant must avoid or mitigate the impacts to a negligible level. If avoidance is not possible, or if mitigation is not possible, or if it is unknown whether mitigation will work, then the Coastal Commission may deny the project. In each case, the Coastal Commission applies the generally accepted legal principal that the applicant bears the burden of proof that the proposed project/action will *not* impact coastal resources.

The California Coastal Commission believes that the current regulatory system should be retained and even strengthened to enable regulatory decision-makers the ability to factor in the current and evolving field of science that indicates that the impact of anthropogenic noise on marine mammals may be significant.

International or multi-lateral approach

Few marine mammals are restricted to the waters of any one country. While the problem of anthropogenic sound is international in scope, the California Coastal Commission's jurisdiction extends only to this State's waters, federal waters off its coast, and impacts on this State's coastal resources, i.e., marine mammals that pass through or live in or on California's coast. It is therefore beyond the scope of our jurisdiction to deal with marine mammals on an international level and we will not comment on this aspect of the problem.

Priorities and Conduct of Research

Diversification and distribution of research funding/Safeguards against bias in research

Bias in scientific research is recognized as a significant problem in all fields of research. The issue of bias in science is not a new one and is not specific to this field of inquiry. Many articles have been written on this subject and scientists and those who work with the scientific community have struggled over ways to deal with this issue. This issue becomes of even greater concern when there are limited sources of funding and the major sources are tied to those who have a vested interest in the outcome of the research. In addition, the very manner in which research funds are typically allocated may frustrate consideration of less damaging alternatives.

There is not now, nor has there ever been, such a thing as pure science. Science does not have absolutes and scientific certainty is relative. However, scientists strive to achieve as much independence and integrity in their work as possible, but they are human. Bias can affect the questions that are asked, the hypotheses posed, the method of research and analysis, which projects are funded, and the interpretations of the results and how they are presented. Bias can be unwittingly introduced or intentional. It is based on personal, social, political, and religious viewpoints. To attempt to deny that it is possible within this field of science, when it occurs in EVERY field of science, is to prevent taking steps to deal with and minimize it. An attempt to ignore it and fail to put into place mechanisms to reduce it can only lead to greater suspicion on the part of the public. This causes a heightened perception of bias and serves no purpose. In addition, because we are aware that one of the principal issues regarding bias and the perception of bias comes from a direct connection between the source of funding and the user, it is necessary to distance the funding from the noise producer and diversify and distribute as much as possible the funding sources for research.[36]

Some believe that peer review and ethical guidelines remove the possibility of bias, but this is not the case. While peer review helps, it does not solve the problem. Peer review does not remove many of the aspects of research that bias can affect as outlined above. It can be prone to bias itself (depending upon the reviewers), poor at detecting gross defects, almost useless for detecting fraud, and does not address the issue of which projects are funded.[37] In addition, the pre-publication "vetting" of manuscripts by the funder, actual interference by the sponsor into the research, or withholding of complete data by the researcher preventing independent analysis, are problems not solved by peer review. Other mechanisms must also be put in place to help reduce the problem.

One of the first questions always asked when reviewing any research is, who funded it? If the only source of funding is from those with an interest in seeing one point of view and that is the only research that has been published on that subject, then the research will too easily be dismissed as biased, even if it may be valid.[3] As decision-makers involved in determining approval and mitigations we believe it is counterproductive to only have research that could be considered biased. If only sound producers and the agencies that regulate them fund all research, that research is subject to question and therefore could be of reduced use to decision-makers. Although we support the creation and funding of a national program to understand the impacts of sound on marine mammals, we do not support funding unless the issue of bias is dealt with explicitly.

There are numerous models for increasing funding diversity, independence, and public transparency. For instance, the National Oceanographic Partnership Program (NOPP) is a collaboration of fifteen federal agencies. NOPP brings the public and private sectors together to support larger, more comprehensive projects. Another model for achieving funding diversification is the National Whale Conservation Fund administered by the National Fish & Wildlife Foundation (NFWF). Legislation could establish a targeted fund at NFWF for research into the effects of undersea sound on marine mammals and other species. Still other models would be the establishment of jointly funded, independent non-profit organizations or expanded funding for federal research through NSF, NMFS, Fish & Wildlife Service, and the MMC.

The research programs should be well coordinated across the government and examine a range of issues relating to noise generated by scientific, commercial, and operational activities. Diversification can produce more comprehensive programs, improve opportunities for researchers, and reduce the perception that bias may occur. Also important in achieving these aims is the use of

3 ** NRC (2000), "sponsors of research need to be aware that studies funded and led by one special interest are vulnerable to concerns about conflict of interest. For example, research on the effects of smoking funded by U.S. National Institute of Health is likely to be perceived to be more objective than research conducted by the tobacco industry," *Marine Mammals and Low Frequency Sound*, National Academy Press, Wash D.C. pg 84.

procedural mechanisms such as stakeholder and public participation, and alternative funding structures, such as quasi-independent agencies, that can further insulate decisions about research funding from dominant, sound-producing funders of research.

It is important to set up transparent safeguards and guidelines that aim to minimize the potential for bias or conflict of interest to occur and to expand study into important areas of research that are not as directly relevant to mission agencies' specific objectives and mandates. Transparency and credibility in research should be supported by mechanisms to create full post-publication access to research data. However, any such mechanisms would need to address concerns about the ownership of the data. Full disclosure of data is necessary to allow others to confirm that any unpublished data do not contradict the conclusions of a published study. Data issues already have been addressed for many subdisciplines in ocean sciences and there is no reason to believe why similar data issues cannot be addressed in this discipline.

We strongly urge that sufficient funding be put into place to study this form of pollution and its impacts, which we believe represents a substantial threat to marine mammal populations. Funding for this critically needed research should not be taken from other existing research programs. Any commitment must be a real one, which means that it is in addition to other programs.

What are priority research areas?

Baseline studies on marine population size, population structure, location of critical habitats, and highest concentrations of marine mammals and their behavior are the most pressing priorities. When projects come for permitting it is essential to know precise information about the species and their population size and structure to do an accurate risk assessment. There is a big difference in considering allowing a possible impact to a species that is threatened or endangered or one whose population is essentially unknown or may be structured in such a way as to have small, localized sub-populations, and species whose populations are relatively healthy. Without adequate knowledge of the population, regulatory agencies cannot determine whether the activity can be reduced to the least practicable impact and projects may be denied unnecessarily. Because managers are faced with making these decisions routinely and these decisions cannot wait for long-term studies to determine more precisely the nature of the impacts, this baseline research must proceed immediately. Having better information about the location of critical habitats, where the highest concentrations of marine mammals are located and at what times of year will make it easier for managers and regulatory bodies to determine whether or not exclusion zones and/or seasonal closures are appropriate.

Studies that should also be given high priority are those that will allow for a valid interpretation of what a biologically significant reaction to anthropogenic sound is. To conduct other research, i.e., to use Controlled Exposure Experiments (CEEs) to determine impacts, without knowing more fully what normal behavior is and what it means will not answer the questions we need answered (see additional discussion below). Current efforts to focus on understanding the effects of noise on marine mammals have not resulted in greater protection to them. More importantly, without a more complete understanding of the baseline behavior of un-impacted animals, it will be extremely difficult to ever gain even a moderately complete insight into the impacts and we believe that funds expended will not be efficiently used.

One avenue that is readily available to obtain baseline information through systematic and observational research, and that does not involve the introduction of additional sound into the environment, is to utilize ongoing permitted sound-producing activities. Many of these currently permitted sound-producing activities carry with them the requirement for monitoring and reporting of the monitoring. Unfortunately, there is no standardized form for obtaining the data required in a way that would make these data available for statistical analysis or for research purposes. Additionally, although required as part of the mitigation for the impacts of the activity, sound producers may, and frequently do, keep the actual data obtained as proprietary. This is inappropriate, given that these are mitigation requirements. If all data were required to be made public and if these data were collected in a systematic way, funds expended for the purpose of mitigation could have a dual benefit of providing answers to many questions and result in a significant saving on research funding.

Other areas of priority for research include:

1) Conduct more complete analysis of past and present stranding data, including obtaining more information on whether or not there were sound activities in the area at the time of the stranding, for both naval sonars and seismic surveys.
2) Develop more effective ways to do monitoring before, during and after noise activity as part of current mitigation required of sound producers so that such monitoring data can be analyzed for impacts. This also requires that pre-activity baseline information be available.

Relative importance of research and mitigation efforts

Research on the effectiveness of current mitigations, the improvement of current tools, and the development of additional tools needs to be given the highest priority. While much of what scientists are attempting to learn about marine mammals is of importance to science and our understanding of these species, managers and regulatory bodies such as the Coastal Commission need information immediately to be able to meet the mandates of current statutes and concerns about protection of these species. Basic research and understanding of animal physiology and behavior requires long-term studies. Answers do not come easily, quickly, or cheaply. In the interim, sound producers need to have some degree of certainty about their ability to get permits and regulators need to have information about the value and advisability of requiring mitigations. Given the high degree of probability that noise does cause adverse impact to marine mammals, regulators cannot wait for long-term answers and must have more information on mitigation as soon as possible.

Permitting and authorization for research

The Coastal Commission agrees that researchers who undertake research on or who incidentally take marine mammals in the course of sound-producing research are in need of timely, predictable, and cost-effective permitting and authorization processes that maintain or enhance current levels of protection for marine mammals under the statutory regimes of the Marine Mammal Protection Act (MMPA) and other federal and state laws. The challenge is implementing an effective process that protects marine mammals while allowing much-needed research to be undertaken.

There are many issues of concern facing researchers and federal and state agencies. These include:

1) Inadequate resources available to conduct permitting and authorization processes in a timely and efficient manner;
2) The funds, time, and regulatory and scientific expertise needed by a researcher seeking to obtain a permit or authorization to conduct acoustic research that could impact marine mammals;
3) Lack of clarity regarding the applicability of other statutes like the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA) that may require documentation in addition to that required by the MMPA (Marine Mammal Protection Act);
4) Lack of clarity regarding when programmatic authorizations or permits are appropriate for repetitive activities that do not change significantly over time; and
5) The underlying circular situation in which the lack of information needed, in part, to make permitting and regulatory decisions is perpetuated by the challenges in permitting research activities that could help address those information needs.

To address this situation, there are several steps that could be taken by the Services, researchers, and funding entities to improve the permitting and authorization processes. The California Coastal Commission does not believe that there is any need for statutory changes for the permitting and authorization processes. In 1996 the California Coastal Commission was instrumental in convening the HESS (High Energy Seismic Survey) Team, one of whose primary purposes was to find ways to streamline the permit process for review of seismic surveys in federal OCS off the coast of California. Based on that experience the California Coastal Commission believes that the needs of the researchers for an improved and streamlined process could be accomplished within the current regulatory framework and existing statutes.

The following suggestions to improve the current process include:

- The Services should receive increased funding for their permitting and authorization divisions and that increased funding should be made available to all relevant federal and state agencies for their permitting and authorization divisions to meet compliance needs.

- The Services should adopt a more coordinated approach to:

    i. Provide research funding entities and researchers with clear guidelines to use in determining whether or not a particular research activity requires an application under federal or state law;
    ii. Provide standard background documents, application information, and references to reduce the cost and time of preparing applications; and
    iii. Develop mechanisms, where appropriate, to collectively process and issue permits and authorizations that are similar based on species, region, or activity.

- The Services, research funding entities, and researchers should work together when appropriate:

  i. To develop programmatic environmental impact statements and assessments and to identify mechanisms to collectively process and issue permits and authorizations especially for repetitive activities that do not change over time;
  ii. To achieve better timing linkages between the process for authorization and permitting, securing funding, and scheduling research operations to minimize potential issues;
  iii. To achieve a more comprehensive and coordinated approach to implementation of both the MMPA and the ESA among the Services; and
  iv. To identify innovative ways to meet regulatory requirements through reductions in potential impacts on marine mammals.

Animal welfare aspects of research—ABR, CEE

There are two experimental techniques that raise significant controversy as to their effectiveness and their implications relative to the welfare of animals: ABRs (Auditory Brainstem Response) and CEEs (Controlled Exposure Experiments). While the Coastal Commission is concerned about the welfare of marine mammals and would not like to see anything done that could harm or kill any individual, its primary concern is to obtain information that will enable it to regulate activities that produce sound in such a way as to eliminate or minimize the effects of that sound. ABRs raise very serious issues regarding the ethical treatment of animals, particularly those that are stranded and in highly stressful situations. This technique provides for the determination of hearing abilities of animals and may also expand the knowledge base to include the hearing values of a variety of species that may likely not be kept in captive situations, but the use of this technique calls for ethical guidelines. The Coastal Commission does not have a position relative to the use of ABR as a technique except to express its concern about making certain that the welfare of an animal is carefully weighed against the possible benefits of using ABR. When using ABR the primary priority when dealing with stranded animals must be their welfare and not the research objective. Nothing should be allowed that will compromise an animal's ability to survive the stranding. With that in mind, the ultimate decision to use ABR or not must be left to those at the scene charged with the rescue and care of these animals.

CEEs, on the other hand, raise an entirely different set of both ethical and research questions. CEEs are experiments in which animals in the wild are exposed to controlled doses of sound for purposes of assessing their behavior or physiological responses.

CEEs are problematic because they introduce additional sound into the ocean and expose not only the target species and/or individuals to be studied, but many additional ones. By doing so, they place animals at risk. In addition, CEEs may tell us whether or not there is an effect, but a better understanding of the behavior and physiology of marine mammals is required to understand the significance of that effect. Thus even a well-designed experiment may not eliminate controversy over a particular activity or project, but may only shift the nature of the debate. Unfortunately, our ignorance regarding the biology and physiology of many marine mammal species is so great that the potential effects of noise and the sound exposures causing these effects is poorly understood. A top priority for understanding what kinds of reactions may be most important for marine mammals exposed to noise must involve studies of baseline behavior of undisturbed animals prior to conducting other research. Until we have a greater understanding of what is a biologically significant response, CEEs may not give us the answers to our questions and thus should be used judiciously and then probably only in concert with other research or as part of a larger research program.

Given the controversial nature of CEEs and the ethical questions they raise, and because they are not a benign form of research, it is particularly important that when CEEs are used, they be carefully designed and their limitations acknowledged. If CEEs are to be used, it is important to have accurate information about the population status of both the target animals and any others that may be exposed. When endangered species or small local populations are involved, the use of CEEs could result in population effects and therefore should be avoided. In some cases, where the species is highly endangered or where there is little or no information about that population, CEEs should not be used, since the risk associated with the experiment may be too great.

For long-term effects, long-term research is required. It is not practical to use CEEs over long time periods or large spatial scales, i.e., the larger the area the more non-target species will be impacted. CEEs should use, as much as possible, sound exposures that are realistic and with the same characteristics of sound that the mammals are likely to be exposed to by ongoing sound operations. Further, for CEEs to be effective they must be preceded, as stated above, by baseline studies of behavior and physiology that enable the results of the experiments to be interpreted as to their significance. To eliminate possible bias and arguments that will make the research valueless for regulatory purposes, if CEEs are conducted, there should be agreement, in advance, as to what constitutes a biologically significant effect.

Lastly, research that can yield conclusive results with less risk of harm to the animals should be preferred. Systematic observations using ongoing sound-producing activities should be used in place of CEEs if they can provide similar information. Systematic studies of ongoing sound-producing activities can strengthen monitoring efforts required as mitigation, while retaining the benefit that such studies do not introduce additional sound directed at the mammals. The advantages of observational studies are increased as more attention is given to optimizing measurement methods and study designs with the greatest power to detect real effects and provide convincing results.

No single research approach solves all of our data needs. Monitoring will always be required for regulated activities, and if monitoring data are collected systematically, gathered, and analyzed, they can provide important information on effects. Long-term correlational studies can provide added detail on effects of ongoing activities, and are especially useful for long-term exposures or difficult to reproduce sounds, and CEEs can constitute one component of a larger research and management program, designed to give us additional information where controlled exposures are necessary.

Recommendations:

1) Anthropogenic sound with the potential to harm marine life should be eliminated where possible or otherwise minimized (e.g., through source reduction and removal; geographic and seasonal restrictions).
2) Given the likelihood that anthropogenic sound may have significant impacts on marine mammals, the degree of uncertainty regarding the nature and extent of those impacts, and the need to consider cumulative and synergistic effects, a precautionary approach should be taken with respect to management of marine mammals.
3) Anthropogenically caused acoustic impacts on marine mammals need to be addressed through a comprehensive and transparent management system. The management system should address chronic and acute anthropogenic noise, long-term and short-term effects, cumulative and synergistic effects, and impacts on individuals and populations.
4) The Services should receive increased funding for their permitting and authorization divisions and that increased funding should be made available to all relevant federal and state agencies for their permitting and authorization divisions to meet compliance needs.
5) Congress should provide funding to have sufficient stranding teams available to review and obtain information on strandings in a timely manner and to increase the level of monitoring to detect strandings or mortalities at sea associated with noise events.
6) The Services should develop a standardized form for the reporting of data from strandings, including consistent necropsy examinations to detect acoustically related injuries. The Services should allow for a limited number of members of the public to be present during necropsies to increase the transparency of the process.
7) Congress should require reporting of any activities involving sound in areas where there was a documented stranding, including date, time, and location of the activity.
8) The management agencies should identify and immediately implement mitigation measures that are effective for noise-producing activities (e.g., source reduction and removal; geographic and seasonal restrictions) as a part of a sustained national research program that includes systematic study of the effectiveness of various mitigation tools.
9) There should be a commitment to fund a national research program, with emphasis on baseline behavior, physiology, and population size, location, and structure. That program should have procedures in place to minimize bias and the perception of bias and should include diversification of funding, a prohibition on the pre-publication vetting by funders, and a requirement that all data obtained with public funds be publicly available.
10) The agencies should work with the U.S. Navy, air gun users (including scientists, geophysical contractors, and oil and gas companies), and the shipping industry to prioritize and ensure the development and use of quieter technologies, and other source reduction tools or methods. In addition, management should be extended to unaddressed sources and activities that have the potential to produce adverse effects (including, but not limited to, commercial shipping, recreational watercraft use, whale watching, and the development and use of AHD and ADDs).
11) The Services should examine novel applications of conservation tools such as designation of critical habitats, marine protected areas, and ocean zoning to protect populations from chronic or episodic anthropogenic noise.

12) The Services should develop standardized and transparent systems and formats for the collection of monitoring data to be able to systematically take advantage of appropriate opportunities to collect data that can be used for statistical analysis, and facilitate the review, aggregation, and publication of data and results of those analyses.
13) All data obtained as a result of mitigation monitoring requirements should be public.
14) The Services should establish training and certification programs to ensure that marine mammal observers are qualified to conduct effective monitoring, enabling data to be utilized for observational research.

Conclusion
Although we know that anthropogenic sound in the ocean is a serious threat, we do not have sufficient information at this time to understand the full extent of the problem. One of the biggest challenges faced in regulating the effects of noise is our ignorance of the characteristics and levels of sound exposures that may pose risks to marine mammals. Given the current state of our knowledge we must therefore take a precautionary approach in the regulation of noise. We must also expand our efforts to protect and preserve marine mammals by instituting and using effective mitigation measures – such as geographic exclusion zones – now, to keep marine mammals at a distance from noise sources that have the potential to harm or kill them. In addition, we must commit to understanding this problem better by funding a national research program. Only through a combined approach – precaution, mitigation, and research – can we assure that these very special resources will be here for the enjoyment of future generations.

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APPENDIX 2

Report of an International Workshop:

Policy on Sound and Marine Mammals

Policy on Sound and Marine Mammals:
An International Workshop

U.S. Marine Mammal Commission - Joint Nature Conservation Committee, U.K.
28-30 September 2004 - London, England

Report of an International Workshop: Policy on Sound and Marine Mammals, 28–30 September 2004, London, England

Erin Vos and Randall R. Reeves

23 December 2005

JOINT NATURE CONSERVATION COMMITTEE

Marine Mammal COMMISSION
An Independent Agency of the U.S. Government

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Foreword: A Brief Summary from the Workshop Conveners

The U.S. Marine Mammal Commission (Commission) and the U.K. Joint Nature Conservation Committee (JNCC) sponsored an international policy workshop on sound and marine mammals in London, U.K., 28–30 September 2004. More than 100 participants from more than 20 countries attended. The Commission and JNCC gratefully acknowledge all those who assisted in organizing and carrying out the workshop.

The workshop goals were to:

- Determine the range of efforts to manage, mitigate, and prevent impacts of human-generated sound on marine mammals;
- Determine how various legal and regulatory frameworks have been or could be used to address acoustic impacts on marine mammals;
- Identify cross-boundary or multilateral issues; and
- Identify innovative management strategies and policies that might be incorporated within national and international frameworks.

The workshop included individual and panel presentations as well as small-group and plenary discussion sessions. It focused on promoting contacts and dialogue among expert scientists, industry representatives, policy-makers, and administrators from around world to share information and perspectives about managing the interactions between anthropogenic (human-generated) sound and marine mammals. The organizers did not set out to produce recommendations. Nevertheless, a number of information and institutional gaps, as well as means to address these gaps, emerged as themes from the workshop. We provide our brief summary below.

1. Basis for Concern and State of Knowledge

- Recent mass strandings of beaked whales and other cetacean species have raised international awareness and concern about the impacts on cetaceans from exposure to loud, episodic anthropogenic sounds in low- and mid-frequency ranges.
- Seismic airguns, military sonar, commercial ships, and sound projectors used in large-scale ocean research produce some of the most powerful and pervasive anthropogenic sounds in the oceans.
- Because of the nature of sound propagation in water and the high mobility and wide distribution of marine mammals, managing marine mammal exposures to anthropogenic sound is transboundary in scope and requires international cooperation.
- A wide variety of human activities (e.g., shipping, oil and gas exploration and development, construction, ocean research, and military defense) undertaken by virtually every coastal nation introduce anthropogenic sound into the oceans and seas.
- Different species respond differently to various types and levels of anthropogenic sound. When responses occur, documented effects range from short-term behavioral change to physical injury, stranding, and death.
- In most developing (and many developed) countries, baseline information on marine mammals and underwater sound is far from adequate, and few or no monitoring programs are in place.

- Policy-makers, scientists, and the general public need a better understanding of the effects of sound on marine mammals at both individual and population levels.
- The levels and other characteristics of human-generated underwater sounds from different sources need to be better documented at local, regional, and global levels.
- Scientists and policy-makers need a much better qualitative and quantitative understanding of the mechanisms that link underwater sound to behavioral and physiological responses by marine mammals. Such understanding should include knowledge of dose-response relationships and thresholds of exposure that trigger given effects.
- The biological significance of marine mammal reactions to anthropogenic sounds needs further elaboration. Scientists and policy-makers need to understand the type and scale of effects that would have long-term or irreversible consequences for an individual or a population. Biological significance likely depends, at least in part, on population status. For example, displacement of a few animals belonging to an endangered population could be highly significant, whereas it might be unimportant for a large, healthy population.
- The immediate, acute, or observable effects of underwater sound on marine mammals are important. However, the potential cumulative, synergistic, and long-term effects, although much more difficult to detect, characterize, and measure, may be as important, or even more important, to marine mammal populations.

2. Managing Risk in the Face of Uncertainty

- Risk assessment and environmental impact assessment processes are not used universally, and are not used in relation to some sources of noise. When such tools are used, the potential impacts on marine mammals from anthropogenic sound are frequently overlooked. Use of these tools and consideration of these potential impacts should become routine.
- Best practices in risk assessment and environmental impact assessment involve:
    (a) Recognizing and quantifying risks and uncertainties;
    (b) Incorporating a precautionary approach;
    (c) Assessing potential impacts early in project design so that the results can be used during implementation; and
    (d) Making use of all available relevant data.
- Modifying the spatial and temporal scope of a sound-producing activity may be one of the most effective ways to reduce its risk to marine mammals.

3. Mitigation Strategies

- In managing the risks of sound to marine mammals, strategies must be tailored to particular situations such that appropriate mitigation tools are employed to address particular types and levels of sound and to protect particular species from harm. In other words, a mitigation strategy that is appropriate for one situation may not be appropriate for another: one size does not fit all.
- The most promising mitigation strategies are those that reduce sound output and those that separate sound-generating activities, spatially and temporally, from marine mammals. This separation may be accomplished through, for example, seasonal or year-round avoidance of areas that may include concentrations of marine mammals, areas of

special importance to marine mammals (e.g., locations used for calving/pupping, resting, feeding), or areas used preferentially by species known or thought to be especially vulnerable to harmful effects of particular types of sound (e.g., beaked whales and naval sonar).

- Mitigation strategies that change sound output or constrain operations may be the most expensive or disruptive for the sound producers.
- The shipping industry is a major contributor to the sound budget of the oceans. Shipping is an international enterprise, with many aspects regulated through the International Maritime Organization. Technologies are available for making quieter ships, and the industry's own interests may converge with the conservation imperative to employ those technologies through, for example, a "green shipping" certification initiative. Many ship owners may be willing to work with scientists and conservationists to develop and implement a strategy for managing ship noise, particularly if the risks of ship noise to marine mammals are clearly communicated.
- The effectiveness of many tools currently used to mitigate the effects of human-generated sound on marine mammals (e.g., soft-start/ramp-up, onboard observers to detect marine mammals) is unproven. Monitoring and experimentation should be conducted to test the effectiveness of these and other mitigation techniques.

4. International Cooperation

- Although no existing international legal instrument directly and explicitly addresses underwater sound as a threat to marine mammals, several multilateral agreements contain language that some interpret as applying to this issue (e.g., International Convention for the Regulation of Whaling, United Nations Convention on the Law of the Sea).
- A few multilateral legal instruments and regional bodies are in early stages of addressing this issue. For example, two regional cetacean protection agreements under the Convention on Migratory Species (ASCOBANS and ACCOBAMS) have passed resolutions and commissioned research related to the effects of sound. The North Atlantic Treaty Organization's Undersea Research Centre supports a major program of mitigation and research, focused on reducing the risks to beaked whales from military sonar during research exercises.
- In the absence of an existing international legal instrument with an explicit mandate to address the effects of sound on marine mammals, it will be necessary to decide among three main options for further action:
    (1) Focus on national and/or regional approaches and abandon a global approach;
    (2) Seek to modify or re-interpret an existing international legal framework; or
    (3) Create a new international legal instrument dedicated, at least in part, to this issue.
- Although human-generated underwater sound is a potential problem for marine mammals worldwide, few nations have domestic legal frameworks to address it. Those domestic frameworks that exist (e.g., in the United Kingdom, United States, Brazil, and Australia) tend to be applied unevenly to different sound sources.
- Successfully addressing this issue at all levels—national, regional, and international—will require that the problem be better documented and communicated clearly and credibly, with explicit acknowledgment of both risk and uncertainty.

- The long-term effectiveness of any strategy to address this issue will be enhanced if the solution has a credible scientific basis and is perceived to be culturally sensitive and fair to all stakeholders.

The Commission and JNCC will continue to work on this issue with due regard for the discussions that took place during this workshop. Although international collaboration on research and international cooperation in management efforts are essential, a separate international (global) treaty to address this issue is not considered a viable solution at this time. The effectiveness of international legal instruments depends on the actions of national governments to implement them.

Although a number of multilateral efforts are ongoing, their effectiveness in addressing the effects of human-generated sound on marine mammals remains to be seen. Given the current state of knowledge, advances in this issue are likely to be achieved through national laws and management programs, international collaboration on research, and international coordination of management via regional and industry-based initiatives. We encourage continued international discussion and cooperation, especially on research to reduce scientific uncertainties and on the development of mitigation strategies.

In September 2005, the Commission completed a policy dialogue on the topic of sound and marine mammals involving a 28-member Advisory Committee composed of representatives the major interest groups. Members of the Advisory Committee will submit non-consensus statements to the Commission that provide their views on various topics. Having benefited from the deliberations of this group, the Commission will submit a report to the U.S. Congress, which will contain major findings and recommendations on domestic and international aspects of this issue. The non-consensus statements from Advisory Committee members will be attached to the Commission's report.

This report of proceedings was drafted by Randall R. Reeves and Erin Vos, with assistance from a number of workshop participants, and reviewed and approved by the Commission and JNCC. The authors circulated the draft report to all workshop presenters and topic specialists for comment, but did not seek consensus on each point. The report attempts to portray discussions among workshop participants and the information as it was presented at the meeting. Participants did not formally represent the positions of their employers or home countries. Rather, they informally discussed their own perspectives and experiences. These proceedings do not necessarily reflect the positions of the Marine Mammal Commission, the Joint Nature Conservation Committee, or their respective governments.

December 2005

David Cottingham
Executive Director
U.S. Marine Mammal Commission

Mark Tasker
Head of Marine Advice
U.K. Joint Nature Conservation Committee

Report of an International Workshop: Policy on Sound and Marine Mammals 28–30 September 2004 London, England

Contents

I. Introduction

As an adaptation to their aquatic lifestyle, many marine mammals use sound as a primary means of interacting with their environment. Their use of sound to communicate, navigate, avoid predators, and find food has helped enable cetaceans (whales, dolphins, and porpoises), in particular, to occupy all of the world's seas and oceans as well as some large river systems. However, their dependence on sound has also made them vulnerable to noise associated with human activities. Since the 1970s, with the development and expansion of the offshore oil and gas industry, marine mammal scientists and managers have expressed concern about the biological effects of the underwater sound related to that industry. During the past two decades, such concern has spread to encompass additional human activities. In particular, a series of beaked whale stranding events concurrent with naval activities during the last decade has raised concerns about the potential impacts of military sonar, and studies of increasing ambient noise levels have led to concerns about the potential for shipping activities to have chronic impacts on marine mammals. As major producers of underwater sound, the shipping industry, the oceanographic research community, the oil and gas industry, and the military have come to be viewed as sources of risk to marine mammals.

In his opening remarks to the workshop, David Cottingham, Executive Director of the U.S. Marine Mammal Commission (Commission), emphasized that the meeting's focus was to be on policy rather than science. He outlined the context of this meeting, noting that in 2003 the U.S. Congress had directed the Commission to organize a series of meetings to survey the nature and range of acoustic threats to marine mammals and develop information on how those threats could be addressed.[1] The Federal Advisory Committee on Acoustic Impacts on Marine Mammals (Advisory Committee) was established in December 2003, consisting of 28 members representing the shipping and oil and gas industries, the academic community (including marine mammal scientists and geophysicists), various environmental nongovernmental organizations, the U.S. Navy, and relevant management agencies within the U.S. government. The Advisory Committee was asked to 1) review and evaluate available information on the impacts of human-generated sound on marine mammals, marine mammal populations, and other components of the marine environment, 2) identify areas of general scientific agreement and areas of uncertainty or disagreement related to such impacts, 3) identify research needs and make recommendations concerning priorities for research in critical areas to resolve uncertainties or disagreements, and 4) recommend management actions and strategies to help avoid and mitigate possible adverse effects of anthropogenic sounds on marine mammals and other components of the marine environment.

The congressional mandate directed that the Commission's efforts to address acoustic impacts on marine mammals be international in scope. Although a number of the organizations represented on the Advisory Committee have offices in more than one country and engage in international activities, the Commission decided to investigate directly how the sound issue is (or is not) being addressed outside the United States. It hoped, in the process, to build relationships to improve

[1] 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."

international communication and cooperation. The Advisory Committee supported the idea of a Commission-sponsored international policy workshop and provided valuable advice in the early planning stages. Among the committee's suggestions was that the Commission seek an international partner to co-sponsor the workshop. The Commission approached the U.K. Joint Nature Conservation Committee (JNCC), and in March 2004 the two agencies agreed to collaborate in drafting the agenda, identifying participants, convening the workshop, and producing this report. The Advisory Committee discussed the proposed topics and agenda for the workshop at its plenary meetings in February, April, and July 2004.

A. Goals of the Workshop

The workshop had the following goals:

- To determine the range of existing efforts to manage, mitigate, and prevent impacts of human-generated sound on marine mammals outside the United States.
- To determine the extent to which legal and regulatory frameworks, other than those provided by U.S. domestic laws and regulations, address acoustic impacts on marine mammals.
- To identify cross-boundary or multilateral issues regarding the management and mitigation of acoustic impacts on marine mammals.
- To identify innovative management strategies and policies that might be incorporated within national and international frameworks.

The intent was not to develop recommendations or necessarily to reach consensus on issues. Instead, the focus was on establishing dialogue across international boundaries and on widening the perspectives and strengthening the knowledge base of workshop participants. The workshop conveners and participants made an effort to share information and improve understanding of the range of views on the topics discussed.

B. Workshop Agenda and Procedures

The annotated workshop agenda is given in Appendix 1. The conveners sought to identify and invite individuals from outside the United States and United Kingdom who would have knowledge about and interest in the topic. A diverse group of individuals drawn from industry, military, environmental, academic, regulatory, and other organizations from more than 20 countries attended the meeting (Appendix 2). A majority of participants were from North America or Europe (42 and 41 percent, respectively), with approximately 9 percent of participants from Australia and Asia, 5 percent from South America, and 2 percent from Africa. About 43 percent of participants were employed by government agencies, and about 52 percent were employed by non-governmental entities such as universities or environmental groups. Workshop participants did not formally represent the positions of their employers or home countries; rather, they were asked to discuss informally their perspectives and experiences.

Experts on marine acoustics, marine mammal biology, international law, policy analysis, and environmental impact assessment gave overview presentations. These were supplemented by a series of background papers provided to participants in advance of the workshop (Appendix 3), 27 posters prepared for display during the workshop (Appendix 4), and other materials provided by participants for distribution at the meeting (IAGC 2004, IAGC no date). In addition, several case studies were presented on the legal and regulatory regimes governing underwater sound and marine mammal protection in specific regions.

C. Organization of the Report

The organization of this report follows the workshop agenda, with each of six topics summarized in turn. To the extent possible, the authors have attempted to eliminate redundancy while recognizing that the topics were often interconnected. All presentations referred to in the report can be found online at http://www.mmc.gov/sound/internationalwrkshp/agenda.html.

The report attempts to portray accurately discussions among workshop participants and the information as it was presented at the meeting. The proceedings recorded in this report do not necessarily reflect the positions of the Marine Mammal Commission, the Joint Nature Conservation Committee, or their respective governments.

II. Topic 1: Overview of Human-Made Sound Sources and Impacts on Marine Mammals

A. Overview of Human-Made Sound Sources in the Marine Environment

John Hildebrand (Scripps Institution of Oceanography, U.S.) provided a brief introduction to acoustics concepts and described sources of human-generated sound and their global distribution in the marine environment. Broad categories of sound were distinguished—continuous vs. intermittent (pulsed) and broadband vs. narrowband. To compare different sounds (e.g., a continuous broadband source and a pulsed narrowband source), the standard approach is to combine pressure, time, and frequency to produce an energy level metric.

Hildebrand described major biological and human-generated components of ambient ocean noise. In general, sounds contributing to ambient noise in the oceans come from natural phenomena such as earthquakes, rainfall, and animal calls, along with anthropogenic activities including shipping, seismic surveys (airguns), and sonar use. Only one good measurement of long-term trends in ambient ocean noise is available: a U.S. Navy Sound Surveillance System (SoSuS) array documented a 10-dB increase in low-frequency (10–1000 Hz) ambient noise in the eastern Pacific Ocean off Point Sur, central California, from 1964 to 2001 (Andrew et al. 2002). Hildebrand considered this increase to be due primarily to shipping, as it seems to correspond to a rapid and consistent upward trend in container ship trades to the United States over the last few decades. As ships pass over the edge of the continental shelf, the low-frequency sounds they produce are transmitted to deep channels and thence can travel over long distances. Nieukirk et al. (2004) illustrated this deep channel phenomenon by reporting that a series of hydrophones along the Mid-Atlantic Ridge have recorded the distant sounds of airguns from seismic vessels almost continuously throughout the year. These sounds are likely coming from deep waters off Europe, Africa, and eastern North and South America.

Hildebrand stressed the value of developing regional and global ocean sound energy budgets and the importance of a long-term monitoring program to track future changes in ambient ocean noise. The most potent individual anthropogenic sound sources in the oceans are underwater nuclear explosions (source levels[2] greater than 300 dB), navy ship shock trials (source levels ~250–300 dB), mid-frequency and low-frequency active sonars (source levels ~200–250 dB), and seismic airguns (source levels ~200–260 dB). A rough annual energy budget might be developed by considering the number of each type of sound source active in a given year, along with individual source characteristics and duty cycles. Hildebrand identified the following priorities for monitoring ocean sound:

- Mapping ocean noise in areas of anthropogenic sound production (e.g., shipping lanes, industrial sites, and navy ranges),
- Initiating long-term ocean noise monitoring,
- Analyzing historic marine anthropogenic noise data,
- Developing global models for ocean noise,

[2] Source and received levels of sound reported in dB re: 1 µPa @ 1 m unless otherwise stated.

- Identifying signal characteristics for anthropogenic noise sources, and
- Determining the relationship between anthropogenic activity level and noise level.

B. Overview of Potential Impacts of Human-Generated Sound on Marine Mammals

In his presentation, Peter Tyack (Woods Hole Oceanographic Institution, U.S.) focused on marine mammals as receivers of sound. The standard model (based on Richardson et al. 1995) for characterizing and managing the effects of sound on marine mammals is to identify zones of influence, with different responses expected at different distances from the sound source, corresponding to lower levels of sound at increasing distances from the source.

Injury from exposure to sound can take several different forms, including auditory and non-auditory physiological damage. Non-auditory physiological damage may occur through blast injury. For example, pinnipeds and odontocetes have been reported killed, and baleen whales seriously injured, from underwater explosions in the wild. In such cases, the actual mechanism of mortality or injury has not been established, but the greatest effects generally occur at boundaries of tissues with different densities, especially gas-liquid interfaces. Acoustically enhanced bubble growth may also play a role in causing non-auditory injury due to sound exposure; Tyack suggested this might be most relevant for prolonged tonal signals and exposures in the immediate vicinity of the source (Crum and Mao 1996). Auditory injuries can be signaled by temporary threshold shifts (TTS) due to system fatigue, or permanent threshold shifts (PTS) that can result either from prolonged or repeated TTS or from brief exposure to very high-intensity sound.

