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.

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:

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[1] Public Law 108-7
[2] 68 *Federal Register* 203 (21 October 2003)
[3] 68 *Federal Register* 238 (11 December 2003)

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 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

[4] Full charter available at http://www.mmc.gov/sound/committee/committee.html.

> 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.

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

- 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

- 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

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

- 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

Subcommittee on Synthesis of Current Knowledge

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

Submitted by Committee Member:

Kenneth C. Balcomb, III

Submission Date: 1 February 2006

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
1 February 2006

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

RDML Mark Boensel, Chief of Naval Operations, Environmental Readiness (N45), U.S. Navy

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

Robert LaBelle, Deputy Associate Director, Offshore Minerals Management, Minerals Management Service (MMS)

Michael Reeve, Ph.D., Head, Integrative Programs Section, Ocean Sciences Division, National Science Foundation

Charles Schoennagel, Deputy Regional Director, Gulf of Mexico Region, MMS

V. Frank Stone, Ph.D., Marine Resources Program Manager, Chief of Naval Operations, Environmental Readiness (N45), U.S. Navy

Frederick Sutter III, Deputy Regional Administrator, Southeast Region, National Marine Fisheries Service (NMFS)

RADM Steven Tomaszeski, Oceanographer of Navy, U.S. Navy

Donna Wieting, Deputy Director, Office of Protected Resources, NMFS

James Yoder, Ph.D., Director Ocean Sciences Division, National Science Foundation

Alternate Committee Members

David Bernhart, Assistant Regional Administrator Protected Resources, Southeast Region, NMFS
Diane Bowen, Marine Mammal Coordinator, U.S. Fish and Wildlife Service
James Kendall, PhD., Chief, Environmental Sciences, MMS
William Lang, Ph.D., Environmental Scientist, Gulf of Mexico Region Office, MMS
Steve Leathery, Permits Division Chief, Office of Protected Resources NMFS
RADM Tim McGee, Chief of Naval Operations, Naval Meteorology and Oceanography Command
Alexander Shor, Ph.D., Program Director, Ocean Sciences Division, National Science Foundation
Judy Wilson, Chief, Environmental Compliance Unit, MMS

Submission Date: 27 January 2006

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.

Federal Subcommittee Members

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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.
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.

[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.

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.

1. Sound Sources

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 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

[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).

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.

[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.

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.

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.
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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International Fund for Animal Welfare (IFAW)
Natural Resources Defense Council (NRDC)
Ocean Mammal Institute (OMI)
Whale and Dolphin Conservation Society (WDCS)

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.

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

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

that are more precise than ± 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).

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).

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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.

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 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

[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.

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]

Extent of the problem. 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.

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

[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.

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).

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

[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.

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]

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.

[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.

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
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)	

Year	Location	Species (numbers) [Zc= Cuvier's, Me= Gervais', Md=Blainville's beaked whales]	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), 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.

Cautionary notes on behavioral impacts and stress. 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.

Impacts of Noise on Other Marine Life

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.

Fish and catch rates. 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).

Invertebrates. 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.

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

[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).

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.

- 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.

[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).

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

[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.

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 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]

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[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).
[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.

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 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.

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

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.

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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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

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Mr. David Cottingham
Executive Director
Marine Mammal Commission
4340 East-West Highway
Room 905
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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

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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" [i] 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

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

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.

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)	

Year	Location	Species (numbers)	Associated activity, when available
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)	
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.[ii] 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.

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

[ii] 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 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.[iii] 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 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

iii ** 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.

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.

Notes

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