It is important to make a conceptual distinction between injury and the disruption of behavior, as these are different classes of effects. Injury is typically analyzed at the individual level. However, assuming that the focus of conservation is on populations rather than individuals, changes in behavior are of interest not in their own right, but as proxies for estimating the impacts of anthropogenic sound at the population level. Tyack described a variety of ways in which behavior can be affected by sound exposure. Avoidance responses are relatively easy to monitor, and can be viewed as indicative of habitat degradation. However, population-level assessment of such an effect may require estimation of how much habitat is affected, what proportion of the population is affected, and whether avoidance interferes with critical activities. Tyack asserted that one of the best examples of a potentially population-level disturbance effect occurred in Laguna Guerrero Negro in Baja California, an area that was abandoned by gray whales during the 1950s and early 1960s when dredging and commercial shipping activities in the area were intense. When those activities stopped in the mid-1960s, gray whales from other lagoons recolonized Guerrero Negro. Another relevant example comes from the western Arctic, where bowhead whales have shown pronounced avoidance responses to seismic activity associated with the oil and gas industry. Whether such behavioral changes have population-level effects remains unclear. Both of these whale populations—gray whales in the eastern North Pacific and bowhead whales in the western Arctic—have increased in recent years.

The biological significance of behavioral disturbance is of great interest to scientists and resource managers, but the concept is difficult to define. Growth, survival, and reproduction are generally regarded as indicative of biological significance. For example, changes in feeding behavior, stranding, and changes in mating behavior in response to sound exposure might be regarded as significant impacts. New tools are improving our ability to evaluate the impacts of sound on behavior. For example, digital acoustic recording tags provide sophisticated metrics to estimate the energy cost of diving, which can be incorporated with energy models to investigate the implications of disrupted feeding behavior. A feeding whale needs to take in more energy than it expends, allowing a reserve for growth and reproduction. Tyack observed that controlled exposure experiments are proving highly informative for characterizing and quantifying whale responses to sound.

Apart from overt behavior, effects that are less readily observed and measured might also be biologically significant. For example, male blue whales produce low-frequency calls for reproductive advertisement. Tyack pointed out that because blue (and fin) whale calls might be heard at distances of up to 1,000 km, their mating system(s) could have evolved to depend on breeding advertisement over vast geographical distances, and the increased ambient noise from ship traffic and other sources may have reduced their potential range of communication by an order of magnitude. It is possible that the whales are managing to compensate for such degradation of their acoustic environment, but in any event, this relatively subtle effect would be exceedingly difficult to detect and measure. Cumulative and synergistic impacts further complicate matters, as repeated or multiple exposures to sound, in combination with other factors such as fisheries bycatch or chemical pollution, may lead to more serious effects. The overall impacts of sound on marine ecosystems (of which marine mammals are a part) also merit consideration.

III. Topic 2: Introduction to National and International Legal and Regulatory Frameworks for Marine Mammals and Human-Generated Sound

The central topic addressed in this section of the workshop was the range of national and international laws and regulatory mechanisms governing acoustic impacts on marine mammals.

The session was organized around a series of short presentations, abstracts of which are provided in Appendix 3. A number of posters also addressed aspects of this topic (Appendix 4, note especially posters 4, 15, 23, 26, and 27).

As case studies, each of the presentations was intended to address the following questions:

- Which countries are considered? What are the main sound sources of concern in the country or region? How is the country or region unique?
- How are various countries alike or different in their approaches to protecting marine mammals and/or regulating anthropogenic sound production? How do their systems of government differ?
- What limitations do countries face in dealing with the impacts of sound on marine mammals?

A. European Seas

Mark Tasker (JNCC, U.K.) defined European Seas as a region stretching from the Arctic Ocean, via the northeastern Atlantic (including the North and Baltic Seas), to the Mediterranean and Black Seas. The area encompasses a wide range of habitats, species, and legal jurisdictions. Tasker gave a brief summary of the various frameworks and instruments in Europe under which anthropogenic sound in the marine environment could be managed, including international "regional seas" conventions, international "conservation" agreements, international economic integration organizations, and national laws. Each type of framework has a different geographic and legal applicability.

Existing regional seas conventions and conservation agreements include the Convention for the Protection of the Marine Environment of the Northeast Atlantic (OSPAR, 1992[3]), Convention for the Protection of the Marine Environment and Coastal Region of the Mediterranean (Barcelona Convention, 1976[4]), Convention for the Protection of the Black Sea Against Pollution (Bucharest Convention, 1992[5]), and Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention, 1992[6]). The regional seas conventions generally define "pollution" as substances or energy that cause harm to living resources. Therefore, they arguably have the potential to be used as frameworks for providing protection to marine mammals from the adverse effects of human-generated sound. Most regional seas conventions have a framework under which more detailed agreements or resolutions may be set; as yet, however, none has

[3] See http://www.ospar.org/.
[4] See http://www.greenyearbook.org/agree/mar-env/barcelona.htm.
[5] See http://www.blacksea-commission.org/; http://www.greenyearbook.org/agree/mar-env/bucharest.htm.
[6] See http://www.helcom.fi/.

produced such an agreement or resolution dealing explicitly with marine mammals and human-generated sound. More geographically limited "subregional seas" agreements include the North Sea Conference under OSPAR, the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS, 1992[7]), and the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS, 1996[8]). Other conventions include the North Atlantic Treaty (NAT, 1949;[9] see B, below).

Although no explicit, binding measures in regard to marine mammals and sound have been taken under any of those instruments, a few developments are evident:

- The North Sea Conference is working to produce a "sustainable shipping" component.
- ASCOBANS is committed to working "towards prevention of other significant disturbance, especially of an acoustic nature." ASCOBANS adopted a resolution on ocean noise and marine mammals; has developed guidelines for seismic operations, recreational boating, and whale-watching; and will begin a program requiring member governments to report on sound-generating military activities in 2005. There has also been some discussion of shipping, with research recommended.
- ACCOBAMS prohibits "any kind of cetacean harassment," and is working toward a resolution on human-generated sound. The resolution would call for more research on the effects of sound on cetaceans and the development of guidelines (with the use of sound prohibited until these are in place). Specific resolutions for whale-watching and the use of acoustic harassment devices are also likely.[10]

The major international economic integration organization in the region is the European Union (E.U.). The E.U. operates through Directives, which are implemented by national laws into which the language of a Directive is often simply transposed.[11] Relevant E.U. Directives of potential relevance to management of underwater sound are those on Habitats (92/43/EEC[12]), Environmental Impact Assessment (EIA; 85/337/EEC[13]), and Strategic Environmental Assessment (SEA; 2001/42/EC[14]). The Habitats Directive calls for the creation of protected areas (for seals, bottlenose dolphins, and harbor porpoises), with strict protection of designated species, including prohibitions on indiscriminate killing or deliberate disturbance of cetaceans. The EIA and SEA Directives require a "look ahead" at possible environmental impacts of certain activities (e.g., those of the oil and gas industry). The difference between an EIA and an SEA is that the former concerns an individual activity and is carried out by the proponent, whereas the latter involves license issuance decision-making for multiple activities and is carried out by, or

[7] See http://www.ascobans.org/.
[8] See http://www.accobams.mc/.
[9] See http://www.nato.int/
[10] After this workshop's conclusion, the ACCOBAMS Meeting of Parties in Palma de Mallorca, Spain passed a resolution (MoP2, Resolution 2.16) on anthropogenic ocean noise.
[11] If a Member State fails properly to implement any provision of a Directive by the prescribed deadline, that provision may still be effective through the European Court of Justice's doctrine of "direct effect." This doctrine allows an individual to invoke a non-transposed provision against the Member State if certain conditions are met (e.g., the provision in question must be unconditional and sufficiently precise).
[12] See http://europa.eu.int/comm/environment/nature/nature_conservation/eu_nature_legislation/habitats_directive/index_en.htm.
[13] See http://europa.eu.int/comm/environment/eia/eia-legalcontext.htm.
[14] See http://europa.eu.int/comm/environment/eia/sea-legalcontext.htm#legal.

on behalf of, government authorities. Both Directives allow for public participation, encourage relevant research, and require measures to reduce the effects of harmful activities. E.U. Member States are individually responsible for implementation of the Directives; the timing and mode of compliance varies significantly from one country to another.

Tasker provided a brief overview of relevant national legislation in the United Kingdom, which has sought to implement and apply the E.U. Directives discussed above by means of domestic law. Their implementation, with respect to human-generated sound, has varied across sectors. For the oil and gas industry, guidelines are applied to the use of seismic sound sources and explosives, and full EIA and SEA requirements are in force. For shipping, fisheries, and aggregate extraction sectors, no requirements currently exist. Guidelines and a prohibition on “reckless” disturbance are in place for the tourism industry, while the military sector makes some use of EIA and has received some guidance from the JNCC.

B. North Atlantic Treaty Organization (NATO)

NATO is an alliance of 26 states from Europe and North America that are party to the North Atlantic Treaty of 1949. Michael Carron (Marine Mammal Risk Assessment Program, NATO) reviewed NATO efforts to address the potential impacts of high-intensity sound from military sonar. Those efforts began after Frantzis (1998) called world attention to the 1996 strandings of Cuvier’s beaked whales in Greece coincident in space and time with the deployment of military sonar. The NATO Undersea Research Centre convened a bioacoustics panel to investigate the strandings, which in turn initiated the Sound, Ocean, and Living Marine Resources (SOLMAR) project, a multinational, multidisciplinary research project, and established “marine mammal risk mitigation” protocols and tools to protect marine mammals during active sonar tests or experiments. Rules are now in place to reduce the likelihood that NATO forces will conduct naval sonar exercises in close proximity to beaked whales.

NATO’s SOLMAR project involves research cruises to study the effects of sound exposure on marine mammal behavior, a crisis response team based in the Mediterranean to investigate cetacean mass strandings, and the development of predictive models of whale distribution (e.g., that of Cuvier’s beaked whale). According to Carron, about half of the known mass strandings of Cuvier’s beaked whales have been associated with nearby military operations. Except in a few of these cases, no direct link has been established between the military operations and the strandings. The SOLMAR project’s goal is to refine and update NATO’s mitigation policies to prevent such events. Although it cannot dictate such policies, the project exerts considerable influence on the manner, location, and scheduling of activities by NATO navies, providing advice on all sonar experiments. As such, the existing NATO Undersea Research Centre Marine Mammal and Human Diver Risk Mitigation Instruction establishes the need for environmental scoping studies as part of sonar test plans, requires visual and acoustic watches during tests, sets restrictions for received levels of sound, and establishes a crisis response team. Thus, all NATO active sonar experiments are governed by strict rules and protocols, with even stricter rules imposed for tests planned in regions known or suspected to be beaked whale habitat. Scientists must adhere to instructions and protocols for human and marine mammal risk mitigation. When under NATO control, military units must follow NATO protocols unless either their own nation has stricter rules or protocols, or the host nation imposes stricter rules. When not under NATO control, military units must follow national or host nation rules and protocols. Because of the organizational complexities of NATO, there are ongoing discussions among member nations concerning the exact risk mitigation protocols that will be used during future NATO exercises.

Following Carron's presentation, attention was called to the fact that Australia's naval forces are engaged in extensive efforts to mitigate the potential effects of their sound-producing activities on marine mammals (see Appendix 4, poster 25).

C. Scientific Committee on Antarctic Research (SCAR)

David Walton (SCAR, U.K.) briefly summarized the Antarctic Treaty System (System). The System was initiated under a 1959 framework agreement (the Antarctic Treaty[15]), which includes 45 sovereign States as Contracting Parties, 28 of which are Consultative (i.e., executive) Parties. The System has since been supplemented by the 1972 Convention for the Conservation of Antarctic Seals,[16] the ecosystem-based 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR[17]), and the 1991 Protocol on Environmental Protection to the Antarctic Treaty.[18] SCAR is an independent international body set up in 1956 to coordinate science programs and facilitate planning and collaboration. The Antarctic continent is a demilitarized natural reserve where "peace and science" are supposed to prevail. Member States have the right to make inspections of any installations in the System area at any time and the right to conduct scientific investigations anywhere. Under the 1991 Protocol, all activities are subject to environmental impact assessment and monitoring. Agreements within the System are reached by consensus, and implementation depends on national compliance. Walton noted that consensus is often more easily achieved on guidelines than on legal changes, and that overlapping jurisdictions can cause problems. National legislation by Member States may establish more stringent requirements than those of the Treaty System, and in fact, the permitting of activities may involve multiple agencies and governments.

Walton provided two background documents in advance of the workshop (Appendix 3). His presentation, together with the background documents, provided (a) a review of available information on anthropogenic marine sound and its implications in the Antarctic, (b) suggested mitigation measures, (c) a proposed approach to risk analysis for use in impact assessments prior to issuance of permits for sound-generating activities, and (d) an attempt to establish background levels of underwater sound against which to assess further inputs from human activities. Anthropogenic sound is not explicitly addressed in the System. Although no military exercises or oil and gas industry seismic exploration occurs in Antarctic waters, anthropogenic sound is of some concern in the region. According to Walton, ship traffic, seismic research, and ice breaking are the principal sources of anthropogenic sound in the Antarctic at present. There is some controversy over the extent to which these activities may affect the region's marine mammals.

In discussion, Wolfgang Dinter of Germany's Federal Agency for Nature Conservation, which advises the German Federal Ministry for the Environment, Nature Conservation and Nuclear

[15] See http://www.antarctica.ac.uk/About_Antarctica/Treaty/treaty.html.
[16] See http://www.oceanlaw.net/texts/seals.htm for full text of the Convention.
[17] See http://eelink.net/~asilwildlife/antarctic1980.html for full text of the Convention.
[18] See http://www.antarctica.ac.uk/About_Antarctica/Treaty/protocol.html.

Safety, called attention to several features of the 1991 Protocol that provide a basis for the regulation of potentially harmful underwater sound. These were summarized in a document circulated at the workshop in response to Walton's background documents and presentation (Federal Agency for Nature Conservation/BfN [Germany] 2004). The features include *inter alia* (a) the System's dedication to comprehensive ecosystem protection and (b) a prohibition on taking, or harmfully interfering with, any mammal except under permit. Dinter's further comments on Walton's background documents referred to, *inter alia*, SCAR's information policy on sound and the relation between CCAMLR and the 1991 Protocol with regard to marine environmental protection (SCAR 2002, 2004).

Walton responded that (a) environmental protection is a relatively new aspect of Antarctic Treaty goals (i.e., it was not part of the Agreed Measures but was introduced as part of the 1991 Protocol),[19] (b) there are differences among countries as to how they view jurisdictional limits in implementing the Treaty, and (c) discussion of legalities has often been excessive in comparison with discussion of costs and benefits of various activities. In his view, a risk assessment approach needs to be used more often to evaluate proposed activities in the Antarctic.

D. United States

Douglas Wartzok (Florida International University, U.S.) summarized the legislative and regulatory situation in the United States. He noted that both the Marine Mammal Protection Act (MMPA; adopted in 1972[20]) and the Endangered Species Act (ESA; adopted in 1973[21]) provide a clear and direct basis for protecting marine mammals from the harmful effects of human-generated sound. The National Environmental Policy Act (NEPA, 1969[22]), Outer Continental Shelf Lands Act (OCSLA, 1953[23]), and Coastal Zone Management Act (CZMA, 1972[24]) also have potential applications to this issue. The MMPA mandates an ecosystem-based approach to management and prohibits the "taking" of marine mammals unless explicitly authorized. "Take" means to harass, hunt, capture, or kill, or to attempt to do so. The ESA prohibits "taking" of any threatened or endangered species, where "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to do so. Thus, if the potential impacts of a sound-producing activity were interpreted to constitute taking under either law, the activity would be subject to regulation. The specific regulations and permitting requirements that apply depend on the type of activity. For example, through permits or other authorizations, the MMPA regulates many of the activities that take marine mammals as a result of introducing sound into the marine environment. However, some major economic activities are currently unregulated under the MMPA (e.g., commercial shipping) or regulated by the MMPA under a more liberal set of requirements (e.g., commercial fishing). NEPA requires federal agencies to review potential environmental impacts of activities that they conduct, fund, or permit, and requires the preparation of environmental impact statements (EISs) in certain cases. OCSLA requires reviews

[19] The Agreed Measures on the Conservation of Antarctic Flora and Fauna were adopted in 1964. These Measures address species protection and protected area designation within the Treaty System. (See http://www.oceanlaw.net/texts/antarctic1964.htm.)
[20] See http://www.mmc.gov/legislation/mmpa.html.
[21] See http://www.mmc.gov/legislation/esa.html.
[22] See http://ceq.eh.doe.gov/nepa/regs/nepa/nepaeqia.htm for full text of the Act.
[23] See http://www.csc.noaa.gov/opis/html/summary/ocsla.htm.
[24] See http://coastalmanagement.noaa.gov/czm/czm_act.html.

of all oil and gas leases and development plans in federal waters, and the CZMA requires the federal government to demonstrate consistency between its actions and the coastal zone management program of coastal states with approved programs.

E. Latin America

Monica Borobia (Brazil) indicated that policies and regulatory frameworks concerning marine mammals and sound are either in early developmental stages or have yet to be addressed in most Latin American countries (broadly defined as those in South and Central America, the Caribbean, and Mexico). She cited three main mechanisms available in Latin America to address marine mammal protection and anthropogenic sound production at the national level: (a) general environmental regulations (including directives, licensing guidelines, and action plans), (b) designation of protected areas, and (c) special protection for endemic or threatened species. In addition, most Latin American countries are parties to multilateral agreements such as the International Convention on the Regulation of Whaling (ICRW, 1946[25]), Convention on the Conservation of Migratory Species of Wild Animals (CMS or the Bonn Convention, 1979[26]), Convention on Biological Diversity (CBD, 1992[27]), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1973[28]), United Nations Convention on the Law of the Sea (UNCLOS, 1982[29]), and International Convention for the Prevention of Pollution from Ships (MARPOL, 1973[30]). Some nations also participate in regional agreements such as the United Nations Environment Programme's Regional Seas Conventions[31] and Associated Protocols on Specially Protected Areas and Wildlife, notably in the Wider Caribbean and South-East Pacific regions where attention to marine mammals, nationally and regionally through action plans and other initiatives or instruments, has been longstanding. As is generally the case with multilateral and regional agreements, implementation is left to the member states and varies widely. There is a general need for increased awareness and capacity (i.e., abilities) with regard to the potential impacts of sound, as well as mobilization and dialogue among various stakeholders in the region.

Borobia offered more specific information related to Brazil's licensing regulations for seismic operations by the oil and gas industry. These began in 1999 and were strengthened in July 2004 by a resolution of the National Environment Council (CONAMA[32]). Initially, a limited, non-specific technical body within the Brazilian Environmental Agency (IBAMA[33]) was responsible for licensing seismic activities, and no specific guidelines were available. Since 1999, IBAMA has worked with industry, local communities, and researchers to review available information regarding socioeconomic issues and the vulnerability of marine resources, and in 2003 the agency issued guidelines for seismic work that consider biologically sensitive areas as well as the need for mitigation measures to protect whales. The guidelines include a prohibition on seismic

[25] See http://www.iwcoffice.org/commission/convention.htm.
[26] See http://www.cms.int.
[27] See http://www.biodiv.org/welcome.aspx.
[28] See http://www.cites.org/.
[29] See http://www.un.org/Depts/los/index.htm.
[30] See http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258.
[31] See http://www.unep.ch/regionalseas/legal/conlist.htm.
[32] See http://www.mma.gov.br/port/conama/index.cfm.
[33] See http://www.ibama.gov.br/.

operations in and near humpback whale calving or mating areas during the months July–November, as well as monitoring programs with land-based and onboard observers. During discussion, Chip Gill of the International Association of Geophysical Contractors called attention to his information paper (IAGC 2004) and abstract (Appendix 4, poster 9) on the questions surrounding humpback whale strandings and seismic activities in the Abrolhos Bank area off Brazil.

The poster by Bolaños-Jiménez et al. (Appendix 4, poster 4) identifies similar initiatives in Venezuela. Under a recent presidential decree, the Venezuelan Ministry of Environment and Natural Resources has been developing terms of reference for environmental impact assessments and various related studies in the oil and gas sector, with an explicit focus on evaluation and regulation of the effects of anthropogenic sound. Moreover, independent and governmental observers working onboard active seismic survey vessels in Venezuelan waters have reported changes in behavior and avoidance reactions by baleen whales.

F. Asia/Pacific Rim

John Wang (FormosaCetus Research and Conservation Group, Taiwan) presented a paper (authored by himself and eight co-authors) that focused on policies and legislation in 13 Southeast Asian countries: China (including Hong Kong), Taiwan, Philippines, Vietnam, Laos, Cambodia, Thailand, Malaysia, Singapore, Brunei, Indonesia, East Timor, and Australia. Although most of those countries confer full legal protection to marine mammals, implementation and enforcement of existing laws are generally lacking, and little effort has been made to assess or manage the potential impacts of human-generated underwater sound in the region. Many sound-producing activities occur in Asian waters. Military naval activity is intense in some parts of the region (e.g., Taiwan Strait), and several of the largest commercial ports and busiest shipping lanes in the world are found there (e.g., Singapore, Hong Kong, Taiwan). In addition, coastal construction activity (e.g., blasting, pile driving) is extensive; blast fishing (although illegal in most countries) still occurs in some places; and offshore oil and gas development is underway in nearly all the countries surveyed. The only one of these classes of potentially harmful activities that is likely to decline in the immediate future is blast fishing; all others are almost certain to increase. According to Wang, the dearth of interest in, and concern about, potential effects of anthropogenic sound on marine mammals in Southeast Asia is due primarily to the lack of regional marine mammal expertise, inadequate funding for local research, and failure of information from the outside to reach Southeast Asia. In addition, the concept of reducing the potential impacts of sound-producing activities is likely to meet resistance, given the implications for the region's economic growth and military interests. Wang argued that more effort is needed to disseminate and exchange information and alert scientists, citizens, and governments of Southeast Asian nations to the issue. He emphasized the importance of culture and politics, and how these affect a nation's attitude toward marine mammal protection.

Australia is an exception to the above generalizations. Marine mammals are protected in Australian waters under the Environment Protection and Biodiversity Conservation Act of 1999.[34] Wang noted that the sanction against "interfering with" any listed species (including five

[34] See http://www.deh.gov.au/epbc/.

"threatened" whale species, nine "migratory" cetacean species, and the dugong) can be interpreted to apply to disturbance or injury from anthropogenic sound. Specifically, offshore seismic operations are subject to guidelines (currently under review) under the Act, including requirements for a 3-km exclusion zone around animals belonging to listed species, onboard visual monitoring to detect whales, soft-start (also known as ramp-up) procedures, and aerial surveys to determine distribution of whales in relation to the area of seismic activity. Seismic operators are not allowed to approach within 20 km of a breeding, feeding, or resting area without further review and mitigation. The Australian military is required under the Act to conduct environmental assessments of its activities, including those that generate sound with potential impacts on marine mammals.

A number of poster presentations addressed related issues in Southeast Asia (Appendix 4, note especially posters 8, 11, 19, and 25).

G. Africa

Policies and regulatory frameworks concerning marine mammals and sound are either non-existent or in early developmental stages in most African countries. The presentation by Ken Findlay (University of Cape Town, South Africa) and Howard Rosenbaum (Wildlife Conservation Society, U.S.) focused on southern Africa, with emphasis on South Africa and Gabon. Forty-five marine mammal species have been documented in the region. To date, concern has centered on areas where baleen whale breeding grounds and offshore oil and gas development sites overlap. Military exercises, academic research surveys, and shipping activities also produce sound in African waters, but their potential impacts have yet to be recognized or addressed. Findlay and Rosenbaum outlined the following options for regulation and environmental management of the offshore oil and gas industry: (a) international conventions and agreements, (b) national legislation and guidelines under oil and gas licenses or production contracts, and (c) industry guidelines through parent companies, operators, or contractors. Relevant international agreements such as UNCLOS, MARPOL, and others exist, but the implementing national governments typically lack enforcement mechanisms and the necessary political will. Two regional conventions may provide relevant frameworks: the Convention for the Protection, Management, and Development of the Marine and Coastal Environment of the Eastern African Region (Nairobi Convention, 1985/1996[35]), and the Convention for Co-Operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region (Abidjan Convention, 1981[36]). However, these Conventions do not explicitly address acoustic impacts on marine mammals at this time.
Although most existing environmental management activities in the region have been carried out by industry (through company policies), Nigeria, Namibia, and Mozambique have adopted domestic laws with environmental guidelines and standards for the oil and gas industry. In addition, South Africa's 2004 Minerals Act requires that environmental management programs be included in all offshore exploration activities, and that seismic surveys incorporate seasonal exclusion zones, observer schemes, operational protocols, reporting, and other requirements for the protection of marine mammals. In Gabon, law 16/93 Relating to the Improvement and Protection of the Environment contains a section that addresses mining and petroleum activities,

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[35] See http://hq.unep.org/easternafrica/EasternAfricaNairobiConvention.cfm.
[36] See http://hq.unep.org/easternafrica/AbidjanConvention.cfm.

and industry regulation typically is delegated to the company or contractor involved on the expectation that it will apply the JNCC or International Association of Geophysical Contractors (IAGC) guidelines (JNCC 2004, IAGC 1998). Both the JNCC and IAGC guidelines offer standards to help minimize potential impacts of sound-producing industrial activities, including seismic surveys. Although none of the strategies currently in place deals effectively with issues related to protection of critical marine mammal habitat, the Wildlife Conservation Society is developing a national marine mammal management plan in partnership with the government of Gabon, and in 2002 Gabon declared a nationwide system of protected areas that includes some marine areas. A report entitled "Environmental Impact Assessment and Mitigation of Marine Hydrocarbon Exploration and Production in the Republic of Gabon" provides a review and recommendations for mitigation strategies involving critical marine mammal habitat in Gabon.[37] Table 1 (see page 71) provides a summary of domestic laws and regulations mentioned in the workshop proceedings. The examples provided are a subset of those discussed during the workshop. No attempt has been made to analyze the information as it was presented.

[37] Authored by Findlay, Collins, and Rosenbaum; available from the Wildlife Conservation Society.

IV. Topic 3: Examining International Legal Frameworks

This section of the workshop addressed the following questions: How can the issue of acoustic impacts on marine mammals best be pursued internationally? What would be the key components of an effective international framework? Have sound or acoustic impacts on marine mammals been effectively addressed by international law or institutions? What short- or long-term actions might be taken in international fora to address this issue?

A. Providing an Analytical Framework for International Regulatory Mechanisms and Fora

To help frame discussions of existing and potential future applications of international law and multilateral agreements, Lindy Johnson (National Oceanic and Atmospheric Administration, U.S.) outlined the key considerations and potential options for international or multilateral legal frameworks. She addressed the following questions:

- What steps should be taken to analyze legal frameworks (e.g., instruments and institutions) for their applicability to the issue of acoustic impacts on marine mammals?
- What short- and long-term actions can be taken to address this issue in international fora?

Instead of immediate action through existing international instruments or fora, Johnson advocated an analytical approach that includes questions and assumptions that should be addressed when considering an international legal strategy. She emphasized the importance of (a) clarifying and agreeing on common objectives; (b) framing the issues; (c) defining appropriate solutions, along with strategies to achieve and evaluate them; (d) identifying relevant institutions or instruments; and (e) ensuring stakeholder involvement. In identifying objectives, it is necessary to retain flexibility and creativity, rather than making assumptions about desirable approaches or outcomes (e.g., that a command-and-control regulatory approach is necessarily the best approach, or that sound is preferably viewed as "pollution"). Although it is useful to identify general objectives (e.g., to define potential adverse effects of sound on marine mammals; to develop mitigation strategies to prevent, reduce, or minimize adverse effects of sound on marine mammals), these need to be specified (e.g., in relation to particular types of sound or species of concern) to facilitate appropriate action. As specificity in objectives increases, so do the difficulties of agreeing on achievable goals. Key questions may relate to the sound sources themselves (e.g., are all sources of equal interest, or do some have higher priority?), the biological issues involved (e.g., which ecosystems or species should be considered?), or the options for management (e.g., how can operational measures, research, outreach and education, and information exchange be incorporated?).

Once objectives have been defined, action may be taken using a variety of tools at various levels. National efforts can stress issues within a single jurisdiction and may therefore face fewer constraints and progress more quickly. Actions at the regional level tend to be better focused than international actions, with fewer parties involved in the decision-making process. International efforts tend to involve transboundary issues and a wider variety of stakeholders, making them intrinsically more complex. It is important to take advantage of all types of tools and fora available, including (a) "hard" law (e.g., treaties, regulations); (b) "soft" law (e.g., resolutions, guidelines); (c) research, cooperation, and coordination; and (d) outreach and education (e.g., information papers). Available instruments for consideration include framework treaties (e.g., UNCLOS); International Maritime Organization (IMO[38]) instruments (e.g., the International Convention for the Safety of Life at Sea [SOLAS, 1974[39]], MARPOL, the Particularly Sensitive Sea Areas [PSSA[40]] provision); conservation treaties (e.g., CBD, ICRW); and regional agreements (e.g., ACCOBAMS). A number of existing instruments could arguably address anthropogenic sound and/or its impacts on marine mammals. However, Johnson reiterated the importance of examining objectives before acting. Furthermore, the precise language of an agreement, its ability to change behavior, its enforceability, its geographic scope, and its comprehensiveness or overlap with other instruments will affect the outcome. In general, existing instruments provide some avenues for progress, but further work is needed if the specified objectives require action.

If no international instrument is available to meet the objectives, two options exist. First, an existing instrument can be amended. This may be easier to accomplish than the second option, but is not likely to produce a comprehensive approach. In addition, procedural issues such as the amendment process deserve serious consideration. Second, a new agreement can be created. This might have the advantage of being more nearly comprehensive (e.g., by addressing various sources of sound in a single instrument), but would require an appropriate international forum that can articulate the need for such an instrument, develop the political will, overcome controversies, engage stakeholders, and provide resources. In deciding on a course of action, it is also important to consider that (a) national governments and international organizations have limited resources and must be convinced that this issue is a priority, (b) international treaties commonly include provisions for sovereign immunity, (c) some sound-producing activities are not currently subject to international oversight, and (d) achieving consensus on an international instrument can drive the results toward a “lowest common denominator,” which may not be effective in achieving stated objectives.

When identifying an international forum to address this issue, key considerations include (a) convincing an international organization to take a leadership role, (b) raising the issue’s profile within that organization, (c) including interested entities that generally may not be represented on delegations, (d) following the rules of procedure, (e) being sensitive to concerns about timing, and (f) identifying types of actions that are possible. Fora with regularly scheduled meetings can facilitate action on an issue, and non-governmental organizations and industry groups may be willing and able to contribute.

Johnson identified a series of possible next steps for the short and long term. It is important immediately to identify objectives, set priorities, and develop strategies. Mechanisms for information exchange, technology development, and setting research priorities are also key in the short term. In some instances, it may be possible to transfer strategies from land-based policy into the marine context. It is important to look for, and take advantage of, “low-hanging fruit” (i.e., to find opportunities in existing instruments and institutions that allow for progress with

[38] See http://www.imo.org/.
[39] See http://www.imo.org/Conventions/contents.asp?topic_id=257&doc_id=647.
[40] MARPOL resolution A.927(22), Guidelines for the Designation of Special Areas under MARPOL73/78 and Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas. See http://www.imo.org/Environment/mainframe.asp?topic_id=760.

relatively little effort, cost, or controversy). A possible example for further consideration is the development of shipbuilding guidelines. In the long term, it will be important to monitor progress on achievement of the objectives; conduct research and monitoring; based on science, determine possible mitigation techniques; and pursue objectives through appropriate international fora and with various types of tools.

B. Panel Discussion—Components of an Effective International Legal Framework

Panelists:

Lindy Johnson, National Oceanic and Atmospheric Administration, U.S.
Scott Kenney, Department of Defense, U.S.
Elena McCarthy, Woods Hole Oceanographic Institution, U.S.
Daniel Owen, Fenners Chambers, U.K.
Karen Scott, University of Nottingham, U.K.
Jon Van Dyke, University of Hawaii, U.S.

This panel brought together experts with different points of view and different experience and knowledge. Several background documents were relevant to the panel's discussion (Appendix 3), notably those by Owen on the application of marine pollution law to ocean noise (Owen 2003), Scott on international regulation of undersea noise (Scott 2004), and Van Dyke on the precautionary principle in ocean law (Van Dyke 2004).

The discussion was organized around the following questions:

1. Do existing regional and international laws and organizations/institutions address acoustic impacts on marine mammals, or could they?
2. What are the key components of effective regional and international legal/regulatory schemes?
3. What challenges might exist in pursuing this issue internationally? What steps might be possible to further the discussion of this issue in relevant international organizations/institutions and what types of actions could be taken in international fora or through international legal instruments to address the issue?
4. How might multilateral legal and regulatory frameworks develop in the future? What changes might be forthcoming, if any?

Questions 1 and 2:

Scott gave a brief presentation summarizing regional and international laws and organizations/institutions. She noted that although no specific instrument exists to address the sound issue explicitly, a number of institutions have begun to address it, notably the International Whaling Commission (IWC,[41] since 1998), ASCOBANS and ACCOBAMS (see above), the Committee on Environmental Protection within the Antarctic Treaty System (see above), and the OSPAR Commission (see above). Only three instruments currently identify noise directly in their texts: the Helsinki Convention (Article 9 on pleasure craft), the 1991 Arctic Environmental

[41] See http://www.iwcoffice.org/.

Protection Strategy,[42] and ASCOBANS. There are three broad categories of potentially relevant instruments: those that (a) control pollution, (b) conserve wildlife or biodiversity, or (c) invoke specific procedures such as environmental impact assessment or use of the precautionary principle (in terms of habitat or species protection). Examples of (a) include UNCLOS and various regional seas agreements (with minimal implementation, however). Examples of (b) may use general obligations to conserve biodiversity, obligations to establish and regulate activities within special areas, or obligations to protect individual species, and include, *inter alia*, the UNCLOS and the CBD, the E.U. Habitats Directive (see above), and the 1979 Bern Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention[43]). Examples of (c) include the general obligations and procedures for environmental consideration associated with various agreements and laws. Flexibility would be needed to take advantage of new science and new law as they become available.

Van Dyke emphasized the precautionary principle as a meaningful component of international law. Its elements include the following: (a) that studies of effects need to precede potentially harmful activities; (b) that the burden of demonstrating "no significant effect" needs to be placed on the proponents of a potentially harmful activity; (c) that alternative (and potentially less harmful) activities need to be considered; (d) that risks and costs need to be internalized; and (e) that action in the face of uncertainty should take place only slowly, cautiously, and with adequate monitoring. Both UNCLOS and the E.U. Directives incorporate this principle. Van Dyke considered that studies of the effects of high-intensity military sonar are inadequate and therefore its use is not consistent with the precautionary principle. Although military forces may themselves have sovereign immunity, the governments that they represent can be held responsible for damages caused by military activities. In Van Dyke's view, although science is central to risk assessment, values and ethics also play important roles.

Kenney expressed his preference for a universal treaty to address the effects of sound, noting that UNCLOS, for example, was intended to cover all uses of the oceans. He cited Article 15 of the Rio Declaration[44] as containing the most nearly universal definition of the precautionary principle. The focus in that instrument is on threats of serious or irreversible damage, with the provision that lack of full scientific certainty should not delay or prevent signatories from taking steps to prevent harm. In Kenney's view, the precautionary principle includes, or should include, reference to the cost-effectiveness of remedial actions.

Kenney commented that domestic legislation key to the effectiveness of regional or international instruments. UNCLOS, for example, cedes to coastal states the obligation to regulate within their Exclusive Economic Zones (EEZs; usually from shore to 200 nautical miles offshore). Many of the activities that produce anthropogenic sound take place within EEZs, and thus sovereign states should determine how to address their impacts. Coastal states therefore play a pivotal and decisive role in determining the effectiveness of any international instrument.

[42] See http://www.arctic-council.org/en/main/infopage/74/ and http://www.arctic-council.org/files/infopage/74/artic_environment.pdf.
[43] See http://www.oceanlaw.net/texts/summaries/bern.htm.
[44] See http://www.unep.org/Documents/Default.asp?DocumentID=78&ArticleID=1163.

McCarthy acknowledged that cost-benefit analyses are a key component of effective regional or international instruments. For example, ship-quieting technologies may have both sound-reduction benefits and relatively low costs to operators. She also stressed the value of regional temporal zoning, and cited Glacier Bay National Park[45] in Alaska as an example. In the park, vessels without noise-reduction equipment onboard are excluded during the summer when whales (and tour boats) are present. Habitat-based, rather than source-based, management and regulation would emphasize the protection of marine mammals' access to critical resources (e.g., ensuring that whales feeding in a particular area can do so without risk of disturbance). In addition, it is important to retain flexibility in international instruments as science and law evolve over time, and political climates change. Finally, effective regional and international schemes should aim first to protect marine mammals in areas where the greatest threats (i.e., sound-producing activities) are concentrated.

Owen described the existing array of instruments for management of anthropogenic sound in the oceans as a rickety amalgam, rather than a functional network. He urged that those instruments be evaluated in terms of the substantive powers or duties they provide. When thinking about key components of instruments, it is important not to neglect the "behind the scenes" provisions. For example, does the instrument include dispute resolution procedures that are compulsory and binding? Does the instrument offer innovative compliance facilitation mechanisms? How are amendments made? How onerous are threshold conditions for the instrument's entry into force (i.e., is there a realistic prospect that the desired measures will ever come into effect?). How serious are the liability measures (i.e., if a standard is breached, what are the penalties or compensation arrangements?). Owen also called attention to a new instrument—the E.U. Directive on Environmental Liability (2004/35/EC[46])—that may be of relevance.

Johnson embraced the concept of a "rickety amalgam" as particularly fitting. She added that what really matters is political will: with it, an instrument is likely to be effective, but without it, it will certainly not be. It is important to understand how a particular institution or forum functions in order to take advantage of its framework. Among other key components of an effective regime are clarity of objectives, enforceability (if hard law), and effectiveness in changing behavior (if soft law). Monitoring is also required to determine how effective the measures have been in achieving the intended objectives.

The initial presentations by panel members on the first two questions were followed by a brief discussion with the audience of "command-and-control" vs. participatory approaches to implementation. To a considerable extent, the approach must depend on the context in which implementation takes place. It was noted that cultural sensitivity, fairness, and parity are necessary for long-term effectiveness.

Question 3:

McCarthy opened discussion regarding challenges and possible next steps. She identified the following as challenges to pursuing this issue internationally: (a) resistance from user groups (e.g., the oil and gas industry, the military), (b) jurisdictional conflicts (often between agencies

[45] See http://www.nps.gov/glba/.
[46] See http://europa.eu.int/comm/environment/liability/.

within the same country), (c) difficulties in enforcement and monitoring, and (d) scientific uncertainty concerning cause and effect. The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP[47]) might be a good forum to foster discussion at the international level.

Owen noted that "parliamentary time is limited" (i.e., that the issue of potential effects of anthropogenic sound on marine mammals must compete for time and resources with other policy and management priorities, such as land-based pollution). A further challenge arises from problems of interpretation. Does the wording of a particular treaty allow it to be applied to anthropogenic sound? Does the wording of the mandate of a particular international organization allow that organization to address anthropogenic sound? To facilitate timely regulatory action by countries, it is also important to identify when such action may be pursued unilaterally and when it may only be pursued through one or more international organizations.

Johnson reiterated the importance of developing political will and the fact that scientific uncertainties are often used to delay action. Other challenges include (a) a lack of strategic planning, (b) limited resources, (c) difficulties in identifying appropriate fora to address the issues, and (d) the "not me" problem (i.e., a lack of awareness or understanding on the part of sound producers). The immediate priority should be to raise awareness, including at the IMO and United Nations Environment Programme (UNEP[48])[49] and perhaps even trying to get the issue onto the agenda of the United Nations' Open-ended Informal Consultative Process on Oceans and the Law of the Sea (UNICPOLOS[50]). It is important to identify the appropriate forum or fora to address this issue. Johnson's idea about the need to build a "drumbeat" regarding the issue (i.e., to start the process with education and raising awareness) was adopted by some of the other panelists as a useful metaphor.

In Scott's view, investing in multiple fora, rather than in a single, all-embracing one, is the more practical approach. Three steps should be taken in the short term: (a) identify particularly sensitive areas[51] and thus establish geographic priorities for protective measures; (b) seek to incorporate concern about sound in environmental impact assessment processes; and (c) explore use of the Bern Convention, for example, as an instrument for addressing the issue of sound and marine mammals.

Van Dyke lamented the sense of denial and inertia that he believes has characterized the responses of industry, the military, and even much of the scientific research sector. In his view, national security-related issues have been allowed to override environmental concerns. He commended the nongovernmental sector (the Natural Resources Defense Council in particular) for taking the lead and working to ensure that the sound issue is acknowledged and addressed.

[47] See http://gesamp.imo.org/.
[48] See http://www.unep.org/.
[49] E.g., through GESAMP.
[50] See http://www.un.org/Depts/los/consultative_process/consultative_process.htm.
[51] E.g., establish Particularly Sensitive Sea Areas (PSSAs) through the IMO, under MARPOL.

Kenney insisted that the main challenge still lies in the scientific realm, and that a threshold of scientific certainty needs to be reached before the case can be made that anthropogenic sound has a direct connection to harmful effects on marine mammal populations.

Non-panelists made several additional points: (a) the need for parties on all sides to acknowledge uncertainty and to strive for clear communication (e.g., by being precise in their terminology and using standard units when making comparisons); (b) the need for parity in the application of scrutiny and regulation, so that all sectors involved in producing potentially harmful sound are treated in the same way; (c) the importance of public education and of finding a "cultural hook" that will facilitate engagement with the issue in different cultural contexts; and (d) the problem that if major sound-producing countries are not signatories to a particular convention or agreement, that instrument's usefulness as a forum or framework could be limited.

Question 4:

Kenney opened the discussion by stating that the U.S. Navy would continue to spend large amounts of money on research and mitigation related to marine mammals and sound. Although militaries do not want to cause harm to marine mammals, and wish to foster environmental responsibility, the need for some military sonar use will persist. The oceans are important for a variety of human uses (e.g., shipping and trade, oil and gas extraction), and military protection is needed to safeguard those uses.

McCarthy predicted that progress would be very slow and probably occur mainly on a regional or sectoral basis rather than as part of a single, overarching international scheme. The regional seas protocols within UNEP are relatively easy to modify and update, and the sound issue is likely to be incorporated gradually into these and other instruments. Some technological innovations can also be expected, as can novel approaches such as green labeling in the shipping industry (e.g., offering "environment-friendly" certification as an incentive for the use of silencing equipment).

Owen expects increasing overlap in the competence of international instruments and organizations (i.e., multiple agreements establishing similar powers and duties and international organizations with similar functions). He also foresees expanding cooperation and coordination (e.g., through memorandums of understanding), which may in turn improve the effectiveness of various instruments.

Johnson expects domestic and regional measures, or specifically targeted international measures, to emerge first. Addressing the issue on an international basis will require creative thinking. Additionally, it may be difficult to negotiate a single overarching international treaty on this issue, because of the diversity of interests involved and the lack of a forum for bringing these interests together.

Scott sees an international convention on underwater sound as unlikely, and predicts that the issue will continue to be framed mainly in terms of conservation rather than pollution reduction. She identified underwater sound associated with oil and gas development (notably the seismic profiling component) as a likely initial object of regulatory attention, particularly on a regional basis. She also suggested that shipping noise would be addressed mainly through the IMO.

Finally, Van Dyke added that clarification and improvement are needed in existing dispute-resolution procedures, liability and compensation regimes, and international and regional procedures.

Non-panelists noted the rapid rate at which new scientific insights are emerging, and also how quickly public awareness of the problems related to sound and marine mammals is expanding (i.e., the "drumbeat" is being heard). Several individuals expressed optimism that mitigation protocols would be developed and that these would spread from national to international contexts, and across sound-source types, as long as public pressure remained strong. It was pointed out, however, that policy-makers would need to be convinced that anthropogenic sound ranks as a high priority relative to other threats to marine mammal populations, and that this may require stronger empirical evidence of harm. Finally, there was discussion about the necessity of recognizing that, particularly in many less developed countries, the strong impetus for resource exploitation is not matched by an effective regulatory infrastructure. Often the capacity is weakest where the need is greatest.

Table 2 (see page 72) provides a summary of multilateral agreements mentioned in the workshop proceedings. No attempt has been made to analyze the information as it was presented during the workshop.

V. Topic 4: Innovative Management, Impact Assessment, and Mitigation Strategies

Among the questions addressed in this section of the workshop were the following: What would be the key components of an effective management scheme for anthropogenic sound and marine mammals? What are, or should be, the goals of management, impact assessment, and mitigation? How can the effectiveness and efficiency of mitigation strategies and impact assessment be evaluated? What roles should regulated groups (e.g., the oil and gas industry, the shipping industry, and the military) and environmental non-governmental organizations play in the development of impact assessment, management, and mitigation strategies?

A. Introduction to Generic Impact Assessment Approaches

Karl Fuller of the U.K.-based Institute for Environmental Management and Assessment gave an overview of basic environmental impact assessment (EIA) in response to the following questions:

- What are the basic steps in environmental impact assessment? What techniques can be used in such analyses?
- What differences exist between countries in their national approaches to risk assessment?

EIA can be defined as a systematic process to predict and evaluate the effects of proposed actions before decisions are made. Fuller described EIA as “best-guess” science, a planning tool, and a vehicle for getting answers in a logical, ordered manner. The general goals of EIA are to guide resource use and improve environmental design, identify mitigation measures, protect human health and safety, safeguard resources and ecosystems, enhance proposed actions, and avoid irreversible harm. Among its benefits are that it provides a common framework for assessing all types of environmental effects, draws on the expertise of appropriate specialists, and ideally presents information in ways that are understandable and that lead to informed decision-making. Acknowledging that EIA should not be seen as a linear series of steps, Fuller identified three key elements that help define the iterative EIA process, as follows:

1. Screening – deciding whether an EIA is needed and appropriate;
2. Scoping – identifying key concerns and determining which of them require focused attention and further investment; and
3. Impact analysis – assessing “baseline” conditions, determining what difference the project will make, analyzing significance of effects, and ensuring that appropriate mitigation measures are in place.

Responsibility for preparing an EIA generally rests with the project proponent. An appropriate regulatory body then has the responsibility to oversee and conduct a review, to make a decision concerning approval or the need for modification and further assessment, and to ensure that the prescribed scenario is effectively delivered.

Special methodological and regulatory challenges can arise in applying the EIA concept to marine contexts, notably that (a) it is difficult to define the extent of the study area; (b) the quantity and quality of baseline data vary, and obtaining such data is expensive; (c) considerable uncertainty exists concerning the responses of organisms to various risk factors; and (d) there is a lack of reference points for determining the significance of impacts. In marine-based EIAs, there is wide use of secondary data (e.g., extrapolation from one species to another) and geographic information systems, more reliance on models and “worst-case scenario” assessments, and more identification of particularly sensitive areas in order to avoid impacts. The precautionary principle also plays an important role. In any EIA process, risk assessment techniques may be most effective when used in conjunction with other tools, offering opportunities for more systematic management of cumulative effects.

EIA should be integrated with project planning. It is especially important in situations where systematic policies and regulations for protection of the marine environment are lacking. Timing is crucial for an EIA to be effective. That is, it needs to be carried out before initiating a project and before significant investment has been made in infrastructure, licensing, etc. Other important considerations are who decides what questions need to be addressed and how the EIA is funded. For example, Ron Kastelein stated that project proponents in the Netherlands are not allowed to cover more than 50 percent of the cost of an EIA, apparently to avoid conflict of interest. Fuller stressed that providing for meaningful public input is one way to ensure that the right questions are addressed in an EIA.

B. Introduction to Uncertainty and Policy-Making: How Do We Deal With the Unknowns?

John Harwood of the Sea Mammal Research Unit at St. Andrews University (U.K.) discussed the following questions:

- How can scientific uncertainty be addressed when making policy decisions? What can policy-makers do when we don't fully understand the range of impacts from sound?
- Beyond creating models, how can we handle uncertainties like those related to the significance of acoustic impacts?
- How can we define a “precautionary approach,” and when/how should such an approach be applied in policy?

Harwood began by drawing a distinction between uncertainties that can and cannot be quantified. Techniques are available for quantifying uncertainty due to measurement error, random variation, and model mis-specification, but Harwood focused on dealing with unquantifiable uncertainties, particularly those due to ignorance. He defined “risk” as the quantifiable probability of a known, undesirable outcome; “pure uncertainty” as uncertainty where possible outcomes are known, but their probabilities cannot be quantified; and “ignorance” as uncertainty where possible outcomes are not known and cannot be quantified. As such, the unknowns in the area of acoustic impacts on marine mammals generally fall into the category of pure uncertainties, rather than ignorance. Harwood’s stated goal was to develop a precautionary approach for reducing the potential impacts (risks) of anthropogenic sound in the face of substantial scientific uncertainty.

As currently applied, mitigation measures for acoustic impacts on marine mammals typically attempt to reduce risk by (a) reducing the probability that any individual is exposed to particular levels of sound, (b) avoiding times and areas of high marine mammal abundance, and (c) ensuring that a sound source is not emitting a signal when an animal is within a calculated "safety zone." However, we generally do not know how effective these techniques are in reducing risk. When experts are unable to agree on a predicted outcome, decision-makers may compare the range of expected outcomes of different scenarios, or look for a risk-averse "minimax" protocol that seeks to minimize the maximum impact. This is one way to implement the precautionary principle.

Harwood emphasized the importance of accounting for uncertainty in models used to estimate or predict risk. He briefly described tools available to evaluate the possible outcomes of different scenarios, and emphasized the importance of applying new data to refine models associated with such tools. The most robust protocol (i.e., most effective across a wide range of scenarios) can be identified, the benefits of current protocols (e.g., soft-starts) can be quantified, and a Bayesian approach can be used to improve weak or subjective information. Bayesian statistical techniques use prior information to interpret observations and accept that many different hypotheses or explanations may be compatible with existing data. Thus, a Bayesian approach may be appropriate for situations of pure uncertainty. It provides an incentive to collect new information, helps identify what new information would be most helpful in reducing risk, and allows for transparency in assumptions made. In practice, such an approach might be applied in a sound exposure model that can be compared to real-world data.

It is useful for policy-makers to have a scenario-based tool for identifying the most robust risk-mitigation approaches. Ideally, such a tool allows sound producers and regulators to determine which techniques reduce risk and by how much. However, risk assessments must account for uncertainties in a precautionary way that creates an incentive to improve understanding of causal mechanisms as well as the accuracy and precision of estimates. Bayesian approaches may be useful for increasing transparency of the decision-making process, incorporating new data, and planning research. An advantage of Bayesian-type models is that they allow for adjustments to increasing or decreasing levels of uncertainty, which may be particularly useful to decision-makers.

C. Introduction to Mitigation Techniques: Options and Effectiveness

Jay Barlow of the National Oceanic and Atmospheric Administration (U.S.) briefly responded to the following questions:

- What constitute state-of-the-art "best practices" in mitigation?
- How do strategies differ for naval sonar, seismic research, shipping noise, and other sound sources? To what extent are mitigation strategies, monitoring technologies, and other techniques transferable across sound sources?
- How could mitigation strategies be made more accessible?
- What are the most promising strategies in development? What can we expect in the future?

His presentation was based on a paper prepared for the Marine Mammal Commission's April 2004 technical workshop on beaked whales (Barlow and Gisiner in review, see Appendix 3). The goal of mitigation can be defined as the minimization of potentially negative effects of anthropogenic sound on marine mammals (from military sonar, airguns, shipping, and fixed sources). Barlow outlined some options for monitoring and mitigating the effects of anthropogenic sound on beaked whales and stressed the challenges of developing and validating effective methods.

An initial premise is that no realistic prospect exists for eliminating all potentially harmful sound sources from the marine environment, and therefore mitigation is essential. Mitigation can be approached in a number of ways, including:

- Modification or removal of the sound source;
- Avoidance of marine mammal habitat;
- Soft-start or ramp-up of the sound source;
- Detection of marine mammals and consequent modification of the sound source's operations;
- Sound screening (e.g., bubble curtains); and
- Use of aversive alarms to keep or drive marine mammals away from the exposure zone.

The removal of a sound source is generally not feasible, given that many sources serve critical purposes (e.g., national defense, shipping) and alternatives are not readily available. Source modification has more promise, and may include changing training protocols for military sonar use, using ship-quieting technology, or altering signal characteristics. Habitat avoidance (e.g., avoiding critical areas inhabited by certain species) may be an effective way of reducing the potential impacts of a particular risk factor. However, such avoidance requires a good understanding of the animals' distribution, relative abundance, and habitat preferences. Many of the world's navies are investing resources in habitat mapping, but the necessary information is not currently available for most species of marine mammals. Ramp-up (as it is called in the United States) or soft-start (as it is known elsewhere in the world) typically involves initially firing a single airgun in a seismic array and adding others gradually until full operation is reached. It has become a relatively standard procedure throughout the seismic survey industry. The presumption behind this procedure is that the animals of concern (e.g., whales) will detect the sound and respond appropriately (i.e., will move away in time to avoid harm). However, too little is known about animal responses to ramp-up to determine the effectiveness of this mitigation strategy. For example, the animals may move vertically in the water column rather than "away" from an approaching (and ever-louder) sound source.

Another typical approach to mitigation is to place observers onboard a vessel or structure to detect marine mammals, with the expectation that sound-generating activities can be modified in response to a sighting and that a critical separation distance can be maintained between the animals and the sound source. In most U.S.-based seismic and naval operations, the critical distance (safety threshold of exposure) is currently based on an estimated received level of 180 dB.[52] Success of this method depends on the probability that any animal within the critical distance of the sound source will be detected, as well as the appropriate selection of safety thresholds and critical distances. Because visual detection probability depends largely on diving behavior, the deep-diving beaked whales represent a special problem. Mitigation observers from ships or aircraft will detect only a small fraction of the animals that are within their range of vision. Passive acoustic techniques offer some promise for improving detection. However,

[52] The U.S. National Marine Fisheries Service is developing exposure limits specific to species group (e.g., large cetaceans versus pinnipeds in water) and source type (e.g., pulsed or non-pulsed sound).

vocalizations by marine mammals are voluntary and therefore not entirely reliable (i.e., an animal will not be detected by this method if it is not vocalizing). In addition, beaked whales are hard to detect with towed surface hydrophone arrays, largely because they tend to vocalize at depth more than they do at the surface. Some improvement may be achieved using bottom arrays or gliders. The efficiency of visual detection for most or all species can be improved by reducing vessel speed when feasible. Active acoustic detection techniques (e.g., "whale-finding" sonar) are also being investigated and may prove useful in the future, although this technology is somewhat controversial because it involves the introduction of additional sound into the marine environment.

Another mitigation method is the use of bubble screens to dampen sound transmission, but its effective use is limited to some stationary sound-generating sites. Acoustic alarms (e.g., pingers) have been employed successfully to deter toothed cetaceans from the vicinity of gillnets (thus reducing bycatch), but they have not been used to mitigate potential impacts of sound on marine mammals.

During discussion, it was noted that although some mitigation methods may be ineffective with beaked whales, they could be effective with other species that are more readily detected. In response to a question as to why active acoustic detection has not proven useful, Barlow observed that target strength similarities result in numerous false positive results (e.g., fish schools may be difficult to distinguish from marine mammals). Finally, in response to a question of how often shutdowns occur when whales are observed from seismic survey vessels, he answered that they do not occur very often, judging by the limited evidence available from industry records.

D. Issues in Management, Risk Assessment, and Mitigation: Concurrent Small Group Discussions (Session 1)

Following the formal presentations, workshop participants met in four small groups to discuss and elaborate upon assigned subtopics. The goal was to elicit and record the range of opinion within each group and not necessarily to seek consensus.

Group A – Evaluating effectiveness (e.g., criteria for assessing effectiveness and efficiency, techniques for evaluation)

This group addressed the following questions:

- What are the goals of mitigation, management, and monitoring? How should those goals be ranked as priorities?
- How is the effectiveness of mitigation strategies evaluated? To what extent is the effectiveness of existing mitigation techniques understood? What can be done to improve that understanding?

Facilitator: Erin Vos
Topic Specialists: Jay Barlow, John Richardson
Recorder: Colleen Corrigan

The group first identified a range of strategic and operational goals of mitigation, management, and monitoring. An overarching goal is to protect ecosystems, species, populations, and/or individual marine mammals. Priorities for protection may vary, depending on such factors as societal values. For example, management efforts may be driven by a desire to protect rare, endangered, endemic, or especially sensitive species, or by concern about the welfare of individual animals. Management may be focused locally, regionally, or globally. Goals may also vary according to the region, country, or legislative context. Other overarching goals might be to reduce marine mammals' exposure to sound (e.g., by detecting the animals within a zone of impact and modifying operations in response), to prevent or ameliorate impacts, to identify and evaluate threats from anthropogenic sound over the short and long term, and to collect baseline information about the range of "normal" conditions and possible effects. Group members argued that management, mitigation, and monitoring efforts should follow logically from an evaluation and ranking of threats, and should be clearly defined in advance of implementation (e.g., through strategic planning). Furthermore, mitigation should be cost-effective and minimize interference with operational goals of sound producers. To the extent possible, mitigation measures should be specific to particular situations. Many interest groups and the public may believe that "something must be done" and that "every little bit helps." Efforts should consider public appearance and expectation, attempting to address perceptions and misunderstandings through communication, transparency, public participation, and local input (e.g., when defining goals). They should also aim to maximize compliance and effectiveness, and allow for continual improvements (e.g., by collecting data to improve future mitigation and employing other adaptive management strategies).

The varied goals of management, mitigation, and monitoring may lead to conflicts. The group discussed how to set priorities. Suggested strategies included the following:

- Get input from a broad range of stakeholders (i.e., strive for inclusive and extensive communications).
- Listen to experts and solicit information.
- Ensure that surveys are conducted before designing a mitigation approach.
- Apply knowledge from elsewhere.
- Examine species vulnerability (e.g., rarity or endemism, endangered status, sensitivity to sound sources).
- Employ tools of risk assessment and environmental impact assessment.
- Remain sensitive to geographic, national, or cultural differences.
- Consider a range of alternatives, and clarify the rationale for decision-making.
- Consider effectiveness in addressing threats from anthropogenic sound.
- Consider cost-effectiveness.

The group then discussed how to evaluate the effectiveness of mitigation. A basic dichotomy exists between the questions of whether a given mitigation strategy is effective and how well it is being implemented. In other words, ineffectiveness could be due to either an intrinsically flawed strategy or a failure to implement it properly. Keeping this in mind, the group identified key strategies to apply in evaluation:

- Establish a monitoring program.
- Analyze existing monitoring data (e.g., Stone 2003).
- Establish standards for data collection and recording to facilitate analysis and broaden information-sharing.

- Make observations from independent platforms and conduct controlled studies where practicable.
- Solicit external review, including "common sense" and expert evaluations.
- Seek to evaluate the effectiveness of all mitigation measures, both individually and in combination.
- Determine whether goals and objectives are being met.
- Acknowledge the limitations of data that have been collected (e.g., purpose of data collection and reporting).
- Evaluate guidelines, best practices, and standards (e.g., through pre- and post-monitoring and analysis).
- Consider costs and practicalities of implementation.

The effectiveness of current mitigation methods likely varies from one species to another. It is crucial to understand behavioral responses of the animals to underwater sounds (whether unmitigated or mitigated), but such responses are largely unknown. Many methods have the potential to cause unanticipated and undesirable side effects (e.g., soft-start /ramp-up, shut-down, and alarms all may increase total sound exposure). The group specifically discussed what is known about the effectiveness of the following seven basic mitigation methods, as well as what might be done to make them more effective:

1. *Modification of the sound source or how it is used* may work in some cases. For example, ship-quieting technologies (e.g., rubber baffles to reduce vibrations) already exist and might be more broadly applied. However, it would be more cost-effective to incorporate these into newly built ships rather than retrofitting existing ones. Adjusting the source characteristics of seismic airguns may prove difficult, although it may be possible to reduce the high-frequency components, which are not needed to produce survey data. Adjustments to seismic survey design (e.g., using more receivers, adjusting array size) are also possible. Long-term experiments that examine specific conditions are needed to evaluate the costs, effectiveness, and short- or long-term feasibility of such modifications.
2. *Avoiding the generation of sound in areas where, or at times when, the animals are especially sensitive* is a promising approach. In many cases (e.g., certain military and research activities), this is relatively cost-effective and simple, and the potential benefits are significant. In order to improve implementation, population densities and spatial and temporal variations need to be evaluated and baseline data need to be collected. The entire habitat or ecosystem should be considered, along with legal and policy issues. One potential drawback is the challenge of enforcing time-area closures.
3. *Soft-start (ramp-up)* has many proponents, but this strategy is essentially untested. Although it may work well with some species, it may be counterproductive, as it increases the overall amount of sound energy introduced into the environment. Also, some marine mammals may initially be attracted to the relatively low-level start-up sounds, thus increasing their vulnerability as the sound source ramps up. Improvements might be made through more regular or routine application of this technique, or through research on marine mammal behavioral reactions (e.g., context- and species-specific responses).
4. *Detection with avoidance or shutdown* may be an effective strategy for some species (e.g., sperm whales), but detection probabilities need to be improved for other species (e.g., beaked whales). In addition, there are difficulties determining when it is safe to restart operations. Improvements might come from better or more appropriate detection procedures to support

avoidance or shutdown protocols in the presence of marine mammals. It is also important to clarify the goals of monitoring (e.g., whether it is to reduce the number of animals in a safety zone or the percentage of the population being affected), and to understand the effects of sound sources at different ranges.

5. *Acoustic alarms* (e.g., acoustic harassment or deterrent devices) to deter animals and reduce their exposure to dangerous sounds may prove effective in some circumstances, but more information, development, and testing would be needed before this strategy could be widely applied. In particular, there are concerns about whether animals would respond appropriately to the alarms (e.g., move away from, rather than toward, the sound source). More studies are needed on specific species under specific conditions.
6. *Specialized technologies,* such as "whale-finding" sonar, infrared, and radar detection, may be useful, but their effectiveness remains largely untested. Further research and development are needed.
7. *Sound screens* can be effective for stationary sources (e.g., pile-driving), although effectiveness varies according to frequency and other variables. Bubble screens and other devices should be used to reduce exposure, where feasible.

The group agreed that the "habitat avoidance" strategy of restricting sound generation geographically or seasonally offered the most benefits and fewest negative side effects. Reduction of total sound production (e.g., reducing amplitude, improving signal processing, eliminating unnecessary or accidental sound, and using sound-screening mechanisms) also was seen as a promising mitigation strategy. The group also agreed that research is particularly needed on soft-start, marine mammal detection techniques, and acoustic alarms.

Group B – Best practices and emerging techniques (e.g., new applications of technology, research and development, standards for application of mitigation strategies)

This group discussed the following questions:

- What constitutes "best practice" in risk assessment, management, and mitigation? For example, what models are used for risk assessment and what factors are considered in those models? What current standards exist for the application of mitigation strategies? How does this vary for different sound sources and across national boundaries?
- How is scientific uncertainty addressed in management, risk assessment, and mitigation?
- What are the greatest needs in risk assessment, management, and mitigation with regard to marine mammals and sound? What are the most promising strategies currently under development? What innovations can be expected in the future?

Facilitator: Zoë Crutchfield
Topic Specialists: Jim Theriault and Sara Wan
Recorder: Katie Gillham

Risk Assessment
The group described several elements of "best practice" in risk assessment (RA). It is important that precaution is built into RA, and that uncertainties are acknowledged and highlighted. More quantitative RA should be the goal, although the insufficiency of data often limits our ability to do more than place broad confidence limits around quantitative elements and conduct sensitivity

analyses. RA should be part of the design process, not something that takes place after a project is already underway or completed. Finally, all relevant data must be used. It was agreed that a consistent terminology and a common international standard for RA would improve global practices.

Currently available RA models include:

- Acoustic Integration Model (AIM), in which biological information (e.g., distribution, diving behavior), sound source, and environmental acoustic input are combined to yield a decision.
- Effects of Sound on Marine Environment (ESME[53]), which is similar to AIM and is currently being developed as a research project with an emphasis on simulating the effects of anthropogenic sound on the physiological function and behavior of marine mammals. ESME uses a combination of data on animal distribution and diving behavior with sound field calculations to develop exposure criteria. Both AIM and ESME are designed for one or two sources of sound in a relatively small, well-defined area, with a small number of animals subject to exposure.
- Sea Animal Kind Area-dependent Mitigated Active Transmission Aid (SAKAMATA), a naval exercise planning tool that provides the operator with tools for "careful mission planning," implementation of "marine mammal monitoring," and implementation of "ramp-up schemes" (see Appendix 4, poster 2).
- The Protective Measures Assessment Protocol (PMAP[54]), which provides "situational awareness for at-sea training" and is not restricted to acoustic impact awareness, but applies to a wide range of activities.
- GIS Tools (developed by the Canadian Maritime Forces Atlantic's Formation Environment[55]), a toolset to identify risk areas associated with planned training missions in eastern Canadian waters. Similar to PMAP, this tool is not restricted to acoustic impact.
- The Environmental Risk Management Capability (ERMC[56]; being developed for the U.K. Ministry of Defence), which includes a "real-time" shipboard risk assessment system integrated with risk mitigation capability.
- The NATO Undersea Research Centre's current risk management tools, which the Centre plans to move to a Web-based server through the SOLMAR (Sound, Oceanography and Living Marine Resources) project. The focus has been on species in the Mediterranean Sea with a specific interest in sperm whales and Cuvier's beaked whales (see Carron presentation, above).
- A risk matrix, a common and relatively simple tool that considers the probability that an event will happen and the likely consequences when it does.
- Predictive Location Abundance Model, which relies on bathymetry and other oceanographic data to predict where problematic sound exposure is likely to occur.

[53] See http://www.onr.navy.mil/sci_tech/ocean/321_sensing/info_oa_esme.asp.
[54] U.S. Navy's CD-ROM tool that provides operators with environmental data and mitigation guidelines for use during routine training. See http://www.enviro-navair.navy.mil/currents/spring2004/Spr04_Nat_Res_Conference.pdf #search='PMAP percent20marine percent20mammal.
[55] See http://www.navy.forces.gc.ca/marlant/environment/fenv_e.asp?category=1&title=43.
[56] See www.mmc.gov/sound/plenary2/pdf/burt.pdf.

- Bayesian frameworks, which offer the potential to improve risk assessment models (see Harwood presentation, above).

The group identified a number of limitations on the use of RA models. There was no consensus on the utility of models in general: some people have faith in them, but others do not. Models can highlight major gaps in knowledge and help rule out unlikely scenarios, but they are difficult to use for predictive purposes. Most of the RA models currently available in this field suffer in important ways from insufficiency of appropriate data, whether qualitative or quantitative. Uncertainty, even when it can be identified, is difficult to incorporate and quantify, and the quality of results obtained from any model depends on the quality of data available to develop them. When a model is used for decision-making, the decision-makers must be made aware of the assumptions made, the model's limitations, and the (often large) uncertainties surrounding outputs. For example, a model output showing no effect (low risk) does not necessarily mean that there will be no effect; power analysis is essential. A standard question to be clarified is whether data must be collected in advance to provide input for model design, or whether a model can be designed first and data then collected to provide input and testing. Finally, RA tends to be project-specific and does not necessarily incorporate holistic consideration of outcomes (e.g., use of alternative technology).

As a result of those limitations, a number of ongoing needs in RA can be identified:

- The determination of risk acceptability thresholds is essential, as it may influence choices of models to apply.
- There is a need for biological baseline data (e.g., population abundance, distribution, behavior) that include an understanding of the population's historical context (e.g., is it already depleted from some other cause or recovering from depletion). We also need a better understanding of how marine mammals respond when exposed to anthropogenic sound (e.g., behavior when feeding or engaged in activities related to reproduction and nurturing).
- Better information is needed on acoustic oceanography (e.g., currents, sound speed profiles, geoacoustic parameterization, transmission loss). However, it was noted that underwater sound sources will need to be employed to obtain some of this knowledge.
- Better sound source data (e.g., sound profiles, transmission models) are needed.
- There is a need for improved techniques to use the effects on individuals to infer population-level effects. This will depend, in part, on number of individuals affected in relation to total population size.
- An increased ability is needed to account for natural changes and distinguish anthropogenic from non-anthropogenic effects.
- There is a need for thorough and consistent identification and acknowledgement of the range of uncertainties in RA models, as well as any other limitations on their use.

Finally, the group discussed the idea that a choice must often be made between having a risk assessment with many limitations and qualifications, or having no risk assessment at all.

Management
The group identified the following elements of "best practice" in management:

- Well-defined goals, bearing in mind that tolerance of risk is subjective and cultural (e.g., some people consider an effect on a single animal to be excessive; others consider effects of a certain magnitude to be acceptable).
- Recognition of, and accounting for, the distinction between individual- and population-level effects (generally not yet feasible).
- Consideration of cumulative, synergistic, and long-term effects (although it is rarely, if ever, possible to define and quantify these).
- Precautionary measures taken to account for uncertainties.

The group then discussed expected future developments in management. They concluded that no single system can be effective for all sound-generating activities or industries, and that therefore multiple approaches will be needed. Stakeholders (especially national governments) need to be encouraged to participate more actively. This may be especially true in less-developed countries where only nongovernmental organizations have been engaged with the sound issue thus far. Finally, increased transparency is imperative.

Mitigation
The effectiveness of many current mitigation techniques is uncertain, and belief in their effectiveness is often rooted in little more than common sense. Much more work is needed to assess effectiveness of different mitigation strategies, preferably using quantitative measures. Group members regarded seasonal and geographical restrictions as the best mitigation tools for protecting a species or population when its critical habitat has been reliably identified (e.g., seasonal restrictions on seismic survey operations in Brazil to reduce exposure of humpback whales on breeding grounds; see Borobia presentation, above). Measures that modify the source to reduce (or even better, to minimize) the level of sound produced were regarded as promising. To achieve "best practice," the aims of mitigation need to be clearly defined, and mitigation measures designed or selected accordingly. In addition, regulatory measures need to be adaptive so that strategies can be reassessed and adjusted as new information on effectiveness becomes available.

Some participants saw great potential for the use of active, broadband sound (i.e., "whale-finding" sonar) to distinguish between targets and therefore to facilitate the "detection/avoidance/shutdown" strategy. Others cautioned that this tool would itself add sound to the environment. Although the limited targeting potential of passive techniques means that there will always be some need for military active sonar, development of passive techniques for object detection (e.g., submarine surveillance) may decrease the need for active sound sources.

The group concluded that no single approach to mitigation was likely to prove universally applicable, but participants saw signs of convergence toward a suite of best practices.

With regard to shipping, (1) the technology for making ships quieter is already available; (2) political will at national and international levels is needed before major progress can be made to curtail or regulate ship noise; (3) management of shipping requires a means of implementation (e.g., exerting domestic jurisdiction over traffic in ports and internal waters); and (4) an obvious form of mitigation is to route shipping lanes away from critical habitat.

Several additional themes emerged during this group's discussion:

- When managing acoustic impacts, it is important to define the effects as either episodic (e.g., seismic surveys, sonar, construction) or continuous (e.g., shipping, pipelines, wind farm operations). It is also important to consider that some of the episodic sound sources (e.g., seismic surveys and sonar) are recurrent and increasing, although these sources may not be in precisely the same geographic area.
- In less-developed countries, precautionary mitigation and management are often especially important because so little is known about marine mammal populations and their critical habitat. A combination of precaution and transfer of mitigation technology is needed.
- At some point, decision-makers cannot wait for better information or models. They need to make decisions based on the best data and analysis available at a given time.

Group C – Policy issues in risk assessment and mitigation (e.g., consistency in the application of mitigation strategies, balancing environmental protection with other societal goals)

This group's discussion was guided by the following questions:

- How are practicality, cost, and efficiency balanced in assessing risk and choosing mitigation strategies? What are the goals of existing risk assessment and mitigation mechanisms? How are protection goals balanced against other societal goals?
- How can sound-producing human activities be conducted in the ocean while minimizing the adverse effects on marine mammals?
- How do mitigation strategies differ for naval sonar, seismic research, shipping, and other sound sources? Why? Are such differences desirable?
- To what extent are mitigation and monitoring strategies and technologies transferable across sound sources, and across national boundaries? How could these strategies and technologies be made more accessible to different groups?

Facilitator: Suzanne Orenstein
Topic Specialists: Paul Macnab and Elena McCarthy
Recorder: Randall Reeves

Both risk assessment (RA) and environmental impact assessment (EIA) are intellectual structures, processes, or frameworks that can facilitate determinations of what is at stake from a proposed activity and what information is available for evaluating the risks of that activity. Either process can be viewed as a societal consultation, where it is known that a particular set of activities is planned, and at least something is known about what species occur in or near the action area and what potential environmental impacts may take place. The intent, then, is to establish what is known, what is not known, and what mitigation tools are available to offset any risks that are identified. EIA provides for case-by-case evaluations that highlight information needs to be addressed through surveys or other types of studies.

Defining risk, or impact, is a difficult and inevitably value-laden process involving both scientific and societal considerations. Even when there is approximate agreement on what should be protected (individuals, populations, species, etc.) and the kinds of risk involved (e.g., displacement, change in behavior, physiological damage), establishing the level of impact that is deemed to be biologically significant can be controversial. For the most part, assessment focuses on observable changes in behavior (e.g., of individuals), which are then interpreted as proxies for biologically significant effects. The biological significance of effects may depend on population status. For example, displacement of a few animals belonging to an endangered population could be highly significant, whereas it would be unimportant for a large, healthy population.

The group discussed several issues related to practicality, cost, and efficiency. First, it was agreed that sound-producing activities will not stop, nor will complete knowledge of risks and impacts be attained. Therefore, uncertainty in risk assessment and decision-making is unavoidable. Incorporating the collection of baseline data on underwater sound into ongoing global ocean monitoring programs would be an efficient way to obtain critical data for use in assessing and regulating anthropogenic sound inputs. Second, the group discussed the idea that society must consider the costs of *not* conducting an activity as well as its risks. Some proposed activities or projects might exceed what is necessary in terms of scope, duration, and geographical extent. The group agreed in principle that, whenever possible, serious efforts should be made to pare down the scale of projects, or to modify the sound source to the lowest feasible level needed to achieve the objective. Such a preventative approach can be taken even in cases of uncertainty. Finally, considerable difference of opinion was expressed on the question of whether foreign companies deliberately take advantage of the poor knowledge base and weak infrastructure in less-developed areas, or whether they in fact operate as guests in such areas and are bound only by the prevailing local regulatory regimes.

When attempting to minimize impacts, information about the species present in an ensonified area is essential. There is a particular need for better data on critical habitat in regions where deliberate sound generation is already occurring or planned (e.g., military activities in the Mediterranean and eastern Asia). In the absence of good information on the animals and the effects of sound exposure, it is preferable to initiate precautionary mitigation while conducting studies to fill the information gaps. Early consultations between sound producers and regulators allow for project modifications when and where possible (e.g., reduce scope, avoid critical habitat). Modification of the scope of an activity or changing the behavior of the operator (sound producer) can be one of the most effective approaches to mitigation. The question of whether sound producers should go beyond the requirements of countries where they operate was controversial. Some participants insisted that outside standards should not be applied to any country; others argued that companies working abroad should be held, at a minimum, to the standards they would face working in their home waters, or even to the highest standards anywhere that such work is undertaken.

The group identified several challenges to successful mitigation:

- Because sound travels, it is difficult to narrow or limit the scope of its effect. This is particularly important to the mitigation of sound that is produced unintentionally (e.g., ship noise).

- Once resources have been invested in a project, product, or type of activity, it becomes less feasible and more costly to make sound-reducing modifications. For example, retrofitting ships with quieting technology is likely to be more challenging than building quieter new ships.
- The great uncertainty surrounding the effectiveness of mitigation measures is a major impediment to their wider acceptance and application.Compliance and enforcement are always challenging.Mitigation strategies should be tailored to the different sound sources

and species of concern (i.e., one size does not fit all):

- *Intentionally versus unintentionally produced sound:* Greater control is generally possible when dealing with intentionally generated sound; however, unintentionally produced sound is expendable (*i.e*., lacks a benefit to humans) and therefore may be more amenable to elimination or reduction through technological innovation (e.g., ship design, signal processing). However, the issue of parity arises because deliberately generated sound tends to be more easily monitored and regulated than unintentionally generated sound. Consequently, some sound producers (e.g., military sonar and seismic) feel unfairly targeted by regulation relative to others (e.g., shipping industry).
- *Levels of management:* There is a need for three different "levels" of management or mitigation (i.e., international, national, and private/industrial), the last of which requires more industry engagement and negotiation. The appropriate level of management depends largely on existing legal structures.
- *Prioritization of management efforts:* Priority for mitigation should be assigned according to severity of impact rather than ease of regulation.
- *Engagement of sound producers:* In general, the shipping industry has not yet engaged in this issue, although navies and seismic operators have. The strategies taken for each source type should be adjusted accordingly. For example, most aspects of the shipping industry are regulated internationally (e.g., through international standards), but monitoring and enforcement is typically done at a national level (e.g., through enforcement in territorial waters). The industry is amenable to regulation, silencing technology is available, and quieter ships are more efficient than noisy ones (meaning that economic incentives may converge with environmental objectives). Many ship owners are said to be receptive and willing to work with scientists and conservationists to develop and implement a sound mitigation strategy. The "green ships initiative" was cited as an example.
- *Costs of alternatives:* Cost is a major factor in decisions to employ some sound sources. It may be difficult to identify or develop alternatives to sound-producing activities based on technological limitations or feasibility issues.

The transferability and accessibility of mitigation strategies may vary from one source type to another:

- Most techniques are transferable, but application and enforcement (i.e., legal regimes) may vary with region, country, and context.
- Mitigation guidelines developed by the JNCC for seismic surveys (JNCC 2004) were developed with the U.K. context in mind, but they have been widely used and cited.
- To improve accessibility, issues related to particular strategies need to be articulated in understandable terms. Having good systems in place to serve as models is also a good way to facilitate transference.

- The need for mitigation measures could be placed on the agendas of international fora and raised to the level of policy discussions in an effort to improve consistency and transference.

Other issues related to accessibility and transferability include uncertainty about the effectiveness of some approaches (a major obstacle to transference of tools and techniques), the need for early involvement of key stakeholders in planning and scoping phases, and the desirability of a global biogeographic information system, or universally accessible geo-referenced database on marine mammal distribution, relative abundance, and critical habitat. Duke University's Ocean Biogeographic Information System (OBIS) was cited as an example.[57] However, regardless of how sophisticated the information system itself may be, it cannot compensate for the lack of basic information on marine mammal populations in many regions, including ones where substantial anthropogenic sound inputs already occur.A belief in the feasibility of mitigation underlies virtually all RA and EIA. Expectations regarding the effectiveness of mitigation are often unrealistically high – participants differed in their degree of confidence that mitigation works. In the starkest terms, what one person regards as successful mitigation, another person may regard as imposition of high costs for no return.

Other differences in point of view were expressed on the subject of who should pay for and conduct an EIA. One view was that when companies or their consultants are responsible, they introduce bias, and therefore the responsibility for conducting assessments should be given to independent bodies. Another opposing view was that proponents and regulatory authorities have complementary roles, and that although the former should be responsible for producing the assessment, the latter has the responsibility for review and approval, thus offsetting any bias in the assessment itself.

Further concern was expressed about the extent to which EIA and RA depend on extrapolation (e.g., from well-studied species to poorly studied ones or from animals in one ecological setting to those in another). The credibility attributed to such extrapolations is always a matter of qualitative personal judgment.

Participants with experience in some less-developed countries expressed strong skepticism regarding the effectiveness of EIA. For example, it often takes place in situations where even basic information is lacking, such as what species occur in the affected area or what features of the habitat are biologically important. Institutional capacity, knowledge base, and political will all vary across countries and regions, making EIA variably effective.

The importance of investing resources in research on marine mammal distribution and critical habitat was a consistent theme, especially in reference to areas where the knowledge shortfall is greatest. At the same time, however, it was acknowledged that some of the existing commitments to mitigation are bound to continue, thus precluding reallocation of resources away from them and toward more research. It was also noted that the oil and gas industry already invests significantly more resources in research than in mitigation.

[57] See http://seamap.env.duke.edu/.

Group D – Prioritizing information needs (e.g., identifying information gaps, criteria for setting research priorities)

This group discussed the following questions:

- What information is needed for risk assessment, and how should it be prioritized?
- What are the information needs relative to various mitigation strategies and technologies, and how should those needs be prioritized?

Facilitator: Lee Langstaff
Topic Specialists: Ron Kastelein and Doug Wartzok
Recorder: Victoria Copley

The overall goals of risk assessment and mitigation should be to maximize both protection of the animals and benefits (realized efficiencies) to the sound-producing "users." Risk assessment (RA) provides a way of focusing resources on key concerns.

Risk can be thought of in several ways. For example, it can be a function of hazard in combination with exposure, or of probability combined with consequence (i.e., chance *x* effect). Distinctions can be made between (1) risks to individuals and populations, (2) risks associated with acute, localized high-intensity exposure and dispersed but chronic low-intensity exposure, and (3) risks of short-term and long-term effects. Hazards or effects can be auditory, non-auditory physiological, or indirect (behavioral), and they can be placed in different categories (e.g., directly damaging to hearing capability, forced stranding, or death of individuals; displacement from important habitat; behavioral changes such as separation of mothers and calves or frequent interruption of feeding or nursing leading to energy deficits). With those considerations in mind, the group attempted to construct a multi-dimensional matrix for RA, consisting of (a) category of hazard, (b) probability of occurrence, (c) severity of response, and (d) whether the impact would be on individuals or the population.

Among the types of capabilities and information needed for RA are the following:

- Ability to determine when an effect has occurred. Ideally, one needs to know the probability of being able to make such a determination.
- Ability to assess effects on individuals in relation to size of population. It is generally easier to detect and measure effects on individuals than on populations. Population effects can be measured as changes in demographic parameters (e.g., growth, survival, reproduction).
- Population information (distribution, population structure, abundance, trend, habitat requirements, etc.).
- Organismal information (e.g., foraging, social, and diving behavior; audiograms [hearing profiles] for species or species groups [e.g., beaked whales, baleen whales]).
- Dose-response information on sound exposure of relevant species. For example, we need to understand the levels of exposure (at given frequencies, etc.) at which permanent threshold shifts (PTS), masking (i.e., disruption of an animal's use of sound), behavioral responses, and other effects will occur.
- Understanding of cumulative effects.
- Three-dimensional, broadband source characterization of relevant sound sources.

- Better models of sound propagation, particularly in shallow water.
- Identification of the most important sound sources likely to pose risks to marine mammals.
- Temporal and geographic distribution of anthropogenic sound-generation in the marine environment, including measurements of, and evaluation of trends in, ambient noise.
- Data integration.

The group also thought that a global review of risk management frameworks could be useful.

Methods by which such information could be obtained include the following:

- Captive animal studies in which experimental protocols are used to obtain audiograms, dose-response information, and improved understanding of physiology and energetics. For example, it was suggested that trained animals could be used for studies of supersaturation in tissues during diving. Establishment of a shared captive animal facility for testing and experimentation would help achieve this.
- Access to operational ship time for observation of behavior and for controlled exposure experiments with free-ranging, instrumented animals at sea.
- Examinations of cumulative impact, including the development of better measures and indicators (e.g., neuroendocrine, glucocorticoid).
- Examinations of population-level effects, including the development of better measures (e.g., how changes in the behavior or physiology of individuals translate into changes in vital rates). However, one drawback of focusing on population effects (e.g., through population monitoring) is that once an impact has been detected, it is already too late to prevent such an impact (which is the main goal of mitigation).
- Development and wider availability of affordable technology.
- Improved stranding notification systems and further development of capacity for rapid response. Among the benefits expected from such improvements are auditory brainstem response (ABR) measurements of hearing capabilities, better-quality specimens, and better-controlled pathology investigations.
- Conducting careful, improved examinations of relevant pathology to document physical effects of exposure.
- Examination of mechanisms linking sound exposure to animal responses (e.g., stranding).
- Data collection, data management, and data analysis in less-developed countries. Greater capacity (e.g., facilities, expertise, funding) will be needed to achieve this.

Among the priorities for RA is information that may aid in the following:

- Can lead directly to risk reduction (e.g., describes how a mitigation tool functions, identifies areas or times where sound inputs will not harm marine mammals).
- Allows for extrapolation from one species, situation, or type of exposure/response interaction to other species, situations, or types of interaction.
- Helps establish and clarify cause-and-effect relationships (e.g., whether and how sound exposure leads to stranding).
- Improves understanding of dose-response mechanisms.

- Helps determine if there is a problem, and how large or small it is (e.g., whether a population-level effect is known or expected).
- Addresses regulatory requirements.
- Adds to public awareness and informed concern, including outreach to less-developed countries.
- Adds to capacity for completing the risk matrix described above.

Information needed for mitigation includes the following:

- Clear objectives that are practical, achievable, and auditable. This requires that acceptable risk is defined, and that the mitigation strategy offers potential for reducing risk to the acceptable level.
- Decision analysis models (perhaps adapted from other industries).
- Understanding of the efficacy and efficiency of mitigation measures (e.g., characterizing behavioral responses). These are likely species- and context-specific, which complicates analysis.
- Cost-benefit analyses of mitigation strategies, which will require means to measure both costs and benefits while recognizing that cost and benefit will be perceived and defined differently by various stakeholders.
- Analysis and integration of data already collected, or being collected, from monitoring.
- Better understanding of distribution, abundance, habitat requirements, and temporal use of various habitat areas (e.g., in relation to critical life history times), including habitat modeling.
- Better understanding of acoustic behavior of the marine mammals of concern and the implications for passive acoustic detection systems.
- Improved data and analyses of visual detection (sighting) probabilities so that mitigation efforts involving onboard observers can be evaluated and made more efficient. It was suggested that the analysis presented by Barlow, illustrating the difficulty of detecting beaked whales, should be extended to other species and further refined. His pessimistic conclusion may not apply to all species (e.g., the sperm whale).
- Exposure mapping, especially at the population level, to help determine how acoustic risks contribute to cumulative risks.
- Further development of active sonar detection systems, including improved equipment, better classification algorithms, and more validation trials to test assumptions.
- An operational understanding of the activity for which mitigation is being undertaken.
- Better understanding of how sound sources can be modified and of benefits that might result from signal alteration.
- Better understanding of ancillary effects of various mitigation strategies. For example, quieter ships might increase the incidence of ship strikes on whales.

Priorities for addressing information needs related to mitigation will depend on the perspectives and interests of those setting them. Among the considerations identified by the group were the following:

- Reduction of risk to the animals of concern.
- Ability of noise producers to continue their activities in a precautionary manner.
- Practicality, feasibility, and auditability.
- Scientific credibility.
- Reduction of uncertainty by investing in research and monitoring that will lead to important, relevant insights.
- Immediacy of the need to know whether a given strategy works.
- Matching mitigation strategies to specific, often local, situations.
- Balance between practicality and state-of-the-art standards.
- Optimization of cost-benefit ratio to ensure that good value is realized from investments.
- Conformity with current regulations and laws.
- Acceptability to public and regulators. This requires communication and education strategies. There are commercial and public relations risks that could arise from decisions to mitigate, or from failures to mitigate.

There was some discussion of how best to secure funding for needed studies, including the suggestion that investments in mitigation of unknown effectiveness might be redirected to fund research. However, many conservationists regard existing mitigation measures as appropriately precautionary, and some such measures are entrenched in regulatory regimes regardless of their effectiveness. Rather than redirecting resources away from mitigation measures that have yet to be shown effective, and toward further research to validate effectiveness, new funding likely will be needed to cover the latter. In addition, investment in experimental mitigation is more likely to provide conclusive, relevant information than is additional operational monitoring. For example, experimental protocols outside the normal operational mitigation requirements (e.g., ramp-up) could be integrated into seismic surveys to test effectiveness and refine the approaches.

Lessons might be learned from other fields of risk analysis and mitigation. For example, dose-response curves are regularly developed and used in toxicology. Epidemiological models that mine existing data and conduct correlation analyses also could be instructive. Such approaches might help avoid such problems as the delay of approximately 35 years from the first recorded instances of “atypical” mass strandings of beaked whales to the recognition of an association between such strandings and the deployment of mid-frequency tactical sonar.

E. Plenary Discussion

Lindy Johnson offered a personal summary of this session with the following five points:

- Defining acceptable risk is key to developing precautionary approaches.
- Sound-generating activities are going to continue; therefore the important issue is how those activities can be modified to lessen the risks to marine mammals.
- Early scoping, clear communication and integration of input, and broad stakeholder participation usually help prevent and resolve problems.
- Stakeholders need to be integrated to the greatest extent possible in the search for solutions.

- International solutions may be important, but should not be seen as a replacement for national and regional approaches.

Concern was expressed that chronic exposure of populations to relatively low levels of sound may not be receiving the attention it deserves, in large part because the effects are likely subtle and difficult to detect, measure, or attribute to a particular cause. Indeed, participants generally agreed on the need to seek a balance in managing the effects of both acute and chronic exposure, and effects at both individual and population levels. However, some participants argued that, in a few cases, marine mammal populations are demonstrably increasing in habitats exposed to significant anthropogenic sound, and that this could be interpreted to mean that the population-level effects of present levels of anthropogenic sound are at least tolerable, if not negligible. Although some felt that maximizing the protection of populations is an overarching goal that should be addressed in a more precautionary manner, others felt this goal must be balanced with a second overarching goal: to recognize the needs of sound producers. Balancing the need for protection with the need to avoid undue restrictions requires subjective policy decisions.

It is important not to lose sight of the need to consider potential cumulative, synergistic, and long-term effects. In addition, it should not be forgotten that in most developing (and many developed) countries, baseline information on marine mammals and underwater sound is far from adequate, and few, if any, monitoring programs are in place. One participant stated that, given that the shipping industry is the largest single source of sustained anthropogenic sound in the world's oceans, it should be the highest priority for management.

Differing views were expressed on seasonal or geographical restrictions. Some argued that there needs to be a solid scientific basis for such restrictions, with benefits to the animals clearly identified, and also that flexibility is needed to ensure that a sufficiently large window of time or space exists to allow needed work to take place. Others pointed to the importance of precautionary judgment in interpreting the scientific evidence. Similarly, although some participants expressed strong interest in investigating source-based mitigation strategies, others argued that reductions in sound levels currently being produced could have the unintended effect of greater sound production in the long run (e.g., needing more seismic surveys because of inefficient data collection). In any case, it was reiterated that "one size does not fit all" in the mitigation of impacts.

One participant suggested that risk assessment should be viewed as a means of organizing and ordering how we think about a problem. In some instances, the greatest uncertainties may be characteristics of the marine mammal population rather than the dose-response characteristics of the relevant sounds. Consideration of such factors can aid in setting priorities and developing management strategies.

There was some discussion of the idea that even if current mitigation measures are not proven to be effective for all species of concern, abandonment of those measures would be politically untenable. There is a need for careful evaluation of presently used mitigation protocols; certain measures may work for some species but not others, and certain other measures might be readily improved. Requirements for some mitigation may be justified as precautionary even if it cannot be shown conclusively to be effective. However, this must not preclude continued efforts to measure performance against intent. For example, it may not be possible to demonstrate that a particular separation distance between an airgun and a whale is “safe” for the whale, but it should be possible to estimate, based on empirical research, the probability of detecting a whale visually within that distance. Such an estimate would help inform an evaluation of the overall effectiveness of this approach to mitigation, as well as efforts to fine tune or improve the approach.

VI. Topic 5: Cross-Boundary Issues and Multilateral Approaches

A. Transboundary Challenges of Addressing Ocean Noise: Several International Focusing Events

Elena McCarthy (Woods Hole Oceanographic Institution, U.S.) addressed the following questions:

- What types of problems arise from the international nature of the issue of acoustic impacts on marine mammals? How can the conflicts be addressed?
- How might international communication and cooperation be improved?

McCarthy introduced this topic with two illustrative case studies that she regards as “focusing events” (i.e., events that brought extensive attention to the issue). One involved the multiple strandings of Cuvier’s beaked whales in Greece in 1996, coincident in time and space with NATO sonar deployments (Frantzis 1998). The other was the stranding of two Cuvier’s beaked whales in the Gulf of California in 2002, coincident in time and space with seismic research by Columbia University’s Lamont-Doherty Earth Observatory (Taylor et al. 2004; see also Richardson et al. poster 22 in Appendix 4). In the Greek event, the ship was owned by 16 NATO Member-States, had an Italian home port, and flew a German flag. Its sonar was owned by the U.S., and its operational area was within Greek waters. In the Gulf of California event, the researchers had received the necessary permits from Mexico, but were sued over whether they had obtained the appropriate authorizations under U.S. law. These examples highlight some of the transboundary challenges posed by anthropogenic sound in the marine environment. Those challenges include (a) jurisdictional and procedural confusion (e.g., regarding where and under what circumstances permits are required); (b) insufficient coordination and communication among government agencies, environmental groups, stranding networks, and other parties; and (c) regulatory inadequacies, often meaning a lack of standards or guidelines for the production of underwater sound. The cases also exemplify the difficulties of establishing cause and effect when the evidence is entirely circumstantial and the mechanism linking stimulus and response is unknown. The absence of an effective multilateral framework can lead to increased operational costs or shutdown, lawsuits, public mistrust, and damaged international relations.

During discussion, it was pointed out that, at least in the Mediterranean, considerable progress has been made since 1996. ACCOBAMS came into force in 2001, and since then stranding networks have been expanding in the region, as has awareness of the importance of rapid response to such events.

Owen speculated about what would happen if regulation of ocean noise developed in a piecemeal fashion. For example, might some researchers using high-intensity sound be tempted to undertake their research in the waters of coastal nations where the regulatory regime is less strict?

Disagreement was evident among workshop participants concerning the standard of evidence that should be met before links between sound exposure and particular impacts on marine mammals are accepted as existing. At one end of the range of opinion were those who believed that a strong correlation should be sufficient. Others insisted that a mechanism of cause-and-effect (e.g., physiological, behavioral) must be established to explain the link.

B. Consequences of Cross-Boundary Contexts: Concurrent Small Group Discussions (Session 2)

Following the formal presentation, four small groups met to discuss and elaborate upon assigned subtopics. The intention was to elicit and record the range of opinion within each group, and not necessarily to seek consensus.

Group A – Differing regulatory frameworks (e.g., varying degrees of protection, differing mitigation strategies, high-seas activities, enforcement and permitting issues, "not in my backyard" phenomena)

This group's discussion focused on the following questions:

- How do regulations and operational strategies differ between countries and in international waters? For example, to what extent are critical habitats, protected areas, and endangered species and populations reflected in the respective regulatory frameworks? What is the significance of any differences?
- How does the regulation of naval sonar, seismic research, shipping, and other sound sources (e.g., moored vs. ship-based sources) differ? Why? How should sources be differentiated in regulations?
- What problems arise from different national and domestic regulatory regimes? How might such problems be addressed?

Facilitator: Suzanne Orenstein
Topic Specialists: Olaf Boebel and Wolfgang Dinter
Recorder: Colleen Corrigan

Discussions began with the identification of key differences in regulatory and operational strategies, as well as the consequences of differing regimes. Differences can be related to the legal regime, the activity or sound source, and the natural values to be protected. International treaties, regional agreements, and national or domestic laws can result in multiple, and even conflicting, commitments or requirements across jurisdictions at all levels. One example discussed was Germany's position regarding research conducted under the Antarctic Treaty System (see comments by Dinter above, page 10). There is also often a lack of clarity about which rules apply in a given region. For example, the U.S., U.K., and Australian navies apply domestic regulations except when operating in a country with stricter regulations, in which case they adhere to the stricter standards. Meanwhile, oil and gas companies comply with the laws of the country in which they are operating and, in some cases, the laws of the country funding a project or operation hold sway. The extent to which oil and gas companies and seismic operations are subject to home-country regulations or the regulations of the country in which they are working at a given time is not always clear. In addition, cross-jurisdictional problems may arise. For example, it is not unusual for sound sources to be operating (transmitting sound) in one jurisdiction (e.g., on the high seas) while the "receivers" of the sound (e.g., marine mammals) are in another (e.g., within a country's EEZ).

Different instruments at varying levels of jurisdiction or regulation often do not use consistent or standard terminology. For example, the terms *endangered*, *critical habitat*, and *depleted* have specific meanings under U.S. law, and these meanings cannot be transferred directly or unambiguously to other regulatory contexts. Various instruments such as the IUCN—World Conservation Union Red List (a non-regulatory classification system), the Convention on International Trade in Endangered Species of Fauna and Flora (CITES, 1973[58]), and the Convention on the Conservation of Migratory Species of Wild Animals (CMS or the Bonn Convention, 1979[59]) have their own unique categories and criteria for identifying species and populations at risk. These "listing" systems are not interchangeable.

Industry-based initiatives to produce non-regulatory operational guidelines are a responsible first step by industry to reduce or prevent impacts. For example, the International Association of Geophysical Contractors developed voluntary industry guidelines to mitigate seismic operators' interactions with marine mammals (IAGC, no date). IAGC's members represent approximately 70 percent of seismic vessels operating worldwide. The IAGC guidelines may be applied in the waters of countries that have no regulations concerning the potential impacts of their activities. There may be some confusion about the application and enforcement of industry-based initiatives in some cases (i.e., the extent to which operational guidelines constitute binding requirements or voluntary "best practices").

The group described a wide variety of problems associated with these differences in strategy:

- International teams of researchers and other user groups may face multiple, possibly conflicting, standards.
- Obtaining multiple research permits from multiple jurisdictions can be costly and time-consuming, making it a serious obstacle to project planning and implementation.
- Threatened populations and critical habitats in some regions or countries may be left with no form of protection.
- The definitions of terms (e.g., endangered species, critical habitat, and protected area) will likely continue to differ among jurisdictions, between regulatory or non-regulatory instruments, and according to different institutions (e.g., IUCN, CITES, CMS), resulting in confusion and inefficiency. Even *within* treaties and agreements, particular terms may end up meaning different things in different jurisdictions, depending how they are interpreted and implemented by domestic authorities. As a result, the standards of protection or regulation may differ.
- Enforcement and compliance may differ according to local capacities or commitments, leading to unpredictable requirements and inconsistent protective measures.
- With regard to marine sound, it is unclear what standards apply to the shipping industry. In general, shipping is regulated internationally (under the IMO and its Conventions) while compliance is monitored and enforced nationally (through implementation of Conventions by sovereign states). For example, ship construction must comply with the SOLAS Convention; the flag state certifies for compliance. Major structural inspections are required every five years, and minor inspections every two and a half years. Beyond the requirements established under IMO, internal shipboard conditions are regulated by

[58] See http://www.cites.org/.
[59] See http://www.cms.int.

the International Labor Organization (ILO[60]), a U.N. agency that seeks the promotion of internationally recognized human and labor rights. By minimizing shipping noise in accommodation areas and reducing vibration, ILO measures have the added benefit of reducing sound pressure levels beneath the hull. Port states are expected to exert control over construction, maintenance, and working conditions through inspections against a risk matrix that includes performance record, with failures targeted for further inspections. Thus the management of shipping is particularly complex.
- Sovereign national governments maintain authority to impose more stringent regulations than international treaties, meaning that some activities may by prohibited by national authorities even though they are allowed under a broader treaty or agreement.

A number of strategies to address problems associated with differences in domestic, regional, and international regulatory frameworks were discussed as follows:
- Standardization and expanded use of voluntary measures and guidelines (e.g., JNCC 2004, IAGC no date).
- Emphasizing convergence of interests between regulators and sound-producing entities. For example, ship owners with concerns about maintenance and fuel efficiency may see benefits of their own in designing quieter ships.
- Persuading sound producers of the need for action *before* definitive evidence is available (i.e., precautionary approaches) through outreach and education. For example, it might be useful to provide the shipping industry with persuasive (i.e., compelling) evidence of the risks to marine mammals from underwater sound. The industry then needs to be challenged to address design and construction issues, bearing in mind that there is a lag time of approximately four years from initial design to use in the trade. Proposed changes will have a better chance of adoption if they are cost-effective.
- Building the body of scientific evidence related to acoustic impacts. Monitoring ocean noise to characterize, quantify, and determine causes of increasing levels (as recommended by the U.S. National Research Council report in 2003) would help achieve this.
- Easing or eliminating barriers to research and facilitating permitting processes in order to improve efficiency and reduce confusion. This could involve the development and application of broadened or global standards or guidelines. It was suggested that programmatic or general environmental impact assessment could be useful, as could development of a global database of permit requirements in various regions. The Scientific Council on Oceanographic Research (SCOR[61]) was cited as providing a potential mechanism.
- Using existing international frameworks to increase consistency across jurisdictions, industries, and regions. One example might be incorporating necessary modifications to ship design and construction into the terms of the SOLAS Convention. This would require that consideration of acoustic effects and sound production standards be added explicitly to the SOLAS agenda. Another example might be using existing guidelines or agreements under UNCLOS as possible models. For example, the Code of Conduct for

[60] See http://www.ilo.org/public/english/about/index.htm.
[61] See http://www.jhu.edu/~scor/. SCOR was the first interdisciplinary body formed by the International Council for Science (ICSU). It is a non-governmental organization for the promotion and coordination of international oceanographic activities.

Responsible Fisheries (Code)[62] may provide a model for port-state control of vessel activities on the high seas. However, the Code has not been successful in eliminating the widespread problem of illegal, unregulated, and unreported (IUU) fisheries, in part because not all states are signatories and in part because all signatories are not equally rigorous in enforcement. Another possible model is the Straddling Fish Stocks and Highly Migratory Fish Stocks Agreement,[63] which seeks to manage and conserve entire populations or stocks in a holistic manner. A final example might be invoking the environmental management system of the International Organization for Standardization (ISO[64]) to address all sound sources through audit-based certification (i.e., demonstrating reduction in sound generation before being certified). This type of system is either in place or being implemented in the Australian and Canadian naval fleets (ISO 14001 standard). Although the entire U.S. fleet may be too large for immediate implementation, such a system could be applied to individual naval bases.

- Using regional seas agreements under which international standards are implemented by national regulations (e.g., CMS regional agreements like ASCOBANS AND ACCOBAMS).

Some participants considered it important to tailor permitting requirements and processes to different sound sources. Others expressed opinions favoring the idea that all sound sources should be treated similarly (i.e., “parity”). For example, some participants argued that activities producing “transient” sounds should be subject to less stringent regulation than those producing more chronic sound.

A distinction was drawn between performance-based and prescription-based regulation. In the former, the success of mitigation is judged by whether or not marine mammals are negatively affected. In the latter, success is measured by the degree to which sound outputs meet a set of prescribed norms.

A distinction was drawn between sound that is an incidental byproduct of the activity (e.g., ship propellers) and sound that is produced deliberately for a function (e.g., sonars). It was acknowledged that these two types of sound may require different regulatory approaches. Regulatory decisions should be made only after considering the characteristics of the sound.

The shipping industry has recently become subject to international regulation with regard to chemical pollution, anti-fouling agents, and ballast water. Once shippers are convinced that mitigation measures are needed for sound reduction, they can be expected to move ahead with development and implementation. However, in the absence of firm scientific evidence of a significant impact on marine mammals from increased ambient noise in the oceans (e.g., temporary or permanent threshold shifts in hearing, masking of communications), some in the shipping industry will continue to question whether its activities should be regulated or its operations should change with regard to sound production.

[62] See http://www.fao.org/fi/agreem/codecond/codecon.asp.
[63] See http://www.un.org/Depts/los/convention_agreements/convention_overview_fish_stocks.htm.
[64] See http://www.iso.org/iso/en/ISOOnline.frontpage.

Group B – Multilateral agreements (e.g., applications of existing international law; enforcement issues, future actions)

This group discussed the following questions:

- What existing multilateral agreements could be used to address the impacts of sound on marine mammals? Have any actions been taken that are specifically directed at underwater sound or at acoustic impacts on marine mammals?
- What international authorities or institutions should be involved in policy decisions related to this issue? What entities are currently involved in discussions of sound in the oceans?
- What types of future regulatory or non-regulatory actions can or should be considered to address this issue?
- How might concerns about international enforcement be addressed?

Facilitator: Zoë Crutchfield
Topic Specialists: Monica Borobia and Giuseppe Notarbartolo di Sciara
Recorder: Randall Reeves

Differing views exist among legal experts regarding the interpretation of multilateral agreements and international law for the management of sound: strict and narrow interpretation versus flexible and broad. The 1969 Vienna Convention on the Law of Treaties[65] calls for interpretation of instruments in good faith based on ordinary meanings and the original intent of the parties. Further, it states that signatories cannot be bound by provisions when they did not intend to be. Some legal experts consider UNCLOS an example in which the terms “pollution” and “energy” were clearly intended, based on the negotiating history, to mean something other than sound. Other experts point out that UNCLOS was intended to be a comprehensive treaty for the oceans, and therefore it should be interpreted in a flexible manner and sound should be included within the ordinary meaning of “pollution” and “energy.” Moreover, UNCLOS explicitly refers to the conservation of whales, and it can therefore be seen as providing a framework for their protection (and that of other marine mammals) from threats that include underwater sound. In general, the group agreed that UNCLOS, given its comprehensive scope, is likely to be the framework treaty most relevant to management of sound in the marine environment and noted that it could feasibly be amended, but recognized the magnitude of such a process. The group also urged that the United States ratify UNCLOS.

As a starting point for discussion, the group attempted to develop a non-exhaustive list of multilateral instruments that might be used to address the effects of sound on marine mammals:

- Marine mammal conservation instruments and institutions that explicitly refer to the issue of anthropogenic sound:
    - ASCOBANS (1992, Baltic and North Seas and, more recently, the north-east Atlantic), which deals with small cetaceans, includes a preamble containing reference to noise disturbance and explicitly refers to “prevention of other significant disturbance, especially of an acoustic nature” in its annex (see discussion under VI.A. European Seas)

[65] See http://www.un.org/law/ilc/texts/treaties.htm.

  - ACCOBAMS (1996, Black Sea, Mediterranean Sea and contiguous Atlantic area), which prohibits "any kind of cetacean harassment," does not explicitly mention human-generated sound, but is working toward a resolution that would do so. [66]
  - The ICRW (1946), which established the IWC and has as a primary goal the conservation of whale stocks, is a global instrument that applies to some large cetaceans but is unlikely to develop a major role in this issue because of its narrow scope. The Convention itself does not explicitly mention human-generated sound, but recent non-binding whale-watching guidelines specifically mention noise disturbance, and a 2004 resolution on western gray whales refers to noise disturbance from oil and gas industry-related activities.
- Conservation instruments and institutions that have referred to the issue of anthropogenic sound but do not deal with marine mammals explicitly:
  - SOLAS (1974) deals with ship design, construction, and equipment, including aspects related to sound production.
  - The Convention on Transboundary Environmental Impact Assessment (Espoo Convention, 1991[67]) applies to the transboundary maritime context and includes the Protocol on Strategic Environmental Assessment (2003);
  - The Particularly Sensitive Sea Areas (PSSA) provision under MARPOL and the IMO is a global scheme that mentions noise. To apply the PSSA concept, a companion legal instrument for the associated protective measure would be needed.
  - The Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention, 1992), a regional agreement that deals with conservation of the Baltic Sea area, contains reference to human-generated sound in Article 9 relating to pleasure craft.
  - The Declaration on Protection of the Arctic Environment's Arctic Environmental Protection Strategy (1991) is a "soft law" regional agreement that includes sound as one of six environmental concerns.
- Five instruments that include a general obligation to prevent pollution or conserve biodiversity[68] and are sufficiently broad in their current form as to apply to sound-producing activities:
  - UNCLOS (1982) is a global framework instrument that includes biodiversity conservation and pollution prevention obligations.
  - CBD (1992) is a global instrument that includes biodiversity obligations, EIA provisions, obligations to protect special habitats, and the Jakarta Mandate on Coastal and Marine Biological Diversity (Jakarta Mandate[69]), which addresses the sustainable use of marine resources;
  - CMS (1979) is an instrument that is global in scope and includes annexes on cetaceans, sirenians, and pinnipeds and a resolution on wind farms;

[66] After this workshop's conclusion, the ACCOBAMS Meeting of Parties in Palma de Mallorca, Spain passed a resolution (MoP2, Resolution 2.16) on anthropogenic ocean noise.
[67] See http://www.unece.org/env/eia/eia.htm.
[68] See the Joint Web Site of the Biodiversity Related Conventions, http://www.biodiv.org/convention/partners-websites.asp.
[69] See http://www.biodiv.org/programmes/areas/marine/default.asp.

  - OSPAR (1992) is a regional convention that defines pollution similarly to UNCLOS and has biodiversity provisions, some of which include specific protocols on biodiversity and on offshore oil and gas development.
  - The Barcelona Convention (1976, amended 1995) is a regional convention that defines pollution similarly to UNCLOS and has biodiversity provisions, some of which include specific protocols on biodiversity and on offshore oil and gas development.
- Instruments and institutions that are potentially applicable to the management of sound but that would require amendment:
  - MARPOL currently applies to "substances" but includes strategies that are appropriate for interpretation that encompasses sound.
  - IMO could develop a convention to deal with the issue of human-generated sound as it did for the issues of ballast water and anti-fouling substances.

Although it was noted that NATO had taken action to mitigate the impacts of naval activities by member countries, the group did not discuss it in detail.

The group identified a number of international actions have been taken that specifically relate to sound:

- ASCOBANS has adopted ten resolutions related to sound, calling for applied research and the development of guidelines. ASCOBANS has developed guidelines for seismic operations, recreational boating, and whale-watching, and will begin a program related to sound-producing military activities in 2005. There has also been some discussion of shipping, with research recommended.
- IWC has produced non-binding whale-watching guidelines that specifically mention noise disturbance, and a 2004 IWC resolution on disturbance of gray whales near Sakhalin Island, Russia, refers to noise disturbance from seismic surveys and other oil and gas industry-related activities.
- CMS has adopted a non-binding resolution on wind farm noise.
- The Offshore Protocol[70] of the Barcelona Convention states that all activities, including seismic surveys, in the Protocol Area are subject to review. By implication, this refers to the potential for disturbance from anthropogenic sound.

In addition, the U.N. Straddling Fish Stocks and Highly Migratory Fish Stocks Agreement introduced the concept of supplementing flag-state control by allowing third parties to board and inspect a fishing vessel suspected to be in violation. This may serve as a useful precedent.

The group identified a number of entities and institutions that are, or should be, involved in policy discussions of the sound issue:

- UNICPOLOS, which addresses only two issues per year. Underwater sound has not yet found its way onto the agenda (although a joint presentation on the issue has already been made by the Ocean Institute, Natural Resources Defense Council, and Silent Oceans). If

[70] Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil, 1994; not yet in force. See http://www.greenyearbook.org/agree/mar-env/barcelona.htm.

it proves impossible to get sound on the UNICPOLOS agenda, the issue could possibly be addressed instead through the U.N. General Assembly.
- The Jakarta Mandate of CBD, with its references to conservation of critical habitat.
- IMO, for universal guidelines on ship construction.
- OSPAR, whose competence concerns "noxious substances." Annex 5 is especially relevant. Parties are supposed to consider all of pollution, thus potentially including sound. OSPAR has already expressed interest in the issue.
- Regional fishery organizations, with a concern for conservation of fish stocks that could extend to interest in the effects of sound on those species.
- Scientific expert groups such as the Intergovernmental Oceanographic Commission (IOC[71]) of the United Nations Educational, Scientific and Cultural Organization (UNESCO[72]), GESAMP, Global Assessment of the State of the Marine Environment[73] (coordinated by UNEP), and IUCN.
- Defense treaty organizations such as NATO.
- Various other governmental and intergovernmental fora including (but are not limited to) the International Seabed Authority,[74] UNEP, Antarctic Treaty Consultative Meetings,[75] North American Commission for Environmental Cooperation[76] under the North American Free Trade Agreement (NAFTA[77]), Asia Pacific Economic Cooperation (APEC,[78] which has marine environment and fisheries working groups), European Union,[79] Council of Europe,[80] and Arctic Council.[81]
- Nongovernmental organizations representing environmental or industry interests (e.g., whale watching, oil and gas, shipping).

Avenues for implementing future regulatory or non-regulatory actions include creating one or more new treaties, and amending or reinterpreting existing instruments, regional agreements, and national laws. Various approaches that might facilitate such actions include the following:
- Adopting guidelines or regulations through the IMO. Port states could prohibit entry and docking by vessels that do not meet those guidelines. However, this could have the effect of shifting the problem to areas with less stringent controls, with no net benefit for conservation (e.g., the requirement for double-hulled tankers).
- Increasing efforts by the international ocean monitoring community to place more hydrophones in the water and provide better baseline data on ambient noise.
- Building on opportunities for cooperative action to refine mitigation methods and encourage compliance provided by the fact that some stakeholders (e.g., the seismic

[71] See http://ioc.unesco.org/iocweb/index.php.
[72] See http://www.unesco.org.
[73] See http://www.unep.org/DEWA/water/MarineAssessment/.
[74] See http://www.isa.org.jm/.
[75] See http://www.scar.org/treaty/meetinglist.html.
[76] See http://www.cec.org/home/index.cfm?varlan=english.
[77] See http://www.nafta-sec-alena.org/DefaultSite/index.html.
[78] See http://www.apecsec.org.sg/apec.html.
[79] After this workshop's conclusion, the European Parliament passed a resolution on the environmental effects of high intensity active naval sonars. (European Parliament Resolution on the environmental effects of high-intensity active naval sonars, PE 347.527. Oct. 28, 2004.)
[80] See http://www.coe.int/DefaultEN.asp.
[81] See http://www.arctic-council.org/.

industry, the military) are already engaged in mitigation efforts. Partnership arrangements involving nongovernmental organizations, government agencies, and industry can provide training, workshops, and other "capacity-building" opportunities.

- Preparing and circulating information papers in international fora (e.g., the IMO, UNICPOLOS, meetings or conferences of the parties of relevant instruments noted above).
- Passing resolutions in appropriate organizations.
- Developing the "green ships" initiative within the shipping industry.
- Inserting underwater noise guidelines into the approval criteria on projects funded by institutions such as the World Bank[82] and the Global Environmental Facility.[83]
- Further developing voluntary initiatives and refining guidelines or codes of conducts within sound-generating industries (e.g., research, oil and gas development).
- Standardizing regular reporting as a key to ensuring compliance (although reporting obligations themselves often are not met).
- Using dispute resolution mechanisms to encourage compliance. This may work in some cases, but some disputes are nevertheless likely to drag on for long periods of time without resolution.
- Establishing a clearinghouse, or central repository of information, on the known and potential effects of sound on marine mammals. This may facilitate awareness raising, exchange of experiences, and the incorporation of sound into environmental impact assessments at the national or regional level.

Actions to mitigate the effects of underwater sound can range from guidelines and codes of conduct to binding treaties. As a general principle, the broader the geographical scope of a measure, the higher the threshold of proof needed to justify regulation. In other words, a globally binding measure would probably need to be buttressed by conclusive evidence of cause and effect. There is some disagreement about the conclusiveness of scientific information currently available on the effects of sound on marine mammals.

Participants differed on the question of whether a given action should be binding (regulations) or non-binding (guidelines, hortatory resolutions). Views sometimes even differ within an industry or interest group. For example, in the shipping industry, American shippers may prefer globally binding regulations, but the U.S. merchant marine is relatively small and does not have decisive influence on the industry overall. The shipping industry may prefer guidelines or codes of conduct (e.g., industry-developed voluntary measures) rather than regulations.

A distinction was made between enforcement (which can accompany regulations and implies liability) and compliance (which is essentially voluntary in the case of non-binding guidelines). Compliance is difficult to monitor in the case of activities at sea, but relatively easy to monitor in the shipping industry through port-state inspections. A need that can arise in enforcement proceedings is for an ability to specify sound sources (i.e., acoustic "fingerprints"). In instances where treaty measures have no threat of penalties, chastising mechanisms may exist to provide incentives to comply. It is crucial that the standards of compliance be clearly stated.

[82] See http://www.worldbank.org/.
[83] See http://www.gefweb.org.

As involved parties become more comfortable with guidelines and convinced of their utility, these may become recommended (and even implemented) practices and procedures. As a result, states may become more willing to sign treaties and thus entrench the guidelines as binding measures. Some non-binding measures (e.g., guidelines, capacity building, information dissemination) can be pursued alongside regulations to make them better understood and more widely accepted.

In the short term, when it comes to multilateral agreements and international law, regional agreements probably offer more feasible options for addressing underwater sound than international instruments because they tend to be more specific to a region's biological characteristics, socioeconomic realities, and implementation capacities.

The proliferation of environmental treaties and agreements since the Earth Summit in Rio de Janeiro in 1992,[84] and indeed since the Stockholm Conference in 1972,[85] has led to "agreement fatigue," a reluctance of some countries to sign onto more instruments and an insistence on improved implementation of those that exist. In some instances, resource limitations are a serious obstacle to further development of international or even regional legal instruments.

Group C – Marine mammal research coordination (e.g., setting priorities among research agendas, stranding response programs, permits)

This group focused on the following questions:

- How can information from around the world be incorporated in the policy-making process at national, regional, and international levels?
- What are the challenges to marine mammal research coordination, and what problems arise from a lack of such coordination?
- How could scientists better inform policy-makers on issues related to marine mammals and sound? What challenges does the scientific community face? What challenges do policy-makers face?

Facilitator: Lee Langstaff
Topic Specialists: Mardi Hastings, Bill Perrin, and Lorenzo Rojas-Bracho
Recorder: Eunice Pinn

Scientists and policy-makers often fail to understand each other's language and needs, resulting in mutual incomprehension and, sometimes, mistrust. If science is to be used optimally to inform policies and laws, scientific findings and their limitations need to be interpreted accurately into non-technical terms and communicated effectively to policy-makers. For their part, policy-makers need to be receptive to scientific input and avoid the temptation to ignore or knowingly misinterpret it. Science-based policy tends to be difficult to formulate and implement, even in the best of circumstances.

[84] See http://www.un.org/geninfo/bp/enviro.html.
[85] See http://www.unep.org/Documents/Default.asp?DocumentID=97.

The group identified several challenges to communication and coordination between scientists and policy-makers, as follows:

- Scientists' involvement in policy-making can impinge on scientific objectivity.
- The results of hypothesis-driven science are not always easy to match with the types of questions asked by policy-makers and managers.
- Honest answers to scientific questions include descriptions of the associated uncertainties, while policy-makers often expect, and sometimes need, unqualified advice from scientists.
- The timescales of science and policy are often mismatched, as many scientific questions require long-term studies for definitive answers, while policy decisions often need to be made quickly.
- Scientific pronouncements can have serious implications for policy if misused, misinterpreted, or taken out of context. Conversely, good science, properly interpreted and communicated, can have a positive influence on policy. Scientists need to be aware of the weight given to their statements and qualify what they say accordingly.
- Scientists are often dismayed by the loss of precision and accuracy that occurs when scientific concepts are translated into non-technical terms and conveyed to a non-technical audience.
- The general state of "information overload" makes it increasingly difficult to transmit non-sensationalist messages to a wide audience. Competition for reader, viewer, or listener attention prompts media to release information prematurely and to opt for sensational, rather than considered and balanced, reporting.
- Misunderstandings often arise as a result of the lack of standardized methods, units, and terminologies, even among scientists.
- Scientific research is intrinsically a "bottom-up," or curiosity-driven, process, but most funding is made available on a "top-down" basis, through contracts and grants to seek answers to specific questions. The results of such work are often viewed with suspicion and considered biased toward the sponsor's desired outcome, even when safeguards against conflict of interest are in place.
- Access to scientific expertise is not uniform around the world, and is affected by geography, politics, and economics. Language barriers and shortages of technically trained people make it difficult in some regions and countries to inform and shape public policy with scientific knowledge.
- Scientific literature (e.g., technical journals) is often expensive to obtain, and it cannot be assumed that just because a study is published, it is widely available to policy-makers.
- In many countries and regions, marine mammal conservation is not a priority; it may not even be on the policy agenda. Concerned scientists may thus face barriers as they attempt to influence policy decisions.
- Military and industrial sound producers are often reluctant, unwilling, or unable to provide key information on their activities. Even when they are willing to release information, the onus may remain on researchers to formulate their requests in particular ways to elicit all of the relevant data.
- Policy-makers usually need to be responsive to a variety of stakeholders, and the scientific community is seen as only one of several stakeholder groups. Thus "scientific opinion" may be given no more weight than that of other groups.

- Staff turnover in government agencies or industry offices can result in the loss of institutional memory and make it difficult for other stakeholders to keep track of whom to contact concerning particular issues.

Coordination of research is always a challenge, but is necessary to avoid duplication of effort and increase the chances of consistency and completeness of information on national, regional, and international scales. Specific challenges to coordination and cooperation include the following:

- Difficulty of identifying common objectives, given the volatility of national priorities and frequent non-transparency or ambiguity of agendas.
- The fact that permitting processes may differ between countries, and multiple permit requirements can add time and expense to collaborative projects. Further, procedures for obtaining permits may change, leading to further delays and confusion.
- Language, cultural, and other differences among researchers from different countries, contexts, or disciplines.
- Lack of standardized methods, units, and terminologies.
- The fact that in most countries and regions, marine mammal conservation is not a priority.
- The tendency of existing international collaborations to involve the same core group of countries or individuals, which reinforces imbalance in scientific and technical capacity.
- Lack of access to key information from certain types of sources (e.g., the military, industries).

The group was not able to identify and agree on specific ways to overcome these challenges, but noted that SCOR might provide a mechanism to improve coordination and facilitate international collaborations.

A number of possible mechanisms for improving the linkages of science to policy and law were identified, as follows:

- Professional organizations, including nongovernmental organizations, can use science-based position papers and press releases to influence and drive the policy process.
- Just as policy-makers need to better understand the positive potential and limitations of science, scientists need to become better acquainted with the policy process and thus with the needs and constraints faced by policy-makers. In fact, project designs and methods can sometimes be selected or shaped to increase the likelihood that the findings will meet the needs of policy-makers. Medical science and some other sciences may provide useful models of this process.
- Scientific advice should clearly delineate options for action and describe the probable consequences for each option.
- Interim or intermediate reporting of research results may facilitate timely policy decisions. However, policies then need to be flexible and adaptive to allow adjustments when final results become available.
- In the U.K., policy-makers refer specific questions to groups of scientific specialists, often without revealing the motives behind the questions. This is a slow and protracted process but generally successful.
- Professional science communicators can play an important role in translation between technical and non-technical audiences.

- Scientific advisory support to policy-makers, whether through staff positions for scientists or standing advisory boards (e.g., the Marine Mammal Commission's Committee of Scientific Advisors), can help ensure that scientific information is conveyed to policy-makers in a timely, accurate, and understandable fashion.
- Articles or commentaries by scientists (or professional science communicators) in major newspapers and news magazines can be an efficient way of disseminating key information.
- Better use can be made of the Internet (e.g., the MARMAM e-mail list server,[86] electronic access to journals) to achieve centralized information sharing.
- Transference of scientific knowledge and advice across international boundaries may be accomplished through internships or scientific extension/exchange programs.
- Provision of non-English abstracts in relevant languages by scientific journals and other publications is a relatively easy way of increasing and expanding access to scientific information.
- International bodies such as ASCOBANS and ACCOBAMS facilitate exchange of information among national representatives, scientists, and nongovernmental organizations. In that regard, these agreements might provide models for other regions.
- Programs initiated and sponsored by professional organizations can help offset the technically disadvantaged positions of some regions or countries (e.g., by providing scholarships and fellowships, offering free or subsidized memberships, and funding attendance at international meetings and conferences). Professional organizations can facilitate courses and training workshops to help build capacity in those regions or countries.
- The IOC has employed a capacity-building specialist to provide a strategic review of data exchange and ocean research funded by the IOC. Comments on this review have been requested from the 129 member countries.
- Any effort to standardize methods, units, and terminologies can be expected to improve communications between scientists and policy- and lawmakers. Standardization, however, should not be allowed to stifle originality and prevent the development of improved methods.
- One way of addressing the problem of bias (perceived or real) in sponsored research is to establish independent scientific panels to review such work.
- As a way of enhancing the quality of scientific analyses and facilitating access to the results, some programs require researchers to publish their findings in peer-reviewed journals as a condition of funding. Project budgets need to be adjusted accordingly to make this feasible.
- Some journals have a mechanism for making full data sets that underlie a published study available electronically to anyone interested in conducting further analyses. Making "raw" data available in this way, with due consideration for the proprietary interests of those who designed and conducted the original study, can improve credibility and encourage scientific discourse.

[86] See http://whitelab.biology.dal.ca/marmam.htm.

***Group D – Improving Regulatory Capacity** (e.g., strategies to enhance abilities of governments to create, implement, and enforce laws and regulations concerning underwater sound)*

Facilitator: Erin Vos
Topic Specialists: Michael Jasny and Mark Tasker
Recorder: Victoria Copley
This group discussed the following questions:

- What are the greatest needs of countries seeking to improve their ability to deal with the impacts of anthropogenic sound on marine mammals? What are the greatest needs in dealing with these impacts internationally?
- What can be done to improve various national or domestic management and regulatory regimes?
- What can be done to improve international or multilateral management and regulatory regimes?

The group began by focusing on what is needed to improve regulatory capacity at the national level. Although the nature and level of needs vary widely from country to country, all require additional political will and better technical, scientific, and management capacity to address sound-related issues. Countries with no suitable management regime may desire one but lack the necessary institutional capacity and resources. In some cases, countries with no management regime may have little or no interest in developing one (e.g., due to suppression, resistance, corruption, or prioritization of other issues). Few, if any, countries that do have management regimes in place have sufficient capacity to address the sound issue in a comprehensive manner. Six major categories of need apply to all countries, especially in the developing world. For each category, several tools and actions were identified that could improve management and regulatory regimes, as described below.

1. At the national level, there is a need for *greater institutional capacity for policy development, oversight, and enforcement*. National administrations need to build expertise in science and policy. For example, mechanisms to provide funding for students might help increase the number of individuals trained to work on sound issues, and job-swap, secondment, or partnership programs could facilitate the transfer of relevant skills and knowledge across governments and institutions. In addition, training programs could be created, or specific topics could be built into existing courses. Such efforts in skill development and sensitization to the sound issue must be accompanied by the creation of outlets for the use of those skills and opportunities to express any heightened awareness. Otherwise, they are likely to cause frustration and disillusionment. National and regional meetings and regular interdisciplinary conferences could help create communication networks and enhance public awareness. These, in turn, could be expected to reduce institutional fragmentation and build political will.
2. The *development of incentives to comply with existing laws and guidelines and to reduce sound production voluntarily* is another area of need at the national level. In general, incentives can be produced by addressing multiple societal values concurrently, considering both conservation and socioeconomic goals. Solutions to sound-related issues may be linked to solutions to other conservation problems, as

well as to economic benefits. It is important to make solutions attractive, or at least tolerable, to user groups (i.e., those that introduce sound into the marine environment). For example, some sound-producing industries may see public relations benefits in developing more environment-friendly practices (e.g., “quiet” cruise ships). Such groups can capitalize on consumer choices in cases where a well-educated or conservation-minded public exists. Financial incentives may be created through tax relief programs and subsidies. It may also be possible to create government markets for new “quieting” technologies. Education and increased public awareness play a key role in creating and communicating incentives for sound reductions.

3. There is a need for more *effective and efficient mitigation and monitoring options that are affordable in a national context*. Long-term approaches to mitigation can produce economies of scale and thereby improve efficiency, while short-term approaches that focus on “low-hanging fruit” (i.e., issues that are relatively easy to address) may also be worth pursuing. It is important to maintain flexibility and creativity as protocols are being developed, as this will maximize effectiveness while avoiding unnecessary expenditures or efforts. For example, seasonal restrictions are best applied in a manner that reflects the dynamics of the natural systems involved. Cumulative impacts (a concept often overlooked in mitigation schemes) should be addressed by placing various types of sound exposure into a wider context of animal health, reproduction, and survival. Coordination of mitigation efforts through a single “gatekeeper” entity (e.g., to complete strategic cumulative impact assessments and to develop ambient noise budgets) may improve coordination and transparency.
4. National regulatory capacity can be improved by *better communication and coordination, heightened awareness about sound-related issues, and education and information-sharing efforts*. For example, central clearinghouses can make information widely available, educational materials can aid policy-makers, and intergovernmental strategy-sharing can enhance management efforts. The development of public awareness and political will may require a stronger conservation ethic (e.g., a shift in cultural values). In all efforts, culturally sensitive approaches that make concerns relevant to the affected parties are likely to be more effective and sustainable. For example, it may be more effective to address the impacts of underwater sound on marine mammals through integration with existing programs to conserve sea turtles in the Caribbean, rather than by creating new, entirely separate marine mammal initiatives in that region. An understanding of local culture is vitally important in effective management.
5. *Capacity for oversight, enforcement, and compliance* is important at both national and international levels. In some cases, enforcement is complicated by a lack of clarity in existing laws or guidelines (e.g., legal definitions of harassment). Where existing regulations can be clarified, it may be useful to standardize these and broaden their application. Barriers to ratification and implementation of legal measures may need to be addressed to allow this. There is a general need to develop competency in authorities charged with implementing existing laws. Financial and human resources often limit government capacity. In such cases, education and training programs may help. There is also a need to enhance compliance where laws or guidelines exist. Both incentives (“carrots,” e.g., financial rewards; see additional discussion above) and consequences or threats (“sticks,” e.g., procedural or criminal litigation, financial

penalties) should be employed when appropriate. Stronger monitoring and reporting requirements may also help, and monitoring by citizen groups and other users can enhance enforcement capacity. User groups themselves may be more inclined to comply if they have a clear understanding of the problem. Stakeholder participation in policy development and management, as well as education and other efforts to build political will, can also help. Finally, many believe that sound-producing operators working abroad have an obligation to adhere to their own country's standards when these are more stringent than those of the host country.

6. Finally, a need at both national and international levels is to *clarify jurisdictional issues and delineate responsibilities between and within governments*. For example, some low-frequency sounds propagate many hundreds of miles and cross multiple jurisdictional boundaries, but the relevant authorities and institutions often lack the capacity to coordinate and cooperate in management. Source-specific and region-centered research, as well as improved dissemination of information, may improve understanding of sound propagation and clarify to managers what types and levels of sound are "significant." Integrated approaches to management and law (e.g., a single national agency to address marine issues) can improve coordination and communication and streamline management processes. It is also important to improve understanding of the laws that determine jurisdictional boundaries, clarifying ambiguities and educating stakeholders.

In addition to the two national/international issues discussed above (numbers 5 and 6), the group identified five categories of actions and tools to improve regulatory capacity at the international level, as described below.

1. There is a need to *develop multilateral instruments and guidelines* to deal with the issue of sound and marine mammals. It may be possible to use existing legal regimes and frameworks to do so (e.g., by expanding existing conventions and agreements to incorporate sound or encouraging additional governments to join). Sound can and should be considered an aspect of habitat quality and therefore merits consideration in ecosystem approaches to management. Sound should be explicitly included in international guidelines and agreements.
2. Another area for improvement is in the *use of experience and knowledge to shape and inform best practices in permitting, mitigation, or other aspects of management*. For example, the JNCC's guidelines for seismic operations, existing industry-defined standards, or sets of standards developed in other jurisdictions might be applied more widely. Improved dissemination of information, job swaps, secondment programs, and model programs also may help.
3. *Broad stakeholder participation* is another key to improving international regulatory capacity. A variety of formal and informal processes might be employed to achieve this throughout all phases of policy-making and management.
4. *Better liability and enforcement mechanisms in existing international law* are desirable. These might require statutory changes or legal challenges leading to judicial interpretations.
5. Finally, *international use of monitoring and adaptive management* would enhance regulatory capacity.

C. Small Group Reporting and Plenary Discussion

One participant urged others not to assume anthropogenic sound is a threat to marine mammals without more compelling scientific evidence. Citing the recent U.S. Commission on Ocean Policy's report as confirmation that marine resources should be available for multiple uses,[87] he pointed out that off California, where low-frequency sound levels have increased by 10 dB over the last 40 years, gray whale populations also have increased. Most notably, the eastern North Pacific population of gray whales is believed to have recovered to a level close to carrying capacity, despite the documented increase in ambient noise. Another participant elaborated on this point, suggesting that even if one accepts that anthropogenic sound is a problem, the resources committed to address it may be currently misallocated. In other words, relative to other threats (e.g., bycatch in fisheries), is it appropriate to force the industry to spend such large sums on the sound issue?

Several participants expressed disappointment that the very existence of a problem is still a matter of debate. They suggested it was simplistic to infer from the evidence of population increase for some marine mammal populations that exposure to anthropogenic sound poses no threat. If the best available scientific opinion indicates that there is a problem, a precautionary approach would be to accept the need for corrective action (mitigation) while at the same time pursuing focused research to improve understanding of the nature and magnitude of the problem.

Common themes from the group reports and ensuing discussion included that (a) both short- and long-term goals and objectives need to be defined and clearly articulated; (b) outreach and education should begin immediately; (c) management of sound should be tailored appropriately to the type of activity involved, and (d) given that the shipping industry has its own economic (energy-conservation) reasons to move toward quieter ships, there may be opportunities for cooperative action.

Table 2 (see page 72) provides a summary of multilateral agreements mentioned in the workshop proceedings. No attempt has been made to analyze the information as it was presented during the workshop.

[87] See http://www.oceancommission.gov/.

VII. Synthesis, Summary, and Future Directions

Mark Tasker provided a personal synthesis to initiate the workshop's final plenary discussion. His presentation is summarized below.

The overall goal of policy is to reduce and further control anthropogenic sound in the world's oceans. The greatest concern is loud low- and mid-frequency sound, the most significant sources of which are shipping, seismic survey operations, and military sonar.

Views differ concerning the relative and absolute significance of sound as a risk factor for marine mammals. Some participants likened the current debate on this issue to the early stages of the controversy over global warming. It is important, however, to continue to seek greater agreement on the environmental effects of underwater sound because any action to manage sound will cost resources. Given that resources are limited, any allocation to address one sound source could have implications for the amount available to address others. Thus, to some extent at least, attention and investment devoted to the sound issue may divert resources away from other conservation issues. At all stages, it is important that cultural choice be respected.

As highlighted in the seven case studies of efforts made in various jurisdictions (Section VI), several challenges must be overcome to regulate ocean sound, including the following:

- The issue was not viewed as significant until recently and even now some stakeholders question its importance.
- Few existing laws or multilateral legal instruments explicitly address the issue, and none focus on it.
- Underwater sound cannot easily be constrained within the borders of countries or other jurisdictional units, so it is by nature transboundary.
- Many nations and a wide variety of stakeholders (shipping industry, oil and gas industry, research community, military, etc.), all with differing priorities, contribute to anthropogenic sound in the oceans.

Rapidly growing awareness of the problem of sound and marine mammals on the part of those involved in sound-generating activities creates opportunities for action. It may be possible in the near future to build on the following:

- The military has sophisticated technological capabilities and financial resources.
- The seismic survey industry has been developing guidelines for mitigation.
- The shipping industry is awakening to the need to address this problem.
- Treaties exist to control and reduce marine pollution, potentially including sound.
- Laws and conventions exist for nature conservation, with some potential for regulating sound.

A number of "next steps" were identified during the workshop. For mitigation, some techniques (e.g., geographical or temporal shifts in sound production to accommodate marine mammal needs) are effective in reducing and preventing impacts. A better understanding of other techniques is needed. For education and outreach, materials and campaigns need to be carefully crafted and culturally sensitive, and public input is therefore essential. The primary aim should be to ensure that the issue is widely debated and placed on relevant agendas. Educational efforts need to be grounded in accurate reporting, with uncertainties explicitly acknowledged. In research, there needs to be a balance of top-down and bottom-up approaches.

Various user groups are at different stages. Tasker believes that the military has made good progress but needs to be more transparent. The seismic industry has guidelines, but those may need to be open for comments and modification (e.g., those in the U.K. are posted on a website for input from interested parties). Industry should be encouraged to continue development and testing of mitigation approaches (noting the considerable investment that has already been made). The shipping industry and ship designers should be challenged to develop quieter technology.

In terms of legal frameworks, it is necessary to consider scale and transboundary aspects. In general, it will be necessary to choose between prescriptive and performance-based models, but the latter is preferable. It was agreed that sound should be incorporated as an element to be considered in environmental impact assessments.

Internationally, the creation of a new treaty on sound and marine mammals would be hard to deliver. Acceptable risk is a cultural choice, and thus universality may be difficult to achieve. However, numerous treaties and other instruments are available, UNICPOLOS offers a way into the U.N. system, and useful lessons may be learned from the climate change debate.

Following Tasker's synthesis, additional points were made by other participants:

- Opportunities exist (e.g., in the shipping industry) to take advantage of the convergence in interests between the sound producers, who for economic reasons want to make vessels quieter, and those who are pushing for regulation and reduction of anthropogenic sound in the oceans.
- Mid-frequency sound (e.g., that of some military sonars) is as much of a concern for marine mammals as low-frequency sound. Regulatory attention needs to be given to both frequency and intensity of sound.
- Source-based mitigation is at least as effective as time/area shifts in operations, and more investment is needed in research and development directed at source modification.
- The necessary research and development for effective mitigation will take considerable time; in the meantime, precautionary management measures are warranted.

In considering what should happen next, participants made the following suggestions:

- With regard to the shipping industry, a compelling case needs to be made that ship noise has adverse effects on marine mammals. The industry must then be challenged to address the problem. The SOLAS convention provides a possible route of access for influencing the shipping industry to move toward quieter operations.
- It is important to distinguish between short- and long-term goals, and to pursue them in tandem.
- Outreach and education should be pursued via information papers circulated in appropriate fora.
- From the perspective of the seismic industry, it was noted that (a) internal educational programs are ongoing; (b) seismic survey vessels provide platforms for obtaining scientifically relevant data (effort and sighting report forms, including periods in non-

operational mode); (c) most future production of oil and gas will come from countries in which government-owned companies predominate, and as a rule, these companies are less environmentally responsible than companies that are publicly owned and accountable for their actions; (d) the idea of systematically soliciting public input and vetting the IAGC guidelines (per the U.K. example) would be welcomed by the industry; and (e) references to the potential effects of seismic activities that appear in educational and outreach materials must be accurate and include appropriate reference to scientific uncertainties.

- U.S. naval forces are investing substantially in research, and a Navy representative encouraged non-military researchers to contribute to naval priorities, especially modeling.
- Nongovernmental organizations (a) expressed their interest in and commitment to further awareness and education on this issue; (b) emphasized the value of a participatory framework in which NGOs work cooperatively with government agencies, regional bodies, and industries to improve mitigation efforts (e.g., guidelines); and (c) characterized their failure to engage in a broad inter-NGO dialogue as a glaring omission in their strategy on ocean sound to date.
- Scientists involved in acoustics research in the marine environment indicated that they wish to (a) establish scientific priorities for sound-generating research, (b) diversify the funding base for their research, and (c) develop outreach efforts that are accurate and that improve public understanding of their work.
- A suggestion was made that sound-generating research should be avoided if possible and that solid justification should be required before permits are issued for such research. A code of conduct for sound-generating ocean research is being developed in Germany.
- Scientists studying the effects of sound on marine mammals need to (a) identify priorities and key information gaps, (b) establish international and interdisciplinary collaborations, (c) publish their results in the peer-reviewed literature, and (d) improve their communication with non-scientists.
- An internationally funded and administered mechanism for investigating mass strandings of cetaceans is desirable (e.g., to achieve complete necropsies of dead animals and obtain as much relevant information as is feasible from live animals).

The workshop goals of (a) describing the range of existing management and mitigation approaches and (b) exploring and describing cross-boundary issues were largely met. The goal of identifying strategies and solutions to policy questions that might be transferable across national boundaries was met only partially. It might be useful to hold further meetings as offshoots of this workshop, focusing on some of the technical issues identified in London. Such meetings might include more case studies in which the entire management process is tracked from problem identification, to directed research, to management decision-making, to implementation.

Table 1. Selected Examples of Domestic Laws and Regulations Mentioned
The examples provided are a subset of those discussed during the workshop. No attempt has been made to analyze the information as it was presented.

Country	Sound Sources Potentially Addressed	Relevant Laws or Means of Regulation	For additional information
Brazil	Seismic survey activities	Resolution 305 of the National Environment Council (CONAMA), July 2004	http://www.mma.gov.br/port/conama/index.cfm
Gabon	Seismic survey activities	Law 16/93 Related to Improvement and Protection of the Environment	
South Africa	Seismic survey activities	2004 Minerals Act	http://www.dme.gov.za/home.asp?menu=publications/guideline_documents.htm
United Kingdom	All activities with potential to kill or disturb cetaceans and other designated species	Wildlife and Countryside Act 1981; Conservation (Natural Habitats &c.) Regulations 1994	http://www.jncc.gov.uk/page-1377
United States	All activities with potential to "take" marine mammals, with some exceptions	1972 Marine Mammal Protection Act; 1973 Endangered Species Act; 1969 National Environmental Protection Act; 1972 Coastal Zone Management Act; 1953 Outer Continental Shelf Lands Act	http://www.mmc.gov/legislation/ http://ceq.eh.doe.gov/nepa/regs/nepa/nepaeqia.htm http://coastalmanagement.noaa.gov/czm/czm_act.html http://www.csc.noaa.gov/opis/html/summary/ocsla.htm

Table 2. Summary of Multilateral Agreements Mentioned

The agreements summarized below are those mentioned in the workshop proceedings, a subset of those discussed during the workshop. No attempt has been made to analyze the information as it was presented.

Agreement Abbreviation	Agreement Name	Date Signed	Date Entered into Force	For more information
Abidjan Convention	Convention for Co-Operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region	1981	1984	http://hq.unep.org/easternafrica/AbidjanConvention.cfm
ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area	1996	2001	http://www.accobams.mc/
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas	1992	1994	http://www.ascobans.org/
Barcelona Convention	Convention for the Protection of the Marine Environment and Coastal Region of the Mediterranean	1976	1978	http://www.greenyearbook.org/agree/mar-env/barcelona.htm
Bern Convention	Bern Convention on the Conservation of European Wildlife and Natural Habitats	1979	1982	http://www.oceanlaw.net/texts/summaries/bern.htm
Bonn Convention (also known as CMS)	Convention on the Conservation of Migratory Species of Wild Animals	1979	1983	http://www.cms.int/
Bucharest Convention	Convention for the Protection of the Black Sea Against Pollution	1992	1994	http://www.blacksea-commission.org/ http://www.greenyearbook.org/agree/mar-env/bucharest.htm
CBD	Convention on Biological Diversity	1992	1993	http://www.biodiv.org/
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources	1980	1982	http://www.greenyearbook.org/agree/mar-liv/ccamlr.htm http://eelink.net/~asilwildlife/antarctic1980.html
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora	1973	1975	http://www.cites.org/
EIA Directive	Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment	1985 (amended 1997)	1985	http://europa.eu.int/comm/environment/eia/full-legal-text/85337.htm
Espoo Convention	Convention on Transboundary Environmental Impact Assessment	1991	1997	http://www.unece.org/env/eia/eia.htm

Agreement Abbreviation	Agreement Name	Date Signed	Date Entered into Force	For more information
Habitats Directive	Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora	1992	1992	http://europa.eu.int/comm/environment/nature/nature_conservation/eu_nature_legislation/habitats_directive/index_en.htm
Helsinki Convention	Convention on the Protection of the Marine Environment of the Baltic Sea Area	1992	2000	http://www.helcom.fi/ http://www.greenyearbook.org/agree/mar-env/helsinki.htm
ICRW	International Convention on the Regulation of Whaling	1946	1948	http://www.iwcoffice.org/commission/convention.htm http://www.greenyearbook.org/agree/mar-liv/icrw.htm
Jakarta Mandate	Jakarta Mandate on Coastal and Marine Biological Diversity (under CBD)	1995	(not applicable)	http://www.biodiv.org/programmes/areas/marine/default.asp
MARPOL	International Convention for the Prevention of Pollution from Ships	1973	1983	http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258
NAFTA	North American Free Trade Agreement	1992	1994	http://www.nafta-sec-alena.org/DefaultSite/index.html
Nairobi Convention	Convention for the Protection, Management, and Development of the Marine and Coastal Environment of the Eastern African Region	1985	1996	http://hq.unep.org/easternafrica/EasternAfricaNairobiConvention.cfm http://www.greenyearbook.org/agree/mar-env/nairobi.htm
NAT	North Atlantic Treaty	1949	1949	http://www.nato.int/ http://www.nato.int/docu/basictxt/treaty.htm
Offshore Protocol (under the Barcelona Convention)	Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil	1994	Not yet entered into force	http://www.greenyearbook.org/agree/mar-env/barcelona.htm
OSPAR	Convention for the Protection of the Marine Environment of the Northeast Atlantic	1992	1998	http://www.ospar.org/ http://www.greenyearbook.org/agree/mar-env/ospar.htm
Rio Declaration	Rio Declaration on Environment and Development	1992	(Not applicable)	http://www.unep.org/Documents/Default.asp?DocumentID=78&ArticleID=1163
SEA Directive	Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment	2001	2001	http://europa.eu.int/comm/environment/eia/sealegalcontext.htm#legal
SOLAS	International Convention for the Safety of Life at Sea	1974	1980	http://www.imo.org/Conventions/contents.asp?topic_id=257&doc_id=647
UNCLOS	United Nations Convention on the Law of the Sea	1982	1994	http://www.un.org/Depts/los/index.htm

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APPENDIX 1: Annotated Workshop Agenda

28–30 September 2004
Holiday Inn Kings Cross/Bloomsbury, London, England

The Marine Mammal Commission and Joint Nature Conservation Committee are sponsoring an international policy dialogue related to the effects of human-generated sound on marine mammals. The workshop results will be used to inform the deliberations of the Commission's Advisory Committee on Acoustic Impacts on Marine Mammals, and ultimately, policy-makers in the United States Congress and around the world.

Goals:

- Describe the range of international efforts in management and mitigation related to marine mammals and sound, considering the extent to which established legal and regulatory frameworks address acoustic impacts on marine mammals on a global scale
- Explore and describe cross-boundary/multilateral issues regarding the management and mitigation of acoustic impacts on marine mammals
- Identify innovative management strategies and solutions to policy questions that might be transferable to national and international frameworks

Expected Products: (all background documents, abstracts, posters, and presentations can be found at http://www.mmc.gov/sound/internationalwrkshp)

- Set of brief background documents
- Collection of abstracts and posters related to international policy for sound and marine mammals
- Workshop report that informs the Marine Mammal Commission's Advisory Committee on Acoustic Impacts on Marine Mammals and can be incorporated into a report to U.S. Congress.

Day 1: Tuesday, 28 September 2004

0900-0930 **Welcome and Introduction –** David Cottingham, U.S. Marine Mammal Commission

0930-1030 **Topic 1: Overview of Human-Made Sound Sources and Impacts on Marine Mammals** (Session Chair: Mark Tasker)

0930-1000 (with Q&A) **Overview of Human-Made Sound Sources in the Marine Environment –** John Hildebrand, Scripps Institution of Oceanography and U.S. Marine Mammal Commission Committee of Scientific Advisors

1000-1030 (with Q&A) **Overview of Potential Impacts of Human-Made Sound on Marine Mammals –** Peter Tyack, Woods Hole Oceanographic Institution, U.S.

1030-1100 **Break**

1100-1420 (with lunch) **Topic 2: Introduction to National and International Legal and Regulatory Frameworks for Marine Mammals and Human-Made Sound** (Session Chairs: Lee Langstaff and Suzanne Orenstein)

Theme: What is the range of national and international laws and regulatory mechanisms governing acoustic impacts on marine mammals?

- Which countries are considered in this case study? What are the main sound sources of concern in the region/country? How is this region/country unique?
- How are those countries alike or different in their approach to protecting marine mammals and/or regulating anthropogenic sound production? How different are their government systems?
- What limitations do these countries face in dealing with the impacts of sound on marine mammals?

1100-1200 **Case Study Presentations** (20 minutes each, including Q&A)

- **European Seas –** Mark Tasker, U.K. Joint Nature Conservation Committee
- **North Atlantic Treaty Organization (NATO) –** Mike Carron, NATO Undersea Research Centre, Italy
- **Scientific Committee on Antarctic Research (SCAR) –** David Walton, British Antarctic Survey, U.K.

1200-1300 Lunch

1300-1420 **Continue Case Study Presentations** (20 minutes each, including Q&A)

- **United States –** Douglas Wartzok, Florida International University and U.S. Marine Mammal Commission Committee of Scientific Advisors
- **Latin America –** Monica Borobia, Independent Environmental Consultant, Brazil
- **Asia/Pacific Rim –** John Wang, FormosaCetus Research and Conservation Group and National Museum of Marine Biology and Aquarium, Taiwan
- **Africa –** Howard Rosenbaum, Wildlife Conservation Society, U.S., and Ken Findlay, University of Cape Town, South Africa

1420-1615 **Topic 3: Examining International Legal Frameworks** (Session Chair: Mark Tasker)

Theme: How can the issue of acoustic impacts on marine mammals best be pursued internationally? What are the key components of an effective international framework? Has sound or acoustic impacts on marine mammals been effectively addressed by international law or institutions? Are there short or long-term actions that could be taken in international fora to address this issue?

1420-1440 (with Q&A) **Providing an Analytical Framework for International Regulatory Mechanisms and Fora –** Lindy Johnson, U.S. National Oceanic and Atmospheric Administration Office of International Environmental Law

- What steps can be taken to analyze existing legal frameworks, examining their applicability to the issue of acoustic impacts on marine mammals
- What steps can be taken to analyze potential short- and long-term actions that could be pursued in international fora to address this issue?

1440-1500 **Break**

1500-1615 **Panel Discussion – Components of an Effective International Legal Framework**

1. Do existing regional and international laws and organizations/institutions address acoustic impacts on marine mammals, or could they? (10 minutes)
2. What are the key components of effective regional and international legal/regulatory schemes? (15 minutes)
3. What challenges might exist in pursuing this issue internationally? What steps might be possible to further the discussion of this issue in relevant international organizations/institutions and what types of actions could be taken in international fora or through international legal instruments to address the issue? (25 minutes)
4. How might multilateral legal and regulatory frameworks develop in the future? What changes might be forthcoming, if any? (25 minutes)

Panelists:

Lindy Johnson, U.S. National Oceanic and Atmospheric Administration
Scott Kenney, U.S. Department of Defense
Elena McCarthy, Woods Hole Oceanographic Institution, U.S.
Daniel Owen, Fenners Chambers, U.K.
Karen Scott, University of Nottingham, U.K.
Jon VanDyke, University of Hawaii, U.S.

1615-1700 **Topic 4: Innovative Management, Impact Assessment, and Mitigation Strategies** (Session Chair: David Cottingham)

Theme: What are the key components of an effective management scheme related to anthropogenic sound and marine mammals? What are the goals of management, impact assessment, and mitigation? How are the effectiveness and efficiency of mitigation strategies and impact assessment evaluated? What roles do regulated communities and environmental NGOs play in the development of impact assessment, management and mitigation strategies? What can we conclude about effective management, impact assessment, and mitigation strategies?

1615-1635 (with Q&A) **Generic Impact Assessment Approaches –** Karl Fuller, Institute of Environmental Management and Assessment, U.K.
- What are the basic steps taken in Environmental Impact Assessment? What techniques can be used in such analyses?
- What differences exist between countries in their national approaches to risk assessment?

1635-1655 (with Q&A) **Uncertainty and Policy-Making: How Do We Deal With the Unknowns? –** John Harwood, Sea Mammal Research Unit, University of St. Andrews, U.K.
- How can scientific uncertainty be addressed when making policy decisions? What can policy-makers do when we don't fully understand the range of impacts from sound
- Beyond creating models, how can we handle uncertainties like those related to the significance of acoustic impacts?
- How can we define a "precautionary approach," and when/how should such an approach be applied in policy?

1700 **Adjourn**

1900 **Conference Dinner: Holiday Inn Kings Cross**

Day 2: Wednesday, 29 September 2004

0900-1400 **Continue Topic 4: Management Strategies, Risk Assessment, and Mitigation** (Session Chair: David Cottingham)

0900-0910 **Announcements and Instructions**

0910-0940 Mitigation Techniques: Options and Effectiveness **–** Jay Barlow, U.S. National Marine Fisheries Service
- What constitute state-of-the-art, “best practices” in mitigation?
- How do strategies differ for naval sonar, seismic research, shipping noise, and other sound sources? To what extent are mitigation strategies, monitoring technologies, and other techniques transferable across sound sources?
- How could mitigation strategies be made more accessible?
- What are the most promising strategies in development? What can we expect in the future?

0940-1130 (with break) **Issues in Management, Risk Assessment, and Mitigation: Concurrent Small Group Discussions (facilitated):**

- **Group A: Evaluating effectiveness** (criteria for assessing effectiveness and efficiency; techniques for evaluation; etc.)
  Topic specialists: Jay Barlow, U.S. and John Richardson, Canada
  - What are the goals of mitigation, management, and monitoring? How should we prioritize those goals?
  - How is the effectiveness of mitigation strategies evaluated? To what extent do we understand the effectiveness of existing mitigation techniques? What is needed to improve our understanding?

- **Group B: Best practices and emerging techniques** (new applications of technology; research and development; standards for application of mitigation strategies; etc.)
  Topic specialists: Jim Theriault, Canada and Sara Wan, U.S.
  - What constitute state-of-the-art, "best practices" in risk assessment, management, and mitigation? For example, what models are used for risk assessment and what factors are considered in those models? What current standards exist for the application of mitigation strategies? How does this vary for different sound sources and across national boundaries?
  - How is scientific uncertainty best dealt with in management, risk assessment, and mitigation?
  - What are the greatest needs in risk assessment, management, mitigation and mitigation in this field? What are the most promising strategies in development? What innovations can we expect in the future?

- **Group C: Policy issues in risk assessment and mitigation** (consistency in the application of mitigation strategies; balancing environmental protection with other societal goals, etc.)
  Topic specialists: Paul Macnab, Canada and Elena McCarthy, Italy/U.S.
  - How are issues of practicality, cost, and efficiency balanced in assessing risk and choosing mitigation strategies? What are the goals of existing risk assessment and mitigation mechanisms? How are protection goals balanced with other societal goals?
  - How can sound-producing human uses of the ocean be carried out while minimizing adverse effects on marine mammals?
  - How do mitigation strategies differ for naval sonar, seismic research, shipping noise, and other sound sources? Why? Are such differences desirable?
  - To what extent are mitigation and monitoring strategies/technologies transferable across sound sources, and across national boundaries? How could these strategies and technologies be made more accessible to different groups?

- **Group D: Prioritizing information needs** (identifying information gaps; criteria for prioritizing research; etc.)
  Topic specialists: Ron Kastelein, Netherlands and Douglas Wartzok, U.S.
  - What are the information needs for risk assessment, and how should we prioritize those needs?
  - What are the information needs related to mitigation strategies and technologies, and how should we prioritize those needs?

1130-1330 Lunch and Poster Session

1330-1415 (with Q&A) **Small Group Reports:** Report back to full group with list of lessons/guidance drawn from presentations and discussions

1415-1500 **Plenary Discussion and Synthesis**

1500-1515 Break

1515-1700 Topic 5: Cross-Boundary Issues and Multilateral Approaches (Session Chair: Mark Tasker)

1515-1545 (with Q&A) **The Transboundary Challenges of Addressing Ocean Noise: Several International Focusing Events –** Elena McCarthy, Woods Hole Oceanographic Institution, U.S.

- What types of problems arise from the international nature of the issue of acoustic impacts on marine mammals? How can we best address conflicts that arise?
- How might we improve international communication and cooperation related to this issue?

1545-1700 **Consequences of Cross-Boundary Contexts: Concurrent Small Group Discussions (facilitated):**

- **Group A: Differing regulatory frameworks** (varying degrees of protection; differing mitigation strategies; high seas activities; enforcement and permitting issues; “not-in-my-backyard” [NIMBY] phenomena; etc.)
  Topic specialists: Olaf Boebel, Germany and Wolfgang Dinter, Germany
  - How do regulations and operational strategies differ between countries and in international waters? For example, to what extent are critical habitats, protected areas, and endangered species/populations reflected in the respective regulatory frameworks? What is the significance of these differences?
  - How does the regulation of naval sonar, seismic research, shipping noise, and other sound sources (e.g., moored vs. ship-based sources) differ? Why? What approach to differentiation between sources in regulation would be most useful?
  - What problems arise from differing national/domestic regulatory regimes? How might these problems be addressed?

- **Group B: Multilateral agreements** (applications of existing international law; enforcement issues; future actions; etc.)
  Topic specialists: Monica Borobia, Brazil and Giuseppe Notarbartolo di Sciara, Italy
  - What existing multilateral agreements could be applied in the management of impacts from sound on marine mammals? Have any actions been taken that are specifically directed at sound or acoustic impacts on marine mammals?
  - What relevant international authorities/institutions should be involved in policy decisions related to this issue? What entities are currently involved in any discussion of sound in the oceans?
  - What types of future regulatory or non-regulatory actions can or should be considered to address this issue?
  - How could we address concerns about international enforcement?

- **Group C: Marine mammal research coordination** (prioritizing research agendas; stranding responses; permits; etc.)
  Topic specialists: Mardi Hastings, U.S., Bill Perrin, U.S., and Lorenzo Rojas-Bracho, Mexico
  - How can we use information from around the world in the policy-making process at national, regional, and international levels?
  - What are the challenges to coordinating marine mammal research, and what problems arise from a lack of coordination?
  - How could scientists better inform policy-makers on issues related to marine mammals and sound? What challenges does the scientific community face? What challenges do policy-makers face?

- **Group D: Improving regulatory capacity** (strategies to enhance a governmental regime's ability to create, implement, and enforce laws and regulations on this issue; etc.)
  Topic specialists: Michael Jasny, Canada and Mark Tasker, U.K.
  - What are the greatest needs for countries seeking to improve their ability to deal with the impacts of anthropogenic sound on marine mammals? What are the greatest needs in dealing with these impacts internationally?
  - What can be done to improve various national/domestic management and regulatory regimes?
  - What can be done to improve international/multilateral management and regulatory regimes?

1700 **Adjourn**

1900-2230 **Reception: Tower Bridge**

Day 3: Thursday, 30 September 2004

0900-1200 **Continue Topic 5: Cross-Boundary Issues and Multilateral Approaches**

0900-1030 **Continue Concurrent Small Group Discussions and Prepare Reports**

1030-1100 **Break**

1100-1145 (with Q&A) **Small Group Reports**: Report back to full group with list of lessons/guidance drawn from presentations and discussions

1145-1315 **Plenary Discussion and Synthesis**

1315-1415 **Lunch**

1415-1600 **Topic 6: Synthesis, Summary, and Future Directions** (Session Chair: Mark Tasker)

Plenary Discussion

1. How have we addressed the goals of the workshop?
2. What are our major findings?
3. What are the key components of the workshop products? How could we structure a useful workshop report?
4. Where do we go from here?

1600 **Adjourn**

APPENDIX 2: Workshop Participants

*indicates workshop organizer %indicates speaker or panelist #indicates topic specialist
^indicates facilitator or recorder &indicates poster presenter

Name	Organization	Country
Acebes, Jo Marie	World Wildlife Fund - Philippines	Philippines
Ainslie, Michael	TNO Physics and Electronics Lab	Netherlands
Barlow, Jay% #	National Marine Fisheries Service	United States
Bauch, Linda	American Petroleum Institute	United States
Bird, Richard	Ministry of Defence	United Kingdom
Bjørge, Arne	Institute of Marine Research	Norway
Bloor, Philip	Department of Trade and Industry	United Kingdom
Boebel, Olaf# &	Alfred Wegener Inst. for Polar and Marine Research	Germany
Bolaños-Jimenez, Jaime&	Ecological Society SEA VIDA	Venezuela
Borobia, Monica% #	Independent Environmental Consultant	Brazil
Boyd, Ian	St. Andrews Univ. Sea Mammal Research Unit	United Kingdom
Burkhardt, Elke	Alfred Wegener Inst. for Polar and Marine Research	Germany
Burt, Claire	Defence Science and Technology Lab	United Kingdom
Caldwell, Jack	Industry Consultant	United States
Campbell, Alyssa	Marine Mammal Commission	United States
Carron, Mike%	Marine Mammal Risk Assessment Program, NATO	Italy/U.S.
Connolly, Niamh	European Science Foundation	France
Copley, Victoria^	English Nature	United Kingdom
Corrigan, Colleen* ^	U.S. Fish and Wildlife Service	United States
Cottingham, David*	Marine Mammal Commission	United States
Crowe, Alice	American Petroleum Institute	United States
Crutchfield, Zoë* ^	Joint Nature Conservation Committee	United Kingdom
Dalton, Penny	Consortium for Oceanographic Research and Education	United States
Decker, Cynthia	Office of the Oceanographer of the Navy	United States
Dinter, Wolfgang#	Federal Agency for Nature Conservation	Germany
Dolman, Sarah	Whale and Dolphin Conservation Society	Australia
dos Santos, Manuel	Unidade de Investigacao em Eco-Etologia	Portugal
Evans, Peter	Sea Watch Foundation	United Kingdom
Fernández, Antonio&	University de Las Palmas de Gran Canaria	Spain
Findlay, Ken	University of Cape Town	South Africa
Ford, Lee-Ann&	Linking Individuals for Nature Conservation	Taiwan
Fuller, Karl%	Inst. of Environmental Mgmt. and Assessment	United Kingdom
Gentry, Roger	National Marine Fisheries Service	United States
Gill, Chip&	Int'l Association of Geophysical Contractors	United States
Gillespie, Douglas	International Fund for Animal Welfare	United Kingdom
Gillham, Katie^	Scottish Natural Heritage	United Kingdom
Gordon, Jonathon	Sea Mammal Research Unit	United Kingdom
Green, Marsha&	Ocean Mammal Inst./Albright College	United States
Harwood, John%	St. Andrews Univ. Sea Mammal Research Unit	United Kingdom
Hastings, Mardi# &	Office of Naval Research	United States
Haun, Jeff	Office of Naval Research – Global	United States/U.K.
Heskett, Erin	International Fund for Animal Welfare	United States
Hildebrand, John%	Scripps Institution of Oceanography and Marine Mammal Commission	United States

Hinchliffe, Peter	International Chamber of Shipping	United Kingdom
Hodgson, Amanda[&]	James Cook University	Australia
Jackson, Graham	Defence Science and Technology Lab	United Kingdom
Jansen, Frans	Dept. of Weapon and Communication Systems	Netherlands
Jasny, Michael[#]	Natural Resources Defense Council	Canada
Jepson, Paul	Zoological Society of London	United Kingdom
Johnson, Lindy[%]	National Oceanic and Atmospheric Administration	United States
Kahn, Benjamin	APEX Environmental	Australia
Kastelein, Ron[# &]	Sea Mammal Research Company	Netherlands
Kaveney, Tom	Department of the Environment and Heritage	Australia
Kenney, Scott[%]	Department of Defense	United States
Ketten, Darlene	Woods Hole Oceanographic Inst/Harvard University	United States
Künitzer, Anita	Federal Environmental Agency	Germany
Kvadsheim, Petter[&]	Norwegian Defence Research Establishment	Norway
LaBelle, Bob	Minerals Management Service	United States
Langstaff, Lee[^]	Facilitator	United States
Lucke, Klaus[&]	University of Kiel	Germany
Ludwig, Stefan	Federal Armed Forces Underwater Acoustic & Marine Geophysical Research Institute	Germany
Lueber, Sigrid[&]	ASMS OceanCare	Switzerland
Lusseau, David[&]	Lighthouse Field Station	United Kingdom
Macnab, Paul[#]	Bedford Institute of Oceanography	Canada
McCarthy, Elena[% #]	Woods Hole Oceanographic Institution	Italy/U.S.
Melton, Rodger	Exxon Mobil	United States
Nachtigall, Paul	University of Hawaii	United States
Notarbartolo di Sciara, Giuseppe[%]	Tethys Research Institute	Italy
Orenstein, Suzanne[^]	Facilitator	United States
O'Sullivan, Christine	Independent Environmental Consultant	Jamaica
Owen, Daniel[%]	Fenners Chambers	United Kingdom
Padovani, Bernard	Compagnie Générale de Géophysique	France
Parsons, Chris[&]	University Marine Biological Station	United Kingdom
Pavan, Gianni[&]	Universita' degli Studi di Pavia	Italy
Penney, Kyle[&]	Department of National Defence	Canada
Perrin, Bill[#]	National Marine Fisheries Service	United States
Pinn, Eunice[^]	Joint Nature Conservation Committee	United Kingdom
Plé, Jean-Pierre	U.S. Department of State	United States
Purdy, Mike	Lamont-Doherty Earth Observatory	United States
Reeves, Randall[^]	Okapi Wildlife Associates/IUCN	Canada
Reynolds, Joel	Natural Resources Defense Council	United States
Richardson, John[# &]	LGL Ltd.	Canada
Rigg, Caroline	Dept. for Environment, Food and Rural Affairs	United Kingdom
Rojas-Bracho, Lorenzo[#]	National Institute of Ecology	Mexico
Rose, Naomi	Humane Society of the United States	United States
Rosenbaum, Howard[%]	Wildlife Conservation Society	United States
Sandeman, Liz	Marine Connection	United Kingdom
Schoennagel, Chuck	Minerals Management Service	United States
Scott, Karen[%]	University of Nottingham	United Kingdom
Stone, Frank	Office of the Chief of Naval Operations	United States
Storrie, Jamie	English Nature	United Kingdom
Tackett, Bruce	Exxon Mobil	United States
Tasker, Mark*[% #]	Joint Nature Conservation Committee	United Kingdom

Theriault, James[# &]	Defence Research & Development Canada Atlantic	Canada
Tirpak, Elizabeth	U.S. Department of State	United States
Tomaszeski, Steven	Office of the Chief of Naval Operations	United States
Tougaard, Jakob[&]	Denmark National Environmental Research	Denmark
Trinder, Colin[&]	Department of Defence	Australia
Tyack, Peter[%]	Woods Hole Oceanographic Institution	United States
van der Sman, Peter	Shell Oil	Netherlands
Van Dyke, Jon[%]	University of Hawaii	United States
Vicente, Elio	Zoomarine-Mundo Aquatico	Portugal
Vos, Erin* [^]	Marine Mammal Commission	United States
Walton, David[%]	British Antarctic Survey	United Kingdom
Wan, Sara[# &]	California Coastal Commission	United States
Wang, John[%]	FormosaCetus Research & Conservation Group	Taiwan/Canada
Ward, Nathalie	Eastern Caribbean Cetacean Network	St. Vincent/Grenadines
Wartzok, Douglas[% #]	Florida International University and Marine Mammal Commission	United States
Weilgart, Lindy	Dalhousie University	Canada
Wieting, Donna	National Marine Fisheries Service	United States
Wilson, Judy[&]	Minerals Management Service	United States
Womersley, Mark	BMT-Singapore	Singapore
Worcester, Peter	Scripps Institution of Oceanography	United States
Wysocki, Roger	Department of Fisheries and Oceans Canada	Canada

OTHER CONTRIBUTORS
(presented posters in absentia)

Name	Organization	Country
André, Michel[&]	Universitat Politècnica de Catalunya	Spain
Benders, F.P.A[&]	TNO Physics and Electronics Lab	Netherlands
Kendall, James[&]	Minerals Management Service	United States
Morrissey, Ron[&]	Naval Undersea Warfare Center	United States

APPENDIX 3: Abstracts and Descriptions of Workshop Background Documents

The Marine Mammal Commission and Joint Nature Conservation Committee collected a series of briefings on the topics listed below. These background papers were intended to give broad summary overviews of the issues, and were provided to participants prior to the workshop and posted on the Marine Mammal Commission's website. (Please note that distribution of these papers does not constitute endorsement by the Marine Mammal Commission and Joint Nature Conservation Committee.) These documents are now available online at http://mmc.gov/sound/internationalwrkshp/backgroundpapers.html.

- **Sources of Anthropogenic Sound in the Marine Environment** (provided by John Hildebrand)

John Hildebrand. 2004. Sources of Anthropogenic Sound in the Marine Environment.
This paper describes the various sources of human-generated sound and their global distribution. It also discusses the need for a long-term monitoring program to track future changes in ocean noise.

- **Marine Acoustic Technology and the Environment** (provided by David Walton)

Scientific Committee on Antarctic Research. 2002. Marine Acoustic Technology and the Environment. Working Paper WP-023, XXV ATCM. 2 pp.
Working Paper 23 was presented by SCAR at XXV Antarctic Treaty Consultative Meeting in September 2002 in Warsaw. This was in response to a request from Treaty Parties for a review of available scientific information on anthropogenic marine acoustic noise and its implications. The paper provides an overview of relevant literature compiled from a workshop meeting and makes some recommendations about mitigation measures.

Scientific Committee on Antarctic Research. 2004. SCAR Report on Marine Acoustic Technology and the Antarctic Environment. Information Paper IP-078, XXVII ATCM. 17 pp.
Information paper 78 was presented by SCAR to XXVII Antarctic Treaty Consultative Meeting in July 2004 in Cape Town. The paper reviews new information available since 2002 and provides a risk analysis approach that can be used for environmental impact assessment in advance of permitting any marine activities that will produce underwater noise. It also attempts to establish the levels of background sound against which anthropogenic noise should be judged.

- **International Regulation of Undersea Noise** (provided by Karen Scott)

Karen N. Scott. April 2004. International Regulation of Undersea Noise. International and Comparative Law Quarterly vol. 53, pp 287–324.
This paper surveys a selection of global and regional instruments which directly or indirectly impact upon the regulation of undersea noise. In its conclusion, this paper attempts to identify further measures that might be taken in order to expedite the development of a comprehensive global legal framework for the regulation of marine acoustic pollution.

- **The Application of Marine Pollution Law to Ocean Noise** (provided by Daniel Owen)

Daniel Owen. 2003. The Application of Marine Pollution Law to Ocean Noise. Annex 1 in Oceans of Noise: A WDCS Science Report. M. Simmonds, S. Dolman, and L. Weilgart, eds. Pp 94–129.
This excerpt from the Whale and Dolphin Conservation Society's 2003 report addresses the application of marine pollution law to the regulation of ocean noise. (Full report available at http://www.wdcs.org)

- **The Evolution and International Acceptance of the Precautionary Principle** (provided by Jon Van Dyke)

Jon M. Van Dyke. 2004. The Evolution and International Acceptance of the Precautionary Principle. In Bringing New Law to Ocean Waters, D.D. Caron and H.N. Scheiber eds. Pp 357–379.
This paper examines how the precautionary principle has been used in recent multilateral treaties and in decisions by international tribunals and national courts, and then summarizes the current content and understanding of this principle.

- **Whales, Submarines, and Active Sonar** (provided by Jon Van Dyke)

Jon M. Van Dyke, Emily A. Gardner, Joseph R. Morgan. 2004. Whales, Submarines, and Active Sonar. 18 Ocean Yearbook 330–63.
This paper summarizes the current scientific understanding of the effect of low frequency active sonar and other loud sounds in the ocean on marine mammals and other marine creatures. It then examines the Navy's justifications for using active sonar and examines how the principles and institutions of international environmental law apply to this new form of ocean pollution.

- **Mitigation and Monitoring** (provided by Jay Barlow and Robert Gisiner)

J. Barlow and R. Gisiner. In review. Mitigating, Monitoring, and Assessing the Effects of Anthropogenic Sound on Beaked Whales. Submitted to the Journal of Cetacean Research and Management.
This paper was originally prepared for the Marine Mammal Commission’s April 2004 technical workshop on beaked whales. It reviews options for mitigating and monitoring the potential impacts of human acoustic activity on beaked whales, providing an analysis of the challenges inherent in developing effective methodologies.

APPENDIX 4: Workshop Poster Abstracts

POSTER SESSION

Wednesday, 29 September 2004

List of Abstracts (Alphabetical by First Author)

1. **M. André, E. Delory, and M. van der Schaar**
   A Passive Mitigation Solution to the Effects of Human-Generated Sound on Marine Mammals

2. **F.P.A Benders, S.P. Beerens, and W.C. Verboom**
   SAKAMATA: A Tool to Avoid Whale Strandings

3. **Olaf Boebel, Horst Bornemann, Monika Breitzke, Elke Burkhardt, Lars Kindermann, Holger Klinck, Joachim Plötz, Christoph Ruholl, and Hans-Werner Schenke**
   Risk Assessment of *ATLAS HYDROSWEEP DS-2* Hydrographic Deep Sea Multi-beam Sweeping Survey Echo Sounder

4. **Jaime Bolaños-Jiménez, Luis Bermúdez-Villapol, Alejandro Sayegh, Janin N. Mendoza M., and Clemente Balladares**
   Evaluation and Management of the Noise Impact on Marine Mammals in Venezuela—Legal and Technical Aspects

5. **Antonio Fernández, Manuel Arbelo, Pascual Calabuig, Carrillo Manuel, Mariña Mendez, Eva Sierra, Pedro Castro, José Jabber, and Antonio Espinosa de los Monteros**
   "Gas Embolic Syndrome" in Two Single Stranded Beaked Whales

6. **Antonio Fernández, Pedro Castro, V. Martín, T. Gallardo, and Manuel Arbelo**
   New Beaked Whale Mass Stranding in Canary Islands Associated with Naval Military Exercises (Majestic Eagle 2004)?

7. **Antonio Fernández, Manuel Arbelo, Eva Sierra, Mariña Méndez, F. Rodríguez, and P. Herráez**
   Pathological Study of a Mass Stranding of Beaked Whales Associated with Military Naval Exercises (Canary Islands, 2002)

8. **Lee-Ann Ford**
   A Nation Without Mercy

9. **Chip Gill**
   Further Analysis of 2002 Abrolhos Bank, Brazil Humpback Whale Strandings Coincident with Seismic Surveys

10. **Marsha L. Green**
    Underwater Noise Pollution: Impacts on Marine Life & Recommendations for International Regulatory Action

11. **Amanda Hodgson**
    The Behavioural Responses of Dugongs to Two Noise Sources: Boats and Pingers

12. **R.A. Kastelein, W.C. Verboom, N. V. Jennings, S. van der Heul, and R.J.V. Triesscheijn**
    The Influence of Acoustic Emissions for Underwater Data Transmission on the Displacement of Harbor Porpoises (*Phocoena phocoena*) in a Floating Pen and Harbor Seals in a Pool

13. **James Kendall, Pat Roscigno, and Cleve Cowles**
    Snapshot of MMS Research on Cetaceans and Anthropogenic Presence

14. **Petter H. Kvadsheim, Erik Sevaldsen, and John K.Grytten**
    Active Sonar and the Marine Environment

15. **Sigrid Lüber**
    Undersea Noise Pollution—A Challenge for Science, Governments and the Civil Society

16. **Klaus Lucke, Wolf Hanke, and Guido Dehnhardt**
    ABR Responses in Two Species of Marine Mammals

17. **D. Lusseau, J.E.S. Higham, S.M. Dawson, and E. Slooten**
    Multi-scale Impact Assessments Can Help Detect Impact, Infer its Mechanism and Consequences and Provide Tools for Management

18. **Ron Morrissey, Nancy DiMarzio, Susan Jarvis, David Moretti, and Mardi Hastings**
    Passive Acoustic Marine Mammal Monitoring Technology for Navy Ranges

19. **E.C.M. Parsons and S. Hung**
    Noise Pollution Case Study: Cetaceans in Hong Kong

20. **G. Pavan, M. Manghi, C. Fossati, and M. Priano**
    Tools for Underwater Noise Monitoring, Marine Mammals' Surveys, and Implementation of Acoustic Risk Mitigation Policies

21. **Kyle Penney and James A. Theriault**
    Environmental Stewardship: Maritime Forces Atlantic's Marine Mammal Impact Mitigation

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A Regulatory Agency Perspective on Anthropogenic Noise and Marine Mammals

A Passive Mitigation Solution to the Effects of Human-Generated Sound on Marine Mammals

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Abstract
Acoustic and physical interactions between human activities and coincident cetacean occurrence have become a threat to marine mammal conservation. Although we do not yet fully understand under what circumstances exposure to loud sounds will cause harm to cetaceans, scientific evidence indicates that such high intensity sounds can cause lesions in acoustic organs, severe enough to be lethal. The use of active acoustic solutions, i.e. acoustic deterrents and active sonar, in areas of interest (shipping, military exercises, gas exploration, etc.) to prevent unfortunate interactions is either range-limited and intrusive or ineffective on cetaceans, specially on those already highly tolerant to noise. An alternative solution based on passive detection, classification and localization has been therefore considered. Here, we introduce a time and cost effective minimal solution applied to sperm whales - but applicable to other cetacean species - to an automatic real-time 3D whale localization. The 3D localization is based on the acoustic signal arrival time-delays and the assumption that sound propagation can be modeled by straight rays, resolving both the azimuth and elevation on a short aperture tetrahedral array of passive sensors and the source distance from the time arrival on a distant fourth hydrophone (wide aperture array). With this configuration, the 3D localization algorithm calculates the whale's position within a 3000m deep and 2500m radius cylinder with an estimated 200m maximum distance error. The system further integrates the tracking of acoustically passive whales by a sperm whale click-based ambient noise imaging sonar. A simulation tool for 3D acoustic propagation was designed to simulate a bi-static solution formed of an arbitrary number of active acoustic sources, an illuminated object, and a receiver all positioned in 3D space with arbitrary bathymetry. Detection and bearing estimates could be performed for silent whales at ranges of 1500m from a 4m diameter array of 32 hydrophones, in a simulated scenario where on-axis click source and ambient noise levels were respectively 200dBrms re 1µPa @1m (full bandwidth) and 60 dBrms re 1µPa in the 1-10kHz band. While an ambitious synthesis of many advanced acoustic technologies, the benefit is an efficient, non-intrusive system which could continuously 3D track cetaceans in areas of interest, therefore mitigating the impact of artificial sound sources on marine mammal populations.

SAKAMATA: A Tool to Avoid Whale Strandings

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Abstract
World-wide a concern exists about the influence of man-made noise on marine life, and particularly of high power sonar. Most concern lies with marine mammals that use acoustics for hunting, communication and/or navigation. This concern is fed by recent strandings of whales that could be related to military sonar transmissions and seismic explorations. Especially sonars that use audible frequencies are harmful for these mammals. However, little is known about the exact influence of active sonar on marine mammals and therefore many countries apply the *precautionary principle*. In practice this means that mitigation measures are defined for the use of active sonars. Implementation of such mitigation measures is no sinecure. Background knowledge (presence of mammal species and their hearing sensitivity and behaviour, acoustic conditions) is often lacking. Therefore historical and *in situ* information must be used. TNO-FEL has developed SAKAMATA, a tool that supports the implementation of mitigation measures in an effective way.

Risk Assessment of *ATLAS HYDROSWEEP DS-2* Hydrographic Deep Sea Multi-beam Sweeping Survey Echo Sounder

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Abstract
The hull-mounted *Atlas Hydrographic* multibeam deep-sea echosounder *Hydrosweep DS-2* is installed on several research vessels (e.g. R/V *Maurice Ewing*, R/V *Meteor,* R/V *Polarstern*) to carry out bathymetric surveys of the sea floor. At full ocean depth (3000 to 11000m water depth), the instrument usually operates in "Deep Sea II" mode. In this mode, three short (24, 12 and 24ms) sound pulses of 15.5 kHz are successively emitted, ensonifying a port-, centre- and starboard beam, respectively. This pattern repeats itself at regular intervals of typically 15 seconds. The resulting swath covers an area of approximately twice the local water depth along the profile line.

The sound pressure level (SPL) capable of causing a temporary threshold shift (TTS) is calculated on the basis of experimentally derived TTS threshold levels and the 3-dB exchange rate, resulting in a critical SPL of 203.2 dB_{RMS} rel. 1µPa. For this calculation, a conservatively estimated effective pulse length of 60 ms, i.e. the sum of the three pulses, is used. Then the corresponding region is derived from the *Hydrosweep DS-2* beam pattern. Again a conservative approach selects the maximum SPL of each of the three consecutive pulses for every direction. The resulting critical region is heart-shaped and bounded by a box of 43 m depth, 46 m width athwartship and 1 m (sic!) width fore-and-aft.

Subsequently, regions where reception of multiple pings could lead to a TTS are determined for increasing numbers of assumed ensonifications. Finally the region where potential critical behavioural responses may occur is determined, assuming a sound pressure level commensurate with results from the Bahamas 2001 stranding event.

For cruising ships (R/V *Polarstern* particularly), the study concludes that the risk of causing a TTS to marine mammals is conservatively estimated to be less then 1 percent of the risk of a collision between the ships-hull and the animal by comparing the relevant volumes and cross-sections. The risk of causing a permanent threshold shift (PTS) will be smaller, though quantification thereof is difficult. For ships on station (zero velocity), the non-zero risk of ensonifying a marine mammal at TTS levels obviously exceeds the risk of collision, as the latter becomes zero. In this later situation, mitigation methods such as a shut down of *Hydrosweep* on station when whales are observed within a certain mitigation radius could serve to eliminate any remaining risks.

Evaluation and Management of the Noise Impact on Marine Mammals in Venezuela—Legal and Technical Aspects

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Abstract
In Venezuela, the legal and regulatory framework includes a series of instruments related to the conservation of natural ecosystems. Accordingly, the Venezuelan State's duties include assuring the conservation and sustainable use of ecosystems and natural resources, as well as to increase both the quality of the human life and of the environment. In a general sense, no specific regulations have been promulgated for the protection of marine mammals. Nevertheless, based on such instruments as the "*National Constitution*", "*Organic Law of Environment*", "*Environment Criminal Act*", and "*Biological Diversity Act*", the Venezuelan State is providing a reference for the protection of the marine habitat and species, including the obligation to prevent, mitigate or correct environmental impacts of economic activities. On the other hand, the Presidential Decree 1257 that deals with *"Guidelines on environmental evaluation of potentially degrading activities*" provides a more specific foundation for evaluating and regulating the impact of sound on cetaceans. Two kinds of activities are considered of special interest for taking into account for conservation and management purposes: 1) oil and gas exploration/production and 2) maritime traffic. On the basis of the above-mentioned Decree, since 2002 the Ministry of Environment and Natural Resources (MARN) authorities have included the evaluation of the effect of sound on cetaceans in the Terms of Reference of Environmental Impact Assessments, Specific Environmental Assessments and Baseline Studies related to the oil industry offshore activities.

Up to the present, the presence of independent observers and MARN officers on board vessels during two seismic surveys reached 1264 hs of effort and yielded 117 cetacean sightings. According to this preliminary results, behavioral changes and/or avoidance reactions have been observed only in mysticetes. Though no research effort is being made currently on the effect of other sources of human-generated sound on these species, specific regulations are being developed jointly by the MARN and non-governmental organizations.

"Gas Embolic Syndrome" in Two Single Stranded Beaked Whales

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Abstract

Introduction:

Lesions consistent with in vivo bubble formation in beaked whales have been recently described in **Nature** by Jepson and col. and Fernández and col. A decompression-like syndrome has been postulated to happen in whales in response to sonar exposure. Gas embolism "in vivo" is difficult to determine some time after death. This report presents a systemic "gas bubble" embolism in two fresh single stranded beaked whales.

Material and Methods:

One adult female and one old male beaked whale stranded on the coasts of Gran Canaria and Tenerife in 2003 and 2004 respectively. Both animals were necropsied around 4 to 8 hours after death. A routine necropsy for whales was carried out by pathologists from the Unit of Histology and Pathology (Institute of Animal Health-Veterinary School-University of Las Palmas de Gran Canaria). A routine histological study was also performed in all the sampled organs, as well as a microbiological study.

Results and discussion:

Both animals showed massive gas bubbles in the portomesenteric system, involving changes in the liver. Gas bubbles were seen macroscopically and microscopically in the venous system, including intestines, liver, lymph nodes, lung, kiney, heart and brain. Although a test of nitrogen content of the gas is now underway, the pathological picture is very similar to an acute massive systemic gas embolism in DCS in humans. It is not known if these cases were associated with sonar activities.

Conclusion:

The present results found in two very fresh beaked whales restate and reinforce the "systemic gas embolism" in beaked whales, a new pathologic entity to be described in cetaceans, with special attention to deep, long duration diving species like beaked whales, which seem to be more susceptible of suffering this embolic syndrome.

Jepson and cols. **Nature** 425:575-576(2003).
Fernandez and cols. **Nature** doi:101038/nature 02528 (2004).

New Beaked Whale Mass Stranding in Canary Islands Associated with Naval Military Exercises (Majestic Eagle 2004)?

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Abstract
Four beaked whales (*Ziphius cavirostris*) stranded in Lanzarote and Fuerteventura (Canary Islands). The first animal stranded the 21st and the last the 28th of July. During the previous week (11th–16th July 2004) an international military naval exercises (Majestic Eagle 2004) took place between the Canary Islands and Morocco. The corpses were autolytic, lacking part of the body in some cases. A necropsy was carried out on 3 out of 4 animals. The last beaked whale that stranded the 28th was not possible to sample. The necropsied animals showed abundant content of aliment in the stomach with, in same cases, large non-digested squids. No macroscopic findings were recorded due to advanced autolysis, but samples from different organs, except the central nervous system, were taken for histology. Samples were processed for routine histological study and also for detecting fat emboli. This report presents epidemiological data and pathological data from this new beaked whale mass stranding associated with naval exercises.

Pathological Study of a Mass Stranding of Beaked Whales Associated with Military Naval Exercises (Canary Islands, 2002)

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Abstract
A study of the lesions of beaked whales in a recent mass stranding in the Canary Islands following naval military exercises provides evidence of the possible relationship between anthropogenic, acoustic (sonar) activities and the stranding and death of marine mammals. Fourteen beaked whales were stranded in the Canary Islands close to the site of an international naval exercise (Neo-Tapon 2002) held on 24 September 2002. Strandings began about 4 hours after the onset of the use of mid-frequency sonar activity. Eight Cuvier's beaked whales (*Ziphius cavirostris*), one Blainville's beaked whale (*Mesoplodon densirostris*) and one Gervais' beaked whale (*M. europaeus*) were necropsied and studied histopathologically. No inflammatory or neoplastic processes were noted, and no pathogens were identified. Macroscopically, whales had severe, diffuse congestion and hemorrhage especially around the acoustic jaw fat, ears, brain, and kidneys. Gas bubble-associated lesions and fat embolism were observed in vessels and parenchyma of vital organs. This *in vivo* bubble formation associated with sonar exposure may have resulted in modified diving behavior that caused nitrogen super-saturation in excess of a threshold value normally tolerated by the tissues (as occurs in decompression sickness). Alternatively, a physical effect of sonar on *in vivo* bubble precursors (gas nuclei), the activation level of which may be lessened by nitrogen gas super-saturation of the tissues, may explain the phenomenon. Both mechanisms might also work together to augment and maintain bubble growth. Exclusively or in combination, these mechanisms might initiate the embolic process. Severely injured whales died, were killed by predators, or became stranded and died due to a more severe cardiovascular collapse during beaching. The present study demonstrates a new pathologic entity in cetaceans. This syndrome that is apparently fostered by exposure to mid-frequency sonar particularly affects deep, long duration, repetitive diving species like beaked whales.

A Nation Without Mercy…

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Abstract
Taiwan is an economically thriving nation with only 1 percent of the population living below the poverty line. Slightly smaller that the states of Delaware and Maryland combined; this tiny island supports a population of 22,749,838 people. With one of the largest commercial shipping industries in the world, Taiwan has proven itself to be an economic success and an environmental failure.

A booming economy has resulted in an environmental catastrophe. Taiwan's complicated international status has led to a lack of international environmental agreements. These agreements have been signed but never ratified; due to this status, Taiwan escapes monitoring for its actions, or perhaps of equally importance, its inactions.

Due to expense and inexperience, the government refuses make marine conservation a serious issue on its agenda. Conditions such as water pollution from industrial emissions, raw sewage, and low-level radioactive waste, and large-scale modification of shoreline habitat have been unable to motivate the central government to recognize and address the environmental issues that threaten the marine life of this island.

Guilty of being the principal culprit behind Asia’s commerce in endangered wildlife, no mercy or compassion is shown for the flora and fauna within Taiwan itself. Still, Taiwan continues to operate without consequence.

Even though, the Wildlife Conservation Law was passed in 1989 and was designed to be comparable to the regulations of CITES, the marine mammal populations of Taiwan continue to suffer from unmonitored military exercises. Government regulations do not allow the conservationist to interfere with military exercises or measure their impacts.

The Taiwanese government presents itself as a democratic, responsible government that is determined to put an end to the illegal trade of endangered species and promises to protect its depleting marine mammal populations; nothing could be further from the truth.

Further Analysis of 2002 Abrolhos Bank, Brazil Humpback Whale Strandings Coincident with Seismic Surveys

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Abstract
A paper, "Are seismic surveys responsible for cetacean strandings? An unusual mortality of adult humpback whales in Abrolhos Bank, northeastern coast of Brazil" (Engel et al. 2004), was presented to the 2004 International Whaling Commission Scientific Committee. It presented strandings data for the northeastern coast of Brazil, the areas where seismic surveys were conducted in 2002, and an overview of the IBAMA efforts to establish guidelines for the seismic activities in the Brazilian coast. While the paper concluded that a scientific correlation between increased adult humpback strandings and seismic surveys along the east coast of Brazil can not be established, the authors nevertheless suggest that seismic surveys be suspended offshore from the Abrolhos Bank region (Bahia and Espírito Santo States) during the humpback whale breeding season from July to November.

The geophysical industry has compiled data on all seismic surveys conducted off the Brazilian coast from 1999 to 2003. It has further conducted an independent analysis of this seismic activity over a 5 year period around the 2002 season as well as the location of the 8 adult humpback whale mortalities noted in Engel et al. 2004 relative to coincident seismic activity. In this poster session the geophysical industry will present details of these data and analyses and will examine the major premises of Engel et al. 2004 against them. It will offer an examination of the scientific literature quoted in Engel et al. 2004 in support of its conclusions as well as how this literature was used, and will draw conclusions about what lessons the 2002 humpback mortalities should offer managers considering mitigations of seismic activity.

Underwater Noise Pollution: Impacts on Marine Life & Recommendations for International Regulatory Action

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Abstract
Anthropogenic noise is a form of pollution that poses significant threats to marine mammals, fish and other ocean wildlife including displacement, injury and mortality. The use of technologies that produce intense underwater noise pollution may be in breach of Article 194(1) of the UN Convention on the Law of the Sea which requires States to take all measures necessary to prevent, reduce and control pollution of the marine environment and Articles 204-206 which require States to assess potentially negative impacts on the environment.

Acoustic energy is not restricted by national boundaries and there is growing consensus that undersea noise pollution should be regulated by responsible international institutions The Scientific Committee of the International Whaling Commission in July 2004 issued a strong statement of concern about intense underwater noise stating that there is compelling evidence that marine mammal populations worldwide are potentially threatened especially by intense military sonars and air guns used in geophysical research and oil and gas exploration. They asked that noise exposure standards be included in national and international ocean conservation plans.

The Scientific Committee to ACCOBAMS issued a formal recommendation on "Man-Made Noise" urging extreme caution in using intense acoustic devices and the 2003 meeting of ASCOBANS passed a resolution affirming their commitment to apply the Precautionary Principle to ocean noise.

NATO representatives met with MEP's, scientists and NGO's in October 2003 to receive petitions signed by 70 environmental groups in Europe and North America, representing memberships of 8.3 million people, and consider requests for regulatory action on underwater noise pollution. NGO's gave a presentation on Intense Underwater Noise Pollution at the Fifth UN Informal Consultative Process on Oceans and the Law of the Sea in June 2004 discussing science, legal aspects and political activities urging international regulation of ocean noise. NGO's worldwide are forming an International Coalition for Ocean Noise Management.

The Behavioural Responses of Dugongs to Two Noise Sources: Boats and Pingers

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Abstract

The objectives of this project were to determine the risk disturbance from boats and pingers (acoustic alarms) through direct observations of dugong (*Dugong dugon*) behaviour. To observe dugongs I developed the blimp-cam; this consists of a helium-filled balloon (blimp) with a mounted video camera. I assessed the behavioural responses of dugongs to opportunistic and experimental boat passes in Moreton Bay, Australia. The feeding and travelling behaviour during 4.5 min focal follows was not affected by the experimental boat passing, the number of passes made, whether the pass was continuous or included a stop and restart, or the individual's position in the herd in relation to these three factors. However, individual dugongs were significantly less likely to remain feeding if a boat passed within 50 m. Feeding herds often responded to boats by performing mass movements, which on average lasted 2 min. During the time of year my study was conducted, boat traffic may disturb dugongs for 0.8 to 6 percent of the time they spend feeding. This level of disturbance presents minimal risk of displacing dugongs from my study site where seagrass beds are large enough for dugongs to move and recommence feeding immediately. The response to an array of two 10 kHz pingers (acoustic alarms designed to reduce entanglement in fishing nets) was also observed. Pinger noise did not significantly affect the rate of dugong movement away from the focal arena surrounding the pingers, the orientation of these dugongs, or the presence or absence of feeding plumes. The results from these pinger experiments suggest dugongs are unlikely to be displaced from important habitat areas by pingers.

The Influence of Acoustic Emissions for Underwater Data Transmission on the Displacement of Harbor Porpoises (*Phocoena phocoena*) in a Floating Pen and Harbor Seals in a Pool

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Abstract
To prevent grounding of ships and collisions between ships in shallow coastal waters, an underwater data collection and communication network is currently under development: Acoustic Communication network for Monitoring of underwater Environment in coastal areas (ACME). Marine mammals might be affected by ACME sounds since they use sounds of similar frequencies (around 12 kHz) for communication, orientation, and prey location. If marine mammals tend to avoid the vicinity of the transmitters, they may be kept away from ecologically important areas by ACME sounds. The most abundant marine mammal species that may be affected in the North Sea are the harbor porpoise and the harbor seal. Therefore, as part of an environmental impact assessment program, two captive harbour porpoises and nine harbour seals were subjected to four sounds, three of which may be used in the underwater acoustic data communication network. The effect of each sound was judged by comparing the animals' positions and respiration rates during test periods with those during baseline periods. Each of the four sounds could be made deterrent by increasing the amplitude of the sound. Both the porpoises and the seals reacted by swimming away from the sound source. The porpoises increasing their respiration rate slightly, but the seals' respiration rate remained the same. From the sound pressure level distribution in the enclosures, and the distribution of the animals during test sessions, discomfort sound pressure level threshold were determined for each sound. The acoustic discomfort threshold is defined as the boundary SPL between the areas that the animals generally occupied during the transmission of the sounds and areas that they generally did not enter during transmission. In combination with information on sound propagation in the areas where the communication system may be deployed, the extent of the 'discomfort zone' can be estimated for several source levels. The discomfort zone is defined as the area around a sound source that animals are expected to avoid. Based on these results, source levels can be selected that have an acceptable effect on harbor porpoises and harbor seals in particular areas. The source level of the communication system should be adapted to each area (taking into account bounding conditions created by narrow channels, sound propagation variability due to environmental factors, and the importance of an area to the affected species). The discomfort zone should not prevent porpoises and seals from spending sufficient time in ecologically important areas (for instance resting, breeding, suckling, and feeding areas), or routes towards these areas.

Snapshot of MMS Research on Cetaceans and Anthropogenic Presence

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Abstract
Initially, the Environmental Studies Program (ESP) addressed broad, general information needed to assess OCS activity compliance with the National Environmental Policy Act; that is, baseline studies or surveys. However, more specific information needs pertaining to those species given protection under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA) began to develop. In the early ESP years, many baseline studies/surveys of protected and endangered species were conducted to develop an understanding of populations, abundance and distributions, and preferred areas for feeding, breeding and birthing. These studies helped address issues pertaining to space conflict and multiple use. Concurrent with this baseline work, research needs associated with the "potential" effects of oil and gas and marine minerals activities began to evolve. These later concerns surrounded potential impacts from sources other than oil spills and drilling discharges, such as noise and disturbance. By the mid-1980's, studies on the effects of noise on marine mammals were initiated in our Alaska and Pacific OCS Regions. In 1987, MMS sponsored a comprehensive literature review of the effects of noise, particularly focusing on the oil and gas industries. In 1992, the Office of Naval Research (ONR) provided core funding to convert this MMS report into an expanded publication: "Marine Mammals and Noise" published by Academic Press (1995).

Featured in the poster are two MMS studies which address the issues of anthropogenic presence, noise and endangered whales. The "Bowhead Whale Aerial Survey Project" is a 20 plus year effort to understand the bowhead migration and potential impacts from anthropogenic presence. The other featured study is the "Sperm Whale Seismic Survey" a multi-phased effort to get snapshot and broad views of the presence and use by sperm whales of the deep waters of the Gulf of Mexico - areas of exploratory oil and gas activities.

Active Sonar and the Marine Environment

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Abstract
A study of the effects of active sonar transmissions on fish and marine mammals in Norwegian waters has been launched, following ordering of new frigates by the Royal Norwegian Navy (RNoN). The objective of the study is to produce a set of recommended rules for naval sonar operations in Norwegian waters based on scientific grounds. The project includes studies of physiological and behavioral effects of sonar signals on fish and marine mammals, as well as development of a decision aid system to assure responsible operation of naval sonars within Norwegian waters.

Undersea Noise Pollution—A Challenge for Science, Governments and the Civil Society

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Abstract
A growing body of evidence indicates that undersea-noise pollution can have various adverse impacts on marine life and thus constitutes a severe threat to the marine organisms and ecosystems. The intense and widespread undersea noise is an issue of increasing importance and has already been addressed by several international institutions (including IWC, IMO, ASCOBANS and ACCOBAMS).

In 2002 ASMS OceanCare founded the European Coalition for Silent Oceans and commissioned a legal analysis on the use of low frequency active sonar (LFAS) by Dr. Alexander von Ziegler, a Swiss expert in sea law. In his expert report entitled "The use of LFA Sonar under International Law" A. von Ziegler concluded that the use of LFAS violates four of the most important general principles of customary law (sovereignty over natural resources and the responsibility not to cause damage to the environment of other states or of areas beyond the limits of national jurisdiction, principle of preventive action, principle of sustainable development, precautionary principle) as well as the obligations deriving from several international conventions. In 2003 the expert report has been distributed to the relevant conventions and to the ministers of defense, foreign affairs and environment of all NATO and UN states. Reactions from numerous ministers showed concern.

Various petitions against the use of military sonar systems have been handed over to the European Parliament and to NATO. The fatal effects of sonar technology have been discussed with the NATO representatives, who since are looking into alternative methods and have intensified efforts to protect marine mammals from the hazardous effects associated with sonar tests. At the 5th UN conference on "Oceans and the Law of the Sea" an NGO delegation presented an overview of the scientific aspects, the legal arguments, and the political activities aiming at placing Ocean Noise under intergovernmental regulation.

ABR Responses in Two Species of Marine Mammals

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Abstract
Plans exist to built numerous offshore wind farms in the North and Baltic Sea, comprising several thousand windmills. The sound emitted during the construction (225+dB re 1µPa) as well as the operation of the windmills is considered to have potentially negative impact on marine mammals. Therefore an audiometric study on harbour porpoises and harbour seals has been initiated within the framework of the research projects MINOS. This study comprises measurements of the absolute hearing threshold of both species in captivity as well as of harbour seals in the wild. These data are prerequisite as a baseline for a subsequent resilience test (TTS test) of the animal's auditory system. The measurement of auditory brainstem response (ABR) is being used in this study. This method is a common tool to investigate the auditory abilities of vertebrates including humans. So far measurements have been conducted on a wild and a captive harbour seal with wideband signals at 4kHz, a male harbour seal with narrow band tone bursts of 0.125 to 16kHz, a male harbour porpoise with tone bursts of 0.3 to 2kHz and amplitude-modulated sounds of 2kHz to 22.4kHz. Thresholds were determined using a correlation technique as well as regression analysis. The resulting audiograms are in accordance with the shape of behavioural audiograms, although thresholds are shifted to higher values. Further animals are currently measured for their absolute hearing threshold and TTS measurements are in preparation. In addition, the responses of seals to broad-band click stimuli was measured comparatively on the captive and on wild animals. ABR waveforms and hearing thresholds were similar to those of the captive individual. It can be concluded that ABR measurements can become a tool for an ecological survey programme with wild-caught animals if more experience is gathered regarding the precise assessment of auditory thresholds under suboptimal conditions.

Multi-scale Impact Assessments Can Help Detect Impact, Infer its Mechanism and Consequences and Provide Tools for Management

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Abstract
Boat traffic, and particularly the traffic associated with the tourism industry, generates a significant proportion of the noise to which cetaceans are exposed because of the overlap between coastal cetacean habitat and this activity. Interactions with vessels are chronic intermittent stressors for cetaceans, but the long-term consequences of these impacts are often difficult to detect due to methodological issues. We report on the framework of a study conducted in Doubtful Sound, New Zealand which assessed the effects of boat interactions on bottlenose dolphins (*Tursiops* spp.). We tested whether the presence of boats, their type, and their behaviour, affected the diving pattern of individuals, the behavioural events observed in groups of dolphins as well as the behavioural state of these groups. We therefore looked for various short-term reactions at the individual and group levels. Combining the effects observed at these two ecological levels allowed us to infer both the mechanisms by which vessel interactions were impacting the dolphins and the long-term biological cost of these interactions for individuals and the population. We found that dolphins were more sensitive to boat presence when they were resting or socialising. We also showed that boats misbehaving increased the effect size of the impact, especially for females. We proposed a multi-level reserve to mitigate these effects based on the dolphins' spatial behavioural ecology. Adapting the management of boat interactions to reduce exposure, either spatially or temporally, during sensitive behavioural states is likely to be an efficient mitigation tool. We think that this framework could be readily applied to other situations where the detection and mitigation of anthropogenic impacts on animals is required.

Passive Acoustic Marine Mammal Monitoring Technology for Navy Ranges

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Abstract

The Office of Naval Research (ONR) program, Marine Mammal Monitoring on Navy Ranges (M3R), has leveraged the infrastructure of U.S. Navy undersea ranges to develop a set of tools for passive detection and localization of marine mammal calls. Widely-spaced, bottom mounted omni-directional hydrophones are used to monitor animal calls over broad spatial and temporal scales. The tools are designed for use with diverse calls including clicks, sweeps, and whistles. Call frequency can vary from 50 Hz to 50 kHz. Calls are detected, precisely time-tagged using a GPS reference, and detection reports generated. Calls are divided in to 2 broad classes, clicks and "everything else." The Time Difference of Arrivals (TDOA) between a master hydrophone and those surrounding are calculated. For clicks, this is done directly using a data association algorithm. For all other calls, a 2-D spectrogram cross correlation is first performed. A hyperbolic tracking algorithm is then used to localize the calls. 3-D tracks are obtained for repetitively vocalizing animals. Included in the tool set are real-time displays that allow simultaneous monitoring of all range hydrophones. For installations such as the Atlantic Undersea Test and Evaluation Center (AUTEC), up to 82 hydrophones covering an area of over 500 square nautical miles are utilized. Displays for receiver detection statistics, individual receiver output spectrograms, and X-Y geo tracking displays are provided. The current detection algorithm runs on a massively parallel Digital Signal Processor (DSP). A replacement processor based on commodity Linux cluster technology is under design. This processor will reduce the cost of hardware by up to a factor of 10, making the tools affordable for a diverse set of applications.

Noise Pollution Case Study: Cetaceans in Hong Kong

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Abstract

Hong Kong has two resident species of cetacean: the Indo-Pacific humpback dolphin and finless porpoise. However, Hong Kong is one of the busiest ports in the world, with approximately half a million oceanic and river-going vessels travelling through its waters every year, including over 10,000 transits by high speed ferries through the area of greatest humpback dolphin abundance. This shipping traffic will eventually increase, as new regular shipping routes to Hong Kong from mainland China have been proposed. Studies have demonstrated changes in dolphin behaviour in response to boat traffic, including avoidance of fast vessels.

In 1995 a sanctuary was established by the Hong Kong government around the islands of Sha Chau and Lung Kwu Chau, an area important for resident humpback dolphins. However, over 200 vessels can surround this sanctuary area at any time, and the Urmston Road shipping channel is located immediately to the north of the sanctuary. The sanctuary itself was a measure to mitigate, and compensate, for the construction of a temporary aviation fuel receiving facility off Sha Chau, the construction of which incorporated pile driving and additional boat traffic. A bubble curtain was used to try to mitigate the noise produced by the pile driving.

Adjacent to the sanctuary in the south is Chek Lap Kok airport, which when at full capacity will have over 700 planes descending and taking off daily, directly over the sanctuary and other critical dolphin habitat. The airport itself is constructed from an island which was an area frequently used by dolphins, prior to the infilling of the surrounding waters and the demolition of the island itself in 1993 to produce the airport platform; all activities involving high noise input into cetacean habitat.

In addition, there are increasing numbers of dolphin-watching vessels specifically targeting areas of high dolphin abundance. A recent land-based study demonstrated that longer dolphin dive times, and shorter periods at the surface, were recorded when dolphin-watching boats were present. Recently, small motorized boats have also been reported chasing dolphins at high speed to the south of the sanctuary area.

Cetaceans in Hong Kong are exposed to high levels of anthropogenic contaminants, their food supply is depleted, and there is evidence of some anthropogenic mortality and injury through fisheries by-catch and ship-strikes. Noise is adding another, potentially major, anthropogenic stressor to already impacted populations.

Tools for Underwater Noise Monitoring, Marine Mammals' Surveys, and Implementation of Acoustic Risk Mitigation Policies

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Keywords: Underwater acoustic monitoring, acoustic risk mitigation, marine mammals and noise, passive acoustics

Abstract

The concern that man-made acoustic signals can affect marine mammals has increased over the past few years, mainly within the context of low-frequency active sonars and seismic surveys. Whether it is in support of acoustic risk mitigation measures, or in the larger context of environmental monitoring, recent years have seen an increasing use of underwater passive acoustics.

Passive acoustics is a powerful tool to be used for (a) expanding knowledge about marine mammals' behaviour, ecology and distribution; (b) monitoring underwater noise; (d) monitoring critical habitats; (e) evaluating the effects of sound exposure on animals' behaviour; (f) implementing mitigation policies by detecting animals within or approaching a possibly dangerous sound exposure area.

To support the Acoustic Risk Mitigation Policies being developed by many national and international civil and military organizations a PC based Sound Analysis Workstation was designed and extensively tested to provide an affordable and flexible tool for wide band acoustic detection and monitoring. It provides detection, processing, storage and plotting capabilities and can be used for both wide area surveys and local monitoring needs.
In many years of extensive use it has been demonstrated the importance of broadband detection, continuous 24/24h monitoring and integration of visual cues to maximize detection capabilities.

The package includes software for 1) recording and analyzing sounds received by up to 8 wide band sensors, 2) manage a sonobuoys' radio receiver, 3) recording and distributing NMEA navigation data, 4) logging and classification of acoustic contacts, 5) logging visual contacts, 6) sharing data among a network of PCs, 7) plot georeferenced data on a GIS.

The research has been carried out within the NATO Undersea Research Centre's SOLMAR Project with ONR Grants N00014-99-1-0709, N00014-02-1-0333, and N00014-03-1-0901.

Environmental Stewardship: Maritime Forces Atlantic's Marine Mammal Impact Mitigation

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Abstract
The Canadian Department of National Defence has a policy of environmental stewardship. In being mindful of the potential impact related to its operations, Maritime Forces Atlantic has undertaken an Environmental Assessment of its training activities in the Atlantic Operating Areas, created the framework of an Environmental Management System, created computer-based environmental risk assessment tools, and has drafted a "Standard Operating Procedure" on the observation of marine mammals and reptiles. This poster will present a brief overview of the effort.

Marine Mammal Monitoring and Mitigation During Recent Seismic Surveys for Geophysical Research

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Abstract
The R/V *Maurice Ewing*, operated by Lamont-Doherty Earth Observatory of Columbia University, conducts academic marine seismic surveys sponsored by the U.S. National Science Foundation. In autumn 2002, a beaked whale stranding occurred in Baja California when the *Ewing* was operating its largest airgun configuration (20 guns; 8600 in^3) nearby. No causal link was confirmed. However, subsequent *Ewing* seismic surveys have included progressively more stringent monitoring and mitigation measures under provisions of Incidental Harassment Authorizations issued by the U.S. National Marine Fisheries Service (NMFS). ***Monitoring*** includes visual observations by trained marine mammal observers during all daytime airgun operations and during nighttime ramp-ups, when allowed. Starting in 2004, a towed hydrophone array is monitored day and night for cetacean calls when the larger airgun configurations are used. ***Pre-cruise mitigation*** includes selecting the smallest airgun array consistent with the geophysics objectives and, where possible, adjusting plans to avoid seasons and/or locations of special concern for marine mammals, sea turtles, and most recently fisheries. ***Mitigation during cruises*** includes ramp-ups, plus power-downs (to one small airgun) or shut-downs when mammals and (recently) sea turtles are detected within a “safety radius”: the 180 dB re 1 µPa (rms) distance for cetaceans and sea turtles, and the 190 dB radius for pinnipeds. Specific rules determine when airgun operations can resume after a shut-down or power-down. ***Acoustic measurements*** showed that the safety radii are greater in shallow than deep water. Recently, depth-dependent safety radii have been applied, and other mitigation measures have been more stringent in shallow waters. ***Conclusions:*** No one monitoring or mitigation measure is entirely effective in detecting marine mammals or avoiding their exposure to strong airgun sounds. However, different monitoring and mitigation techniques can be complementary. In judiciously chosen combinations, they can substantially reduce the likelihood of biologically-significant effects. These benefits have costs to the seismic operator.

Canadian Environmental Legislation Impacting to Sonar R&D

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Abstract
Defence Research and Development Canada (DRDC) Atlantic has a number of projects which require the transmission of acoustic energy. Because of potential adverse environmental affects, a number of Canadian laws and Department of National Defence (DND) policies impact on these research activities. In particular the Fisheries Act, the Oceans Act, the Canadian Environmental Assessment Act (CEAA), the Canadian Environmental Protection Act (CEPA), and the Species at Risk Act (SARA) influence the operation of research trials. Under CEAA research activities on CFAV Quest within Canadian waters are exempt from the requirement to carry out an environmental impact assessment; however, DND policy requires that the assessment be carried out. This poster provides an overview of the relevant legislation and policies together with a description of DRDC Atlantic's approach to addressing the various concerns in its EA process.

Effects From Pile Driving Operations on Harbour Porpoises at Horns Reef Offshore Wind Farm, Monitored by T-PODs and Behavioural Observations

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Abstract

The world's largest offshore wind farm was build on Horns Reef in the Danish North Sea in 2002. It consists of 80 2 MW wind turbines, mounted on steel monopile foundations. The monopiles were driven into the seabed with a hydraulic hammer, a procedure generating high underwater noise levels (not quantified). Underwater acoustic alarms (AQUAmark pingers and seal scrammer) were deployed prior to each pile driving operation in order to deter marine mammals from the vicinity of the operation and hence protect them from excessive sound exposure.

Reactions of harbour porpoises was monitored by visual surveys from ship and by acoustic dataloggers (T-PODs), both inside and outside of the wind farm.

Average time from end of each pile driving operation to the first porpoise encounter recorded by the T-PODs increased significantly from the average time between encounters in periods without pile driving (from 50 minutes to close to 300 minutes). Average interval between first and second encounter after end of pile driving was not significantly larger than outside pile driving periods, indicating return to levels normal for the construction period as a whole.
Observations from ship surveys showed a significant change in surface behaviour on days with pile driving at distances up to 10 nautical miles from the wind farm. The most frequent behaviour changed from non-directional movement (presumably associated with feeding) to directional movement on days with pile driving operations.

Both data sets points to a strong and immediate effect of the pile driving operations (caused by AQUAmark pingers and seal scrammers and impact sounds from the hydraulic hammer), followed by a rapid recovery to the situation normal for the construction period. This normal situation was not undisturbed, as other, less noisy activities took place during the entire period, as well as a general high level of ship traffic during construction.
A separate, ongoing study will address permanent effects from the construction and operation of the wind farm.

The study was supported financially by the Danish National Energy Authority.

Whales and the WAXA: Defence Sponsored Whale Research off the West Coast of Australia

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Abstract
The Western Australia Exercise Area (WAXA), situated near Perth, Western Australia, is one of the primary maritime exercise areas of the Australian Defence Force (ADF). The waters of the WAXA are used extensively by ships, submarines and aircraft of the ADF, and shared with merchant shipping, commercial fishing and recreational activities such as whale watching.

Parts of the WAXA are also an important migration route for the humpback whale (*Megaptera novaeangliae*) and an aggregation area for the blue whale (*Balaenoptera musculus*). In recognition of the periodic presence of these threatened species in the WAXA, the Australian Department of Defence has sponsored and coordinated an extensive research program into the status and habits of blue whales in the WAXA. This research has been conducted in collaboration with leading researchers and government regulatory authorities.

In a wider context, Defence has also undertaken an exhaustive review of all activities carried out at sea and the way in which these activities may have an impact upon all aspects of the environment, including marine mammals. Coupled with the specific knowledge gained from the WAXA blue whale research program, Defence has developed a range of standard environmental risk mitigation measures which are employed by all ADF units operating at sea.

This poster will:

- Describe relevant geographical and biophysical features of the WAXA, including the status of marine mammals and blue and humpback whales in particular.
- Describe Defence activities in the WAXA, including history of use.
- Outline the planning and conduct of ADF activities to minimise risks to marine mammals.
- Describe Defence-sponsored whale research in the WAXA.
- Describe liaison and consultation undertaken by Defence with regulatory authorities, researchers and other stakeholders regarding protection of marine mammals.

Regulatory Authority of the States Over Acoustic Activity, With Emphasis on California

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Abstract

In the United States the Federal Coastal Zone Management Act (CZMA) designates management authority to States over federal waters off shore of the States, once a state's coastal management program is certified by the federal government. The CZMA gives state coastal management agencies regulatory control (federal consistency review authority) over all federal activities and federally licensed, permitted or funded activities affecting the coastal zone (regardless of whether they occur within, landward or seaward of the coastal zone boundary), if the activity affects the land or water uses or natural resources of the coastal zone. In California the California Coastal Commission (CCC) is the designated coastal management agency. The regulations and the regulatory processes in California under the federal CZMA and under State law (the California Coastal Act) will be discussed with respect to underwater acoustic activities. Policy evolution over the past two decades will also be examined, as well as comparisons and contrasts with procedural and policy positions taken by other states.

In addition, the discussion will include examples of mitigation requirements imposed by the States on activities that produce sound, including seismic surveys for oil and gas, geologic investigations and other research, pier and platform decommissioning, naval activities, etc.

A Regulatory Agency Perspective on Anthropogenic Noise and Marine Mammals

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Abstract
MMS administers about 7,500 active leases on 40 million acres of the Outer Continental Shelf (OCS). The OCS makes a significant contribution to the national energy supply, providing 25 percent of the natural gas and 30 percent of the oil produced in the United States. The MMS carries out its mission of managing OCS mineral resources through a variety of efforts: estimating national OCS energy resources; assessing environmental impacts; funding research to assess and manage impacts of activities and to monitor changes in the quality and productivity of the marine environment; leasing OCS acreage; analyzing and permitting proposed actions; inspecting operations; enforcing statutory and regulatory requirements; and providing scientific and technical assistance to other nations.

The MMS protected species program involves complying with the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA); analyzing impacts; designing mitigation, monitoring guidelines and management approaches; and providing information necessary for promulgating regulations; and identifying, funding, and participating in research necessary for the protection and enhancement of protected species and their habitat.

MMS has focused two programmatic environmental analyses (under the National Environmental Policy Act [NEPA]) on noise producing activities (seismic surveys and explosive removals of offshore structures). The programmatic environmental assessments characterize activities and the environment in which they occur, document potential environmental impacts and mitigation measures, and evaluate proposals.

To avoid or reduce the potential impacts of noise MMS, implements mitigation measures (based on NEPA analyses, ESA consultations, and MMPA collaboration) through a variety of mechanisms including regulations (30 CFR Part 250 - Oil and Gas and Sulphur Operations in the Outer Continental Shelf) that implement provisions of the OCS Lands Act (U.S. Code Title 43, Chapter 29, Subchapter III), lease stipulations, and notices to lessees (which clarify requirements addressed in our regulations).

APPENDIX 5: List of Relevant Acronyms and Abbreviations

Abidjan Convention	Convention for Co-Operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region, 1981
ABR	auditory brainstem response
ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area, 1996
AIM	Acoustic Integration Model
APEC	Asia Pacific Economic Cooperation
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas, 1992
Barcelona Convention	Convention for the Protection of the Marine Environment and Coastal Region of the Mediterranean, 1976
Bern Convention	Bern Convention on the Conservation of European Wildlife and Natural Habitats, 1979
Bonn Convention	Convention on the Conservation of Migratory Species of Wild Animals, 1979 (also known as CMS)
Bucharest Convention	Convention for the Protection of the Black Sea Against Pollution, 1992
CBD	Convention on Biological Diversity, 1992
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources, 1980
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna, 1973
CMS	Convention on the Conservation of Migratory Species of Wild Animals, 1979 (also known as the Bonn Convention)
CONAMA	Conselho Nacional do Meio Ambiente (Brazilian National Environmental Council)
CZMA	Coastal Zone Management Act (U.S.), 1972
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIA Directive	Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment (E.U.), 1985 (amended 1997)
ERMC	Environmental Risk Management Capability, U.K. Department of Defence
ESA	Endangered Species Act (U.S.), 1973
ESME	Effects of Sound on Marine Environment, U.S. Office of Naval Research
Espoo Convention	Convention on Transboundary Environmental Impact Assessment, 1991

GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
Habitats Directive	Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (E.U.), 1992
Helsinki Convention	Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992
IAGC	International Association of Geophysical Contractors
IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renovaveis (Brazilian Environmental Agency)
ICRW	International Convention on the Regulation of Whaling, 1946
ICSU	International Council for Science
ILO	International Labor Organization
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission (under UNESCO)
ISO	International Organization for Standardization
IWC	International Whaling Commission
Jakarta Mandate	Jakarta Mandate on Coastal and Marine Biological Diversity (under CBD)
JNCC	Joint Nature Conservation Committee
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973
MMPA	Marine Mammal Protection Act (U.S.), 1972
NAFTA	North American Free Trade Agreement
Nairobi Convention	Convention for the Protection, Management, and Development of the Marine and Coastal Environment of the Eastern African Region, 1985/1996
NAT	North Atlantic Treaty, 1946
NATO	North Atlantic Treaty Organization
NEPA	National Environmental Policy Act (U.S.), 1969
NGO	non-governmental organization
OBIS	Ocean Biogeographic Information System, Duke University
OCSLA	Outer Continental Shelf Lands Act (U.S.), 1953
Offshore Protocol	Protocol for the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Seabed and its Subsoil, 1994 (under the Barcelona Convention)
OSPAR	Convention for the Protection of the Marine Environment of the Northeast Atlantic, 1992

PMAP	Protective Measures Assessment Protocol, U.S. Navy
PSSA	Particularly Sensitive Sea Area (provision under MARPOL and IMO)
PTS	permanent threshold shift
RA	risk assessment
Rio Declaration	Rio Declaration on Environment and Development, 1992
SAKAMATA	Sea Animal Kind Area-dependent Mitigated Active Transmission Aid
SCAR	Scientific Committee on Antarctic Research (under the Antarctic Treaty)
SCOR	Scientific Council on Oceanographic Research
SEA	Strategic Environmental Assessment
SEA Directive	Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (E.U.), 2001
SOLAS	International Convention for the Safety of Life at Sea, 1974
SOLMAR	Sound, Ocean, and Living Marine Resources
SoSuS	Sound Surveillance System, U.S. Navy
TTS	temporary threshold shift
UNCLOS	United Nations Convention on the Law of the Sea, 1982
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICPOLOS	United Nations' Open-ended Informal Consultative Process on Oceans and the Law of the Sea

APPENDIX 3

Understanding the impacts of anthropogenic sound on beaked whales (reprint)

Understanding the impacts of anthropogenic sound on beaked whales[1]

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This paper is dedicated to the memory of Dr. Edward Thalmann (1945-2004).

ABSTRACT

This review considers the effect of anthropogenic sound on beaked whales[2]. Two major conclusions are presented: (1) gas-bubble disease, induced in supersaturated tissue by a behavioural response to acoustic exposure, is a plausible pathologic mechanism for the morbidity and mortality seen in cetaceans associated with sonar exposure and merits further investigation; and (2) current monitoring and mitigation methods for beaked whales are ineffective for detecting these animals and protecting them from adverse sound exposure. In addition, four major research priorities, needed to address information gaps on the impacts of sound on beaked whales, are identified: (1) controlled exposure experiments to assess beaked whale responses to known sound stimuli; (2) investigation of physiology, anatomy, pathobiology and behaviour of beaked whales; (3) assessment of baseline diving behaviour and physiology of beaked whales; and (4) a retrospective review of beaked whale strandings.

KEYWORDS: BEAKED WHALES; ZIPHIIDAE; NOISE; MANAGEMENT; ACOUSTICS; CONSERVATION; STRANDINGS

INTRODUCTION

Beaked whales (family Ziphiidae) are among the least understood marine mammals. The family consists of approximately 21 species that spend relatively little time at the surface and occur almost exclusively in deep waters beyond the continental shelf. Most of our current knowledge of beaked whales is based on studies of stranded specimens. Reports of occasional mass strandings of beaked whales (i.e. strandings of two or more whales other than a cow-calf pair,

[1] This paper arose out of a workshop convened in April 2004 by the US Marine Mammal Commission in Baltimore, Maryland, USA.
[2] Diverse fields (marine mammal ecology, medicine, behaviour, physiology, pathobiology and anatomy, human diving physiology and acoustics) were represented at the 2004 workshop and were brought together for an interdisciplinary discussion of various topics related to interactions between beaked whales and anthropogenic sound. These included sound propagation and acoustic exposure during specific stranding events, behaviour and ecology of beaked whales, beaked whale distribution, abundance and habitat, beaked whale anatomy and physiology and the efficacy of existing monitoring and mitigation efforts.

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Geraci and Lounsbury, 1993) date back to at least the early 1800s. Since 1960, however, 41 'mass' strandings of Cuvier's beaked whales (*Ziphius cavirostris*) have been reported worldwide (Brownell *et al.*, 2004; Taylor *et al.*, 2004). Furthermore, these probably represent only a small proportion of all beaked whale strandings. Some of these recent mass strandings were concurrent with naval manoeuvres and the use of active sonar (Frantzis, 1998[3]; Anon., 2001; Jepson *et al.*, 2003). The overall pattern of strandings has raised concerns that certain sounds from sonar could directly or indirectly result in the death or injury of beaked whales, particularly Cuvier's beaked whales. Additional concerns have been raised that sounds from seismic surveys might have similar effects (Taylor *et al.*, 2004).

Recent stranding events

Several recent mass strandings have led to suggestions that exposure to anthropogenic sounds negatively affects beaked whales. The temporal and spatial association of mass strandings of beaked whales and offshore naval manoeuvres was first noted in 1991 (Simmonds and Lopez-Jurado, 1991). Since then, a series of 'atypical' (Frantzis, 1998) beaked whale strandings, temporally (within hours or days) and spatially (less than 50km) associated with naval manoeuvres, have been better documented and are briefly summarised below. These strandings lend further support to the hypothesis that exposure to certain anthropogenic sounds may harm these animals.

Greece, May 1996

Frantzis (1998) reported an 'atypical' mass stranding of 12 Cuvier's beaked whales on the coast of Greece that was associated with acoustic trials by vessels from the North Atlantic Treaty Organisation (NATO). He was the first to hypothesise that these strandings were related to exposure to low-frequency military sonar. However, the sonar in question produced both low- and mid-frequency signals (600Hz, 228dB Sound Pressure Level (SPL) (re: 1μPa at 1m Root Mean Square (RMS))[4], 3kHz, 226dB SPL, D'Amico and Verboom, 1998). Frantzis's hypothesis prompted an in-depth analysis of the acoustic activity during the naval exercises, the nature of the strandings and the possibility that the acoustic source was related to the strandings (D'Amico and Verboom, 1998). Since full necropsies had not been conducted and no gross or histological abnormalities were noted, the cause of the strandings could not be determined unequivocally (D'Amico and Verboom, 1998). The analyses thus provided some support but no clear evidence for the hypothesised cause-and-effect relationship of sonar operations and strandings.

Bahamas, March 2000

When multiple beaked whales atypically stranded in the Bahamas in March 2000, researchers were aware of the possible link to anthropogenic sound sources and thus facilitated a more comprehensive examination of the dead animals. However, in most cases, analyses were performed on decomposed carcasses or tissues. Seventeen cetaceans (one spotted dolphin, *Stenella frontalis*, nine Cuvier's beaked whales, three Blainville's beaked whales, *Mesoplodon densirostris*, two minke whales, *Balaenoptera acutorostrata* and two unidentified beaked whales) stranded on 15-16 March 2000 on beaches of the Bahamas Islands. Eight beaked whales were returned to the water alive and one dead specimen was not readily accessible for necropsy. As a result, only five of the stranded beaked whales were examined *post mortem* and only two of these were marginally fresh enough to allow a more detailed pathological analysis of lesions. Initial gross necropsy of these five beaked whales indicated that the animals were in good body condition and that none presented any gross indication of debilitating infectious disease. Computerised tomography of two animals and detailed dissection of five heads indicated subarachnoid haemorrhages in the temporal region and haemorrhage in the cochlear duct of two of the animals. The *post mortem* time to examination varied from hours to several days, unfortunately compromising these analyses. The interim report of the investigation concluded that these findings were consistent with acoustic or impulse injuries that resulted in the animals stranding. The gross and histopathological evidence indicated cardiovascular collapse, which is often associated with other signs of extreme physiological stress observed in live, beach-stranded marine mammals (i.e. hyperthermia, high endogenous catecholamine release; Anon., 2001; see also Balcomb and Claridge, 2001). The role of intracranial and acoustic fat injuries in the strandings and mortalities was not clear. Analysis of acoustic sources used in the Bahamas naval exercises revealed that four of five ships were using mid-frequency sonar (AN/SQS-53C: 2.6-3.3kHz, ~235dB SPL, AN/SQS-56: 6.8, 7.5 and 8.2kHz, ~223dB SPL; Anon., 2001). The final report of the joint US National Oceanographic and Atmospheric Administration (NOAA) and US Navy investigation into the stranding event, including the full suite of pathological investigations is still pending. The event raised the question of whether the mid-frequency component of the sonar in Greece in 1996 was implicated in the stranding, rather than the low-frequency component proposed by Frantzis (1998).

Madeira, May 2000

The stranding in the Bahamas was soon followed by another atypical mass stranding of Cuvier's beaked whales in the Madeira Islands. Between 10 and 14 May 2000, three Cuvier's beaked whales stranded on two islands in the Madeira archipelago. NATO naval exercises involving multiple ships occurred concurrently with these strandings, although NATO has thus far been unwilling to provide information on the sonar activity during their exercises. Only one of the stranded animals was marginally fresh enough for a full necropsy (24 hours post-stranding). The necropsy revealed evidence of haemorrhage and congestion in the right lung and both kidneys (Freitas, 2004), as well as evidence of intracochlear and intracranial haemorrhage similar to that observed in the Bahamas beaked whales (D. Ketten, unpublished data).

Canary Islands, September 2002

In September 2002, a beaked whale stranding event occurred in the Canary Islands. On 24 September, 14 beaked whales (7 Cuvier's beaked whales, 3 Blainville's beaked whales, 1 Gervais' beaked whale, *M. europeaus*, and 3 unidentified beaked whales) stranded on the beaches of Fuerteventura and Lanzarote Islands, close to the site of an international naval exercise (called Neo-Tapon 2002) held that same day. The first strandings began about four hours after the onset of the use of mid-frequency sonar activity (3-

[3] Frantzis (1998) cited the following references: Robinson *et al.* (1983); Miyazaki (1989); Simmonds and Lopez-Jurado (1991) and Tortonese (1963).

[4] Unless otherwise noted, all SPL values are RMS pressures referenced to 1μPa at 1m.

10kHz, D'Spain *et al.*, 2006; Jepson *et al*., 2003). Seven whales (1 female Blainville's beaked whale, 1 female Gervais' beaked whale and 5 male Cuvier's beaked whales) are known to have died that day (Fernández *et al.*, 2005). The remaining seven live whales were returned to deeper waters. Over the next three days, three male and one female Cuvier's beaked whales were found dead and a carcass of an unidentified beaked whale was seen floating offshore. A total of nine Cuvier's beaked whales, one Blainville's beaked whale and one Gervais' beaked whale were examined post mortem and studied histopathologically (one Cuvier's beaked whale carcass was lost to the tide). No inflammatory or neoplastic processes were noted grossly or histologically and no pathogens (e.g. protozoa, bacteria and viruses, including morbillivirus) were identified. Stomach contents were examined in seven animals and six of them had recently eaten, possibly indicating that the event(s) leading to their deaths had had a relatively sudden onset (Fernández *et al.*, 2005). Macroscopic examination revealed that the whales had severe, diffuse congestion and haemorrhages, especially in the fat in the jaw, around the ears, in the brain (e.g. multifocal subarachnoid haemorrhages) and in the kidneys (Fernandez, 2004; Fernandez *et al.*, 2004). Gas bubble-associated lesions were observed in the vessels and parenchyma (white matter) of the brain, lungs, subcapsular kidney veins and liver; fat emboli were observed in epidural veins, liver sinusoids, lymph nodes and lungs (Jepson *et al.*, 2003; Fernandez, 2004; Fernandez *et al.*, 2004; 2005). After the event, researchers from the Canary Islands examined past stranding records and found reports of eight other strandings of beaked whales in the Canaries since 1985, at least five of which coincided with naval activities offshore (Martín *et al.*, 2004).

Gulf of California, September 2002

In September 2002, marine mammal researchers vacationing in the Gulf of California, Mexico discovered two recently deceased Cuvier's beaked whales on an uninhabited island. They were not equipped to conduct necropsies and in an attempt to contact local researchers, found that a research vessel had been conducting seismic surveys approximately 22km offshore at the time that the strandings occurred (Taylor *et al.*, 2004). The survey vessel was using three acoustic sources: (1) seismic air guns (5-500Hz, 259dB re: 1μPa Peak to Peak (p-p); Federal Register, 2003); (2) sub-bottom profiler (3.5kHz, 200dB SPL; Federal Register, 2004); and (3) multi-beam sonar (15.5kHz, 237dB SPL; Federal Register, 2003). Whether or not this survey caused the beaked whales to strand has been a matter of debate because of the small number of animals involved and a lack of knowledge regarding the temporal and spatial correlation between the animals and the sound source. This stranding underlines the uncertainty regarding which sound sources or combinations of sound sources may cause beaked whales to strand.

Although some of these stranding events have been reviewed in government reports or conference proceedings (e.g. Anon., 2001; Evans and Miller, 2004), many questions remain. Specifically, the mechanisms by which beaked whales are affected by sound remain unknown. A better understanding of these mechanisms will facilitate management and mitigation of sound effects on beaked whales. As a result, in April 2004, the United States Marine Mammal Commission (MMC) convened a workshop of thirty-one scientists from a diverse range of relevant disciplines (e.g. human diving physiology and medicine, marine mammal ecology, marine mammal anatomy and physiology, veterinary medicine and acoustics) to explore issues related to the vulnerability of beaked whales to anthropogenic sound. The purpose of the workshop was to (1) assess the current knowledge of beaked whale biology and ecology and recent beaked whale mass stranding events; (2) identify and characterise factors that may have caused the strandings; (3) identify ways to more adequately investigate possible cause and effect relationships; and (4) review the efficacy of existing monitoring and mitigation methods. This paper arose out of the discussions at that workshop.

OVERVIEW OF RECENT FINDINGS

A number of scientists have prepared papers describing acoustic activities and propagation characteristics during some stranding events, beaked whale biology including behaviour and ecology, distribution, abundance, anatomy and physiology and mitigation and management (Barlow and Gisiner, 2006; Barlow *et al.*, 2006; D'Spain *et al.*, 2006; Ferguson *et al.*, 2006; MacLeod and D'Amico, 2006; MacLeod *et al.*, 2006 and Rommel *et al.*, 2006). These are briefly summarised here and where appropriate, we have made some general recommendations for further research topics.

Acoustic characteristics

D'Spain *et al.* (2006) described the acoustic sources and propagation parameters associated with several of the stranding events: Greece, 1996, the Bahamas, 2000 and the Canary Islands, 2002. The authors found that these three events shared three common features. One common environmental feature was deep water close to land (e.g. offshore canyons). Whether this feature influenced beaked whale distribution (e.g. species that stranded prefer this habitat), accentuated the effects of the sounds through reflection and reverberation from the bathymetry and/or acted in some other way is not clear. A second environmental feature common to all three events was the presence of an acoustic waveguide (see D'Spain *et al.*, 2006 for more details). Thirdly, the authors noted common transmission characteristics, including periodic sequences of transient pulses (i.e. rapid onset and decay times) generated at depths shallower than 10m (in the Bahamas and Canaries) by sound sources moving at speeds of 2.6m s^{-1} or more during source operation (see table 1 in D'Spain *et al.*, 2006 for more details).

The sound sources in use during the Gulf of California stranding event in September 2002 included both a sub-bottom profiler and multi-beam sonar system (Table 1). Air guns can neither be confirmed nor ruled out as a cause of these strandings and retrospective analyses are needed to investigate the possible role of these other sound sources in the stranding event.

It is not yet clear whether high-intensity sound sources alone are sufficient to trigger beaked whale strandings, or whether certain acoustic, biological or environmental characteristics must co-occur with these stimuli. A more complete understanding of the source characteristics and propagation of anthropogenic sounds associated with beaked whale strandings would be extremely useful in predicting and preventing future incidents of this nature, but it is often difficult to obtain such specific information, which may be sensitive for many of the parties involved.

Based on the available data, we recommend research to: (1) identify key characteristics of sound (e.g. frequency, amplitude, energy, directional transmission pattern, use of arrays vs. single sources, etc.) that may affect beaked whales; (2) identify characteristics of anthropogenic sounds associated with historic stranding events; (3) estimate the possible range of sound levels the animals received prior to stranding; (4) characterise environmental parameters that influence sound propagation and model site-specific sound propagation (on *post hoc* and predictive basis), especially where detailed environmental data are not immediately available; and (5) measure the behavioural responses of beaked whales in the presence of sound.

Behaviour and ecology

MacLeod and D'Amico (2006) reviewed the behaviour and ecology of beaked whales and their relevance to the impacts of sound on beaked whales. Specifically, they reviewed beaked whale social structure, life history, ecology, sound production and function and the characteristics of their habitat. Multiple strandings of beaked whales that occur concurrently with sound-generating anthropogenic activities often include a large proportion of immature and juvenile animals. However, it is not known whether juveniles are disproportionately affected, the age structure observed in the strandings is representative of that in beaked whale populations, or the strandings indicate geographic separation of demographic groups. If juveniles are disproportionately affected, it might suggest a relationship between the dimensions of some part of the anatomy and the wavelength of the sound involved or, alternatively, an age-specific behavioural response.

Recent tagging data from Cuvier's and Blainville's beaked whales from the Mediterranean Sea and Canary Islands (Tyack, unpub. data) have revealed several notable features of their dive profiles: (1) dives to depths near 2km and lasting nearly 1.5hrs; (2) slow ascent rates; and (3) a series of 'bounce' dives to 100-400m between the deeper, longer dives. The implications of this dive pattern are discussed below. We recommend a combination of short- (hours to days) and long-term studies (weeks to months) on the behaviour of beaked whales using multiple methods (e.g. D-tags which measure received sound levels as well as other movement data, time-depth recorders and visual observations) to better describe 'normal' behaviour.

Distribution, abundance and habitat

Barlow *et al.* (2006), Ferguson *et al.* (2006) and MacLeod *et al.* (2006) reviewed global distributions and abundance of beaked whales. Our understanding of the distribution of many beaked whales is very limited and based primarily on observations of strandings and a limited number of at-sea sightings. The identification of important habitat is generally compromised by insufficient and inconsistent observation effort. It is clear that research effort must focus on: (1) population structure, possibly using genetic data from archived samples (bone, skin, etc.) housed in museums and other collections around the world; and (2) population distributions.

Estimates of abundance and density are hindered by the typical surfacing behaviour of beaked whales at sea: their blows are generally not visible, they have low surfacing profiles and they spend the majority of their time at depth (Hooker and Baird, 1999; Baird *et al.*, 2004; Barlow and Gisiner, 2006). In addition, beaked whales tagged by Johnson *et al.* (2004) vocalised only when they were deeper than 200m, an observation that has important implications for passive acoustic monitoring. The importance of identifying, classifying and understanding vocalisations of beaked whales and the potential utility of passive acoustic monitoring must be noted. For such monitoring to be effective, future research must (1) develop and test detection algorithms; (2) ground-truth detection methods by coupling visual and passive acoustic studies and by monitoring vocalisations in areas for which there are good density estimates; and (3) investigate the behavioural context of vocalisations. In addition, it is important that effort be expended on: (1) estimation of abundance and densities of beaked whale species, especially in those areas where sound-producing activities are planned or regularly carried out; (2) systematic surveys that include oceanographic data to help identify key habitat characteristics; and (3) increase understanding of movement patterns via multiple methods (e.g. telemetry).

An improved understanding of basic beaked whale biology will advance the potential for predictive habitat modelling and may help managers and sound-producers predict which areas support high densities of beaked whales

Table 1

Acoustic characteristics of sound sources and propagation during stranding events.

Name	Centre frequency	SPL	Beam direction	Model propagation?
Greece[1], May 1996				
TVDS	600Hz	228dB re: 1μPa at 1m (RMS)	Horizontal	Yes
TVDS	3kHz	226dB re: 1μPa at 1m (RMS)	Horizontal	Yes
Bahamas[2], March 2000				
AN/SQS 53C	2.6kHz; 3.3kHz	~235dB re: 1μPa at 1m (RMS)	3° down from horizontal	Yes
AN/SQS 56	6.8kHz; 7.5kHz; 8.2kHz	223dB re: 1μPa at 1m (RMS)	Horizontal	Yes
Madeira, May 2000				
Unknown	Unknown	Unknown	Unknown	Unknown
Canary Islands, September 2002				
Unknown	Unknown	Unknown	Unknown	Unknown
Gulf of California, September 2002				
Air gun[3]	Broadband	236-262dB re: 1μPa at 1m (p-p)	Vertical	No
Multi-beam sonar[4]	15.5kHz	237dB re: 1μPa at 1m (RMS)	Omnidirectional	No
Sub-bottom profiler[3]	3.5kHz	204dB re: 1μPa at 1m (RMS)	Vertical	No

Sources: [1]D'Amico and Verboom (1998); [2]Anon. (2001); [3]Federal Register (2003); [4]Federal Register (2004). For more details, please see D'Spain *et al.* (2006).

and how this density may vary with season. However, we advocate a cautious approach when applying habitat models to regions that have not been thoroughly studied (i.e. extrapolating behaviour or habitat usage from one area to another) due, for example, to documented differences between known high density areas of beaked whales in different ocean basins (Barlow *et al.*, 2006; Ferguson *et al.*, 2006).

Anatomy and physiology

Rommel *et al.* (2006) reviewed the limited information available on anatomy and physiology of beaked whales. Given the scarce knowledge and the important conservation and mitigation implications, it is important that much more research be conducted on the anatomy and physiology of beaked whales, as well as the pathological changes caused by exposure to sound. We agree that emerging evidence supports the hypotheses that: (1) normal beaked whale diving patterns may lead to chronic tissue accumulation of nitrogen; and (2) chronic tissue accumulation of nitrogen may make beaked whales particularly vulnerable to diving related pathologies when their diving patterns are disrupted by exposure to intense sound. Research is needed in two key areas to further evaluate these hypotheses: (1) the factors contributing to nitrogen supersaturation, including normal and acoustically altered dive profiles and the depth at which complete lung collapse occurs; and (2) the potential for *in vivo* bubble nucleation and/or growth within tissues as a result of exposure to sound and/or disruption of normal diving patterns. In addition, the following are required: (1) better descriptions of normal gross and normal microscopic anatomies of healthy beaked whales (e.g. from incidental fishery takes and from 'normal' strandings); (2) investigations of the direct impacts of sound on tissues (*ex vivo*) presumed to be most susceptible to anthropogenic sound; (3) better descriptions of pathological changes in stranded beaked whales exposed to sound; (4) standardisation of gross and histopathological examination protocols for all beaked whale strandings, with special emphasis on the occurrence of gas and fat emboli and methods to prevent introduction of gas emboli during necropsies; (5) better descriptions of blood flow patterns in the vicinity of tissues potentially sensitive to sound; and (6) better descriptions of the anatomy and function of tissues and organs involved in hearing in beaked whales.

Comparative studies involving multiple beaked whale species and surrogate species (e.g. *Kogia*) may be useful. However, caution is required when extrapolating from other species to beaked whales. We therefore believe that when feasible, attempts should be made to rehabilitate live stranded beaked whales to provide opportunities for research not possible or more difficult with animals in the wild. However, it should be noted that an animal being held in rehabilitation will not experience the physiological challenges or adaptations associated with diving to depths of more than 500m; clearly observations made of a sick animal at the surface must be interpreted with caution.

Monitoring and mitigation

Barlow and Gisiner (2006) discussed the effectiveness of current monitoring and mitigation practices and described promising new tools for improving monitoring and mitigation in the near future. Current monitoring often involves a single observer using low-power (7×) binoculars searching for beaked whales and other marine mammals in all sea states during both day and night. Although it has been suggested that monitoring after dark may be aided with recent night-vision technologies, this would require appropriate testing before being considered practical. Barlow and Gisiner (2006) provided a crude estimate that the visual methods currently employed may result in as little as a 1-2% chance of detecting beaked whales (the actual value will vary considerably depending on *inter alia* sea state and experience of observers). The present authors concur that these methods are ineffective in appreciably reducing interactions between beaked whales and potentially hazardous sound sources. Even using current best practices in visual surveys, such as those employed in line-transect abundance surveys with highly experienced observers, the probabilities of detecting beaked whales are 20-50% at best (Barlow and Gisiner, 2006). Passive acoustic sensors have not been used as part of beaked whale noise risk mitigation because little was known about their vocal behaviour. Recent data (Johnson *et al.*, 2004) indicate that passive acoustics may increase the probability of detecting beaked whales when the sensors are deployed at greater than 200m depth. However, any use of passive acoustic sensors at the surface must be tested carefully before being considered appropriate; it is possible beaked whales do not echolocate at shallower depths (Johnson *et al.*, 2004; Zimmer *et al.*, 2005). Other new sensing technologies such as active acoustics and radar have also not yet been tested sufficiently to assess their potential for detecting beaked whales.

Both long- and short-term research projects would help to better assess and mitigate the effects of anthropogenic sound on beaked whales. Important long-term studies include: (1) descriptions of population structure; (2) assessment of distribution and abundance for stocks and species; (3) development and testing of habitat use models; (4) assessment of population trends in local areas (e.g. in Abaco, Bahamas); and (5) systematic collection of information from live stranded and dead beaked whales. These studies would help to better identify sites of known or likely beaked whale occurrence, enable better assessment of the likely effects on individuals and populations from a given sound regime and lead to improved understanding of the clinical signs and pathologies of sound exposure. We also recommend the following short-term strategies: (1) detect and evaluate impacts of anthropogenic sound activities on beaked whales whenever a potential incident that may be a result of sound occurs; (2) conduct surveys for strandings and/or floating carcasses during and after anthropogenic sound activities; (3) determine the probability of detecting a floating carcass; (4) determine whether beaked whales avoid or approach vessels; and (5) incorporate behavioural reactions of beaked whales to anthropogenic sources of sound into monitoring measures.

POTENTIAL MECHANISMS

Although a number of beaked whale stranding events coincided with naval activities and active sonar use (e.g. Simmonds and Lopez-Jurado, 1991; Frantzis, 1998; Anon., 2001; Jepson *et al.*, 2003), the mechanism(s) by which sonar may lead to stranding and sometimes the death of beaked whales is not well understood. Determining such mechanisms is not only of scientific interest, but important in terms of mitigation. If, for example, the primary cause of strandings is a behavioural response in which whales avoid sound by moving into shallow water, then perhaps only those sound producing activities in close proximity to land need to be managed. Similarly, if these events resulted from abnormal acoustic propagation due to unusual environmental conditions (e.g. waveguides – D'Spain *et al.*, 2006), then producers of sound need to monitor environmental conditions prior to introducing sound and mitigate when certain conditions occur. However, the available evidence is not currently sufficient to reach such conclusions.

Several possible mechanistic pathways through which sonar may lead to stranding and/or death of beaked whales are shown in Fig. 1. The first potential pathway entails a behavioural response to sound that leads directly to stranding, such as swimming away from a sound into shallow water. An alternative scenario involves a behavioural response leading to tissue damage. Such responses could include: a change in dive profile; staying at depth longer than normal; or remaining at the surface longer than normal. All of these responses could contribute to gas bubble formation, hypoxia, cardiac arrhythmia, hypertensive haemorrhage or other forms of trauma. Another pathway is through a physiological change such as a vestibular response leading to a behavioural change or stress induced hemorrhagic diathesis leading to tissue damage. Finally, beaked whales might also experience tissue damage directly from sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. Each of these potential mechanisms is described in detail below and at present it is not possible to rule out any of these.

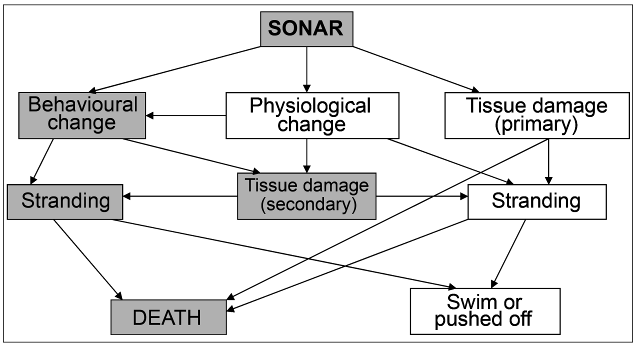

Fig. 1. Potential mechanistic pathways by which beaked whales are affected by sonar. Whereas we are unable to eliminate any pathways as implausible given current data, most of our discussions focus on the left side (shaded boxes) of the diagram. Note that death will not necessarily be the end result of sonar exposure in every case and that behavioural change, physiological change, primary tissue damage, secondary tissue damage, or stranding may occur without leading to death. This figure is intended to outline potential mechanisms of only those exposures which do lead to observed effect.

Behavioural response

Beaked whales may respond to sound by changing their behaviour, which could lead to a stranding event prior to the onset of physical trauma (Fig. 1, left). For example, in areas where deep waters occur in close proximity to shallow waters (e.g. 'canyon areas' of the Bahamas, oceanic islands), beaked whales may swim into shallow waters to avoid certain sounds and could strand if they are unable to navigate back to deeper waters. The end result of stranding may be that animals swim away, are pushed off, or die of hyperthermia or other stress-related causes resulting from the actual stranding. Evidence that some of the stranded beaked whales in the Bahamas succumbed to cardiovascular collapse due to hyperthermia (Anon., 2001) is consistent with this mechanism, although the final pathology report for this stranding event is still pending and the proposed mechanism does not account for some of the trauma observed in that event (e.g. subarachnoid haemorrhage). The array of pathologies (Anon., 2001; Fernandez, 2004) observed in the beaked whales from the Bahamas and Canary Islands mass stranding in 2002 suggest injuries in addition to those typical of the physical effects of stranding itself.

Behavioural response leading to tissue damage

Acoustically induced behavioural responses may lead to tissue damage prior to stranding. Such responses may include altered dive profiles, remaining at the surface for prolonged periods or remaining at depth. Physiological responses could include hypoxia (from longer than normal time at depth or increased energy or oxygen use at a given time) or elevated nitrogen supersaturation of tissues, leading to formation of gas bubbles (from altered dive profiles).

One potential mechanism that deserves particular consideration is an acoustically induced behavioural change (dive response) that leads to formation of significant gas bubbles, which damage multiple organs or interfere with normal physiological function. Such a mechanism would be similar to decompression sickness in human divers and would have two parts: a dive response precipitating adverse gas bubble formation and pathology. Because many species of marine mammals make repetitive and prolonged dives to great depths, it has long been assumed that marine mammals have evolved physiological mechanisms to protect against the effects of rapid and repeated decompressions. To date, two physiological adaptations have been identified that may afford protection against nitrogen gas supersaturation: lung alveolar collapse at depths of 20-70m and 'elective circulation' involving vasoconstriction to the peripheral circulation during diving (Kooyman *et al.*, 1972; Ridgway and Howard, 1979; Zapol *et al.*, 1979; Davis *et al.*, 1983). However, Ridgway and Howard (1979), the only researchers who have assessed nitrogen gas accumulation in a diving cetacean, trained bottlenose dolphins (*Tursiops truncatus*) to dive repeatedly to 100m and found that the muscle of the dolphin was substantially supersaturated with nitrogen gas. From nitrogen washout curves, they estimated that this species experienced lung collapse at approximately 70m of depth, thus making it susceptible to nitrogen gas accumulation when making repetitive dives shallower than 70m. Houser *et al.* (2001) used the data from Ridgway and Howard (1979) to model the accumulation of nitrogen gas within the muscle tissue of other marine mammal species. The model was limited in that it necessarily assumed similar depths of lung collapse for all cetaceans and that exchange of nitrogen gas between tissue compartments ceased below the depth of lung collapse. The model predicted that those cetaceans that dive deep and have slow ascent/descent speeds would have tissues that are more supersaturated with nitrogen gas than other marine mammals. While the predictions for beaked whales were in excess of 300% supersaturation at the surface, this should be viewed cautiously because of the limitations of the model used and the problems of using extrapolations from other species.

Dive profiles of three species (Cuvier's and Blainville's beaked whales and bottlenosed whales, *Hyperoodon ampullatus*; Hooker and Baird, 1999; P. Tyack, unpub. data) suggest that at least some species of beaked whales have dive profiles not previously observed in other marine mammals. These led to the suggestion that some beaked whales may chronically accumulate nitrogen in a manner not dissimilar to human 'saturation divers'. The critical components of this dive sequence include: (1) very deep and long foraging dives (to as deep as 2km and lasting as long as 90mins); (2) relatively slow, controlled ascents, followed by (3) a series of 'bounce' dives to between 100-400m depth (Hooker and Baird, 1999; P. Tyack, unpub. data). Thus, if any part of this dive sequence was affected by a behavioural response to sound (e.g. extended time at surface without the requisite bounce dives), it could induce excessive levels of nitrogen supersaturation in tissues, driving gas bubble and emboli formation in a manner similar to decompression sickness in humans.

It is clear that long-term studies on the behaviour of beaked whales to better define a baseline of 'normal' behaviour are needed. Obtaining baseline dive profiles via several methods over extended periods (e.g. D-tags, time-depth recorders) is especially important. We unanimously agree that highest priority should be given to designing controlled-exposure experiments to investigate the responses of beaked whales to anthropogenic sounds. Nowacek *et al.* (2004) conducted a controlled exposure experiment in northern right whales (*Eubalaena glacialis*) responding to a novel alerting stimulus. This study demonstrated that whales responded to stimuli at received sound levels as low as 133dB (re: 1μPa), with an immediate ascent followed by an extended surfacing interval. It was hypothesised that abnormal changes in dive behaviour in beaked whales could precipitate pathologic bubble formation in tissues. By applying innovative technology, researchers can further investigate behavioural responses and begin to examine physiological responses to sound. Designing exposure studies that are acceptable from both a scientific and animal welfare perspective is difficult. We recommend that the best way to design such experiments is through a workshop of appropriate experts.

Determining whether beaked whales are susceptible to developing gas bubbles due to changes in behaviour or physiological condition may prove to be even more difficult. To date, while there is no evidence of *in vivo* bubble formation in any marine mammals (but see Jepson *et al.*, 2003; 2005; Fernandez *et al.*, 2004), it is also true that no studies have been conducted to specifically look for the formation of intravascular bubbles during or following repetitive diving. Although it is possible to conduct such studies with shallow diving species such as bottlenose dolphins, until such work is conducted with deep-diving species such as beaked whales, it will not be possible to gain an insight into this possibility. As noted above, marine mammals have long been thought to have evolved anatomical, physiological and possibly behavioural adaptations to their marine environment to mitigate the risk of bubble formation (e.g. Harrison and Tomlinson, 1956; Ridgway and Howard, 1979; 1982; Falke *et al.*, 1985; Ponganis *et al.*, 2003). Despite these adaptations, recent theoretical and pathological evidence suggests that cetaceans can produce *in vivo* bubbles or experience tissue injury as a result (Jepson *et al.*, 2003; 2005; Fernandez *et al.*, 2004; 2005). These data and interpretations are the subject of continuing scientific debate (Fernandez *et al.*, 2004; Piantadosi and Thalmann, 2004).

Modelling predictions (Houser *et al.*, 2001) support the hypothesis that beaked whale tissues could be greater than 300% saturated with nitrogen. *Post mortem* evidence of acute and chronic gas emboli-associated lesions in liver, kidney, spleen, and lymph nodes of eight dolphins, one harbour porpoise (*Phocoena phocoena*) and one Blainville's beaked whale that stranded in the United Kingdom (Jepson *et al.*, 2003; 2005) also support this hypothesis. In addition, gas and fat emboli and widely disseminated microvascular haemorrhages were found in ten beaked whales examined in the Canary Islands mass strandings event in September 2002 (Jepson *et al.*, 2003; Fernandez *et al.*, 2004; 2005). In humans and experimental animals, such gas and fat emboli released into the venous system and deposited in the pulmonary capillary beds may travel through arterio-venous shunts into the systemic circulation. Prior to, or concomitant with this, respiratory and cardiovascular dysfunctions may occur with a biphasic response at the brain-spinal cord level, an initial, venous embolic obstruction and vasoconstriction, followed by secondary vasodilatation and prolonged (reactive) hyperaemia (Shigeno *et al.*, 1982). This haemodynamic process may explain the widespread cerebral congestion and edema, with spongiosis, intracranial perivascular haemorrhages and subarachnoid and intraventricular haemorrhages described in the beaked whale mass strandings.

A number of areas of research are required to further investigate whether beaked whales are susceptible to gas bubble formation, either as a function of altered behaviour or as the direct impact of sound on existing bubble nuclei. It is important that detailed necropsies are conducted of all freshly dead beaked whales, especially those whose deaths are correlated in both space and time with sound events. These necropsies should be conducted under laboratory procedures with rigorous protocols, e.g. opening the braincase underwater before the head is separated from the body or tying off primary vessels prior to removal, so as to avoid introducing bubbles during the necropsy. A standardised protocol for beaked whale necropsies is being developed to address these needs.

Experimental studies are needed to determine whether marine mammals can develop *in vivo* gas bubbles due to alterations in their dive profiles and to document precise levels of nitrogen supersaturation necessary to invoke such bubble formation. Specifically, ascertaining the onset of lung collapse and its impact on nitrogen gas kinetics is critical to determining what physiological effects any changes in dive profile might have on tissues. In the absence of live beaked whales for such studies, comparative studies could be conducted using marine mammals that are accessible and trainable. Physiological effects in shallow diving cetaceans and deep divers should be compared cautiously as deep divers will experience different physiological demands from environmental conditions at 1-2km and will likely have different adaptations and responses to those conditions. The depth at which lung collapse occurs is key to any modelling of nitrogen supersaturation because lung collapse prevents gas exchange and nitrogen absorption by the blood. The depth at which the lung collapses might be estimated using bottlenose dolphins with arterial blood sampling and blood nitrogen analyses. These results could then be compared to *post mortem* determination of lung collapse by compression testing of the lungs of a bottlenose dolphin carcass. Comparable results would support the use of *post mortem* testing of beaked whale lungs to determine the depth at which lung collapse occurs in those species. To test the hypothesised scenario that adverse gas bubble formation may result from a change in dive behaviour, it will be necessary to determine whether beaked whale tissues supersaturate with nitrogen and if so, to combine that information with dive profiles and potential changes in dive profiles. The scenario of gas bubble formation secondary to a behavioural response is plausible and merits rigorous investigation.

Physiological change

Haemorrhagic diathesis

The Bahamas beaked whale report listed twelve possible causes for the lesions observed and one proposed mechanism was haemorrhagic diathesis (Anon., 2001; 2002). Haemorrhagic diathesis is a tendency to bleed that results from one or more of several conditions, including: (1) depletion of clotting factors (disseminated intravascular coagulation (DIC); (2) a hereditary deficiency in one or more of a suite of blood clotting factors; or (3) platelet dysfunction or thrombocytopenia. Humans with the hereditary deficiency develop haemorrhages in regions similar to those of the beaked whales (i.e. subarachnoid spaces and the inner ear; Palva *et al.*, 1979) and hypertension increases the likelihood of such patients suffering intracranial bleeds (Hart *et al.*, 1995). If beaked whales are subject to haemorrhagic diathesis, stress caused by exposure to sound may cause them to haemorrhage. Similar haemorrhages in human patients can cause headache, nausea and vomiting, confusion, ataxia, dizziness, loss of consciousness and even death (Hart *et al.*, 1995). By analogy, intracranial haemorrhages observed in beaked whales may have resulted in disorientation, a subsequent inability to navigate and eventual stranding (Anon., 2001).

While nothing is known currently about clotting abilities or DIC in beaked whales, a lack of clotting factors has been noted in some cetacean and pinniped species, which may be related to diving adaptations. Northern elephant seals (*Mirounga angustirostris*) have platelets that are less prone to triggering clotting at high pressure, such as at depth (Field *et al.*, 2001) and they are prone to DIC (Gulland *et al.*, 1996). Lack of certain clotting factors, specifically Hageman's factor, Fletcher factor activity and Factor IX, are common to all of the limited number of cetacean species studied to date (Lewis *et al.*, 1969; Robinson, A.J. *et al.*, 1969; Saito *et al.*, 1976). If all cetaceans lack multiple clotting factors, it is not clear why beaked whales exposed to sonar might be more susceptible to the effects of haemorrhage than other species. However, the fact that few other species stranded simultaneously in cases involving sonar may in part be a reflection of differences amongst species' perceptions of an event as stressful, fundamental susceptibilities to stress, or differences in subsequent responses to the event. Future studies are needed on the haematology and physiology of coagulation in beaked whales to determine whether they are predisposed to haemorrhaging. In addition, future studies should investigate differences in behavioural responses of beaked whales to stressful stimuli.

Vestibular response

Marine mammals could become disoriented due to a vestibular response to sounds. Tullio's phenomenon, or dizziness induced by sound, has long been known of in humans (Tullio, 1929). The peripheral vestibular system of beaked whales may be affected by sound, affecting their ability to navigate. Beaked whales, which are usually found in deep waters, might, if disoriented, move into shallow waters and be unable to navigate back to deeper waters. However, Balcomb and Claridge (2001) observed that when pushed towards deep water, several animals swam away without the characteristic rolling or turning movements typical of animals with vestibular pathology. Furthermore, disorientation can result from a number of phenomena, making it difficult to detect and attribute a vestibular response to sound exposure in the presence of other potentially contributing factors.

Primary tissue damage leading to behavioural response

Sound may damage tissue directly through acoustically mediated bubble growth or tissue shear. A scientific workshop organised by the US NOAA/National Marine Fisheries Service was held in 2002 to consider the potential for resonant effects of sound to induce tissue injury in cetaceans (Anon., 2002). Modelling of acoustic resonance in lungs of cetaceans and comparative data from other animal systems (e.g. humans, dogs, pigs) suggested that only minimal tissue injury is likely to result from such a mechanism because tissue displacements are minute (Anon., 2002). The only exception is the large excursions of tissue that could occur where two dramatically mismatched tissue boundaries intersect in which there was minimal damping by associated tissues. Discussions also occurred on the possibility of a mechanism of sonar-related tissue injury in cetaceans from acoustically mediated bubble growth, particularly in tissues supersaturated with nitrogen, as may occur towards the end of a dive (Anon., 2002). This concept was primarily based on the work of Crum and Mao (1996) and Houser *et al.* (2001). Crum and Mao (1996) modelled the likelihood of acoustically driven bubble growth in humans and marine mammals by the process of rectified diffusion. The model assumed modest levels of nitrogen tissue (super)saturation and predicted that relatively high sound pressure levels (>210dB re:1μPa) would be necessary to induce significant bubble formation in human divers or marine mammals at 300-500Hz. Houser *et al.* (2001) estimated that levels of nitrogen supersaturation in some tissues of some deep-diving species, such as the northern bottlenose whale, could exceed 300% near the surface, raising the possibility that acoustically mediated bubble formation might occur at received sound pressures and sound durations lower than those predicted by Crum and Mao (1996). The workshop therefore recommended that the Crum and Mao model (1996) be used to estimate the threshold sound pressure levels for the higher levels of nitrogen tissue supersaturation predicted to occur from typical beaked whale dive profiles (Anon., 2002).

Isolated porcine liver tissue, polyacrylamide gels and human blood that have been compressed 4-7 atmospheres for 1-3hrs and then decompressed to ambient show extensive bubble development when exposed to high intensity (230dB SPL re:1μPa) ultrasound of 37kHz (Crum *et al.*, 2005). The authors postulated that the underlying mechanism might be destabilisation of pre-existing bubble nuclei by the ultrasound exposure, resulting in bubble growth by static diffusion in supersaturated tissue. Although these experiments demonstrated a possible mechanism by which bubble growth might occur, it did so under conditions that are different from those to which beaked whales may have been exposed during the stranding events. Thus, it is premature to judge acoustically mediated bubble growth as a potential mechanism and we recommend further studies to investigate this possibility. Further exposure studies should be conducted on marine mammal tissues by saturating them, exposing them with frequencies and amplitudes of interest and testing for minimum levels that could result in tissue damage.

Acoustic resonance

Anon. (2002) also considered the possibility that beaked whales are susceptible to effects of acoustic resonance (see discussion above). Most participants agreed that the best available models indicated that acoustic resonance is highly unlikely in the lungs of beaked whales, but recommended further studies to fully eliminate this hypothesised mechanism. They did not evaluate the possibility of resonance in other organs or structures and therefore recommended further modelling to determine if those would be susceptible to resonance. Given the full discussion in Anon. (2002), this mechanism is not discussed in depth here. The authors do, however, endorse the three areas of study recommended in Anon. (2002): (1) the possibility of resonance in the lung throughout the dive profile of beaked whales; (2) the potential for other organs or structures to be affected by acoustic resonance (either through modelling or empirical observation); and (3) the possibility that animals experience tissue shear (and determine how such injuries might appear).

Primary tissue damage leads to death

Some of the above mechanisms (i.e. gas bubble disease, haemorrhagic diathesis, acoustic resonance) could lead to lethal tissue damage. For example, the intracranial haemorrhage seen in the Bahamas and Canary Islands animals could have been caused by a stress response and associated haemorrhagic diathesis or bubble formation rupturing local capillaries. Although some of the stranded beaked whales were found dead, it is not clear whether these animals were alive when they first stranded. Several animals in all the events stranded alive and some either swam away or were pushed offshore. Even though their eventual fate is unknown, they did not die immediately. Determining whether sound exposure causes tissue damage that leads directly to death will be difficult and likely will require a process of elimination regarding other possible mechanisms. Testing the hypothesis that death results directly from sound-related tissue damage will be facilitated greatly by access to freshly stranded specimens that have been exposed to sound.

EDUCATION AND COORDINATION

As discussed below, education, communication and co-ordination will all facilitate the investigation of the effects of sound on beaked whales and mitigation measures to avoid adverse effects.

Education

Greater public outreach and education can be achieved through: (1) improved communication with environmental non-governmental organisations; (2) established links among scientists, the public and local and state policymakers; and (3) increased dissemination of stranding response information to the general public.

Co-ordination and communication

Improved co-ordination and communication is required among: (1) stranding responders to develop an international standardised protocol for necropsy; (2) sound producers, stranding responders and researchers to facilitate planning and preparation prior to sound exposure events and to monitor animal behaviour opportunistically; (3) sound producers and researchers to conduct retrospective analyses; (4) stranding responders to provide comprehensive databases to the public; (5) scientists and museums to obtain genetic samples from museum collections to evaluate population structure; and (6) terrestrial mammal and marine mammal physiologists to increase understanding of beaked whale physiology. Interaction across scientific disciplines (e.g. human dive physiology, terrestrial mammalogy, marine mammal behaviour, etc.) is critical to an improved understanding of this problem and broad research co-ordination and co-operation are needed.

CONCLUSIONS

Monitoring and mitigation

Current visual survey efforts to detect beaked whales in areas of acoustic activity are probably ineffective as a mitigation aid. Key limiting factors include sea state, amount of daylight, experience of observers and the diving and surfacing behaviour of beaked whales, which makes them either difficult to see or unavailable for visual observation at the surface for long periods of time. For the same reasons, surveys to determine distribution and abundance are also difficult and limited in their reliability. However, additional sensing technologies, such as passive acoustics, active sonar and radar, are currently in development that may increase scientists' abilities to detect beaked whales. Improved baseline data on distribution, abundance and habitat preferences of beaked whales are needed, in addition to increased effort in detection and recovery of dead and injured animals for improved understanding of the effects of anthropogenic sound.

Research

Although no potential mechanisms can be eliminated at this stage, we highlight gas bubble formation mediated through a behavioural response as plausible and in need of intensive study. Intensive research is needed to eliminate or confirm this hypotheses. The following four research priorities will provide better insights into its possible role.

(1) Controlled exposure experiments should be the top research priority. These experiments are critical for investigating beaked whale responses to sound. A multi-disciplinary workshop is needed to co-ordinate and design these experiments.
(2) There is an urgent need for studies of anatomy, physiology and pathology of beaked whales, particularly in situations where there is a known cause of death (e.g. bycatch). A comprehensive, standardised necropsy protocol is needed to make the best possible use of animals that become available through stranding or fisheries interactions.
(3) Baseline descriptions of diving behaviour and physiology of beaked whales are required to be able to better evaluate the potential for beaked whales to experience gas bubble disease from changes in dive behaviour.
(4) Finally, a retrospective review of all stranding records is necessary, as well as new studies in areas beaked whales are concentrated and exposed to anthropogenic sounds. To the greatest extent possible, retrospective analyses should: (1) describe and compare pathologies from all stranding events; (2) model the received sound level at sites where sound-related stranding occurred; (3) document all anthropogenic sound sources during stranding events; (4) assess population level effects in areas where sufficient data are available (e.g. the Bahamas); (5) evaluate distribution of all strandings relative to surrounding oceanographic/topographic features and possibly-related anthropogenic sound activities; and (6) identify areas where beaked whales are present and naval exercises have occurred, but strandings have not been documented and compare those situations with documented stranding events.

Reviews should not interpret lack of strandings as sufficient evidence of no effect, because animals that die offshore may not wash ashore, animals that strand may not remain on the beach for more than one tidal cycle (Taylor *et al.*, 2004) and observation effort can vary markedly by location. Furthermore, whether or not strandings occur, activities involving anthropogenic sounds that may affect beaked whales should be documented to identify common features of habitat, species present or involved and acoustic properties to facilitate management and mitigation of such activities.

Understanding and evaluating potential mechanisms will aid managers in knowing when, where and how to best mitigate interactions between anthropogenic sound and beaked whales. The interdisciplinary approach of the workshop greatly facilitated exchanges of knowledge among scientists of disparate disciplines. The importance of interdisciplinary co-ordination and communication in solving this environmental problem cannot be overemphasised.

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