Acoustic Deterrence of Harmful Marine Mammal-Fishery Interactions:

Proceedings of a Workshop held in Seattle, Washington, 20-22 March 1996

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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At the request of the National Marine Fisheries Service, the Marine Mammal Commission convened an international workshop in Seattle, Washington, to examine issues related to the use of accoustic deterrent devices in fisheries. This workshop report was submitted by the Marine Mammal Commission to the National Marine Fisheries Service in partial fulfillment of Purchase Order NA95AANFG0624.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

A workshop was held in Seattle, Washington, 20-22 March 1996, to consider problems and uncertainties related to the use of acoustic deterrents in the conservation and management of marine mammals. Acoustic deterrent devices have been used to help solve two distinct types of fishery-marine mammal conflict: (1) bycatch of marine mammals in fishing gear, and (2) depredation by marine mammals on fish caught in fishing gear, confined in aquaculture enclosures, or aggregated or constrained at "choke points" in river systems. Acoustic alarms (mainly small, low-intensity sound-generators called "pingers") have been developed for "alerting" marine mammals to the presence of fishing gear, with the goal of reducing bycatch rates. High-intensity acoustic "harassment" devices (AHDs) have been used widely to reduce depredation on fish, especially by pinnipeds.

The workshop's main objectives were to: (a) evaluate experimental and other evidence concerning the efficacy of acoustic deterrents in preventing or reducing interactions between marine mammals and fisheries, including aquaculture operation; (b) identify critical uncertainties about the effectiveness of acoustic deterrent devices and their effects on marine mammals and other biota; (c) identify and establish priorities for relevant research; and (d) develop guidelines for when, how, and under what conditions acoustic deterrents should be incorporated into management. Workshop participants included representatives of the fishing industry, environmental groups, and manufacturers of acoustic deterrent devices, staff members from government agencies in the United States, Canada, and Australia, and scientists from seven countries and 21 institutions. Participants broke into working groups with specific terms of reference, and the reports of the working groups are included as part of the overall workshop report.

Bycatch Issues

The results of a controlled experiment with pingers in the Gulf of Maine sink gillnet fishery in 1994 were the focus of the bycatch discussions. In this experiment, nets with active pingers caught significantly fewer harbor porpoises than control nets. It was generally agreed that pinger use offers a promising means of reducing the bycatch of harbor porpoises in this type of fishery. The results of another experiment off Washington and an experimental fishery in the Gulf of Maine in 1995 were consistent with those of the 1994 Gulf of Maine study. There was a strong consensus that pinger use should be incorporated immediately into the management regime for the Gulf of Maine sink gillnet fishery. It was expected that full-scale pinger deployment could achieve a sufficient reduction in the harbor porpoise bycatch to meet the requirements of the 1994 amendments to the Marine Mammal Protection Act (MMPA). However, higher than anticipated numbers of harbor porpoises were caught in experimental fisheries in Massachusetts Bay and on Jeffreys Ledge in spring 1996, following the workshop. Thus, the expectation may not be valid. If pingers are not efficacious, the only other apparent means of meeting the requirements would involve large-scale, time-area fishery closures in the Gulf of Maine.

Although pingers are already being used extensively by fishermen outside the Gulf of Maine on an *ad hoc* basis, there is much uncertainty about their long-term efficacy and about their efficacy in fisheries that involve marine mammal species other than the harbor porpoise.

Participants strongly urged against regarding the pinger as a panacea for reducing bycatch. They pointed out that, in the Gulf of California (Mexico) where the critically endangered vaquita is threatened by fishery bycatch, the introduction of pingers as a substitute for fishery closures would be ill-advised (and possibly disastrous). For the present, the only situations where pingers can reasonably be expected to significantly reduce bycatch are fixed gillnet fisheries in which the harbor porpoise is the main species of concern.

It is uncertain how long-lasting the efficacy of pingers will prove to be in a given fishery. Will the target animals (e.g., harbor porpoises) become less responsive to the alarm effect of the pingers over time? It also is uncertain how pingers may affect non-target species. While the potential benefits of a pinger program seem fairly clear -- reduced harbor porpoise mortality, continuation of the fishery -- the environmental costs are less clear. Until the uncertainties are resolved, both the bycatch and the status of the affected marine mammal populations should be closely monitored.

The workshop concluded that this is an appropriate time for carefully designed pinger experiments in the drift gillnet fisheries for swordfish and other pelagic species off California and New England. These fisheries differ in many ways from sink gillnet fisheries and involve bycatch of a greater variety of marine mammal species (including some that are endangered or threatened). The experimental design should include: use of the currently standard pinger, placed and deployed according to the particular conditions in these fisheries; randomization of active and dummy pingers between sets from the same vessel; power analysis, in advance, to determine necessary sample sizes and observer coverage; and single-blind controls, with only the on-board observers knowing whether the pingers on a given set are active or not.

The workshop also concluded that pinger experiments in coastal gillnet fisheries along the U.S. east coast south of the Gulf of Maine would be premature at present. Substantially more information is needed about fishery characteristics and bycatch before scientifically rigorous experiments can be designed.

The use of acoustic devices to reduce baleen whale mortality in fishing gear (particularly humpback whales in Newfoundland cod traps) was not discussed in detail. Available information indicates that entanglement and mortality have been substantially reduced due to a combination of factors, including the routine use of acoustic devices by fishermen. The workshop concluded that there were no critical uncertainties requiring priority attention in this regard.

Depredation Issues

Although the MMPA originally allowed fishermen and fish farmers to use lethal force against predators to protect their catch, gear, and stock, they are no longer allowed to do so under the 1994 amendments to the Act. Thus, the pressure to develop non-lethal deterrent methods has increased. As wild fish stocks decline, and aquaculture enterprises and pinniped populations increase, the conflicts are bound to become more numerous and more intense.

Since the early 1980s, AHDs have been used throughout the aquaculture industry in North America to combat depredation by otariids (California and Steller sea lions, west coast only) and phocids (harbor seals, both coasts; gray seals, east coast only). They have also been used in some fisheries to keep pinnipeds away from caught fish and from natural or artificial aggregations of fish. Workshop discussion centered on two aspects of the use of AHDs: (1) whether it achieves the desired result, and (2) the degree to which it may negatively affect marine mammals, including ones that are not involved in the depredation, and other biota.

AHDs used during the 1980s and early 1990s typically had the desired effect of keeping pinnipeds away from the protected sites, but only for a relatively short time. After several weeks of effective deterrence, the pinnipeds would become less responsive to the AHDs. In fact, the acoustic signal of an AHD often was interpreted as having a "dinner bell" effect, alerting predators to the presence of a fish pen, trap, or net. It then became necessary to alter the signal (which usually meant increasing the output), move the transducers, or resort to other means of deterrence., including shooting the animals. New, very high-intensity AHDs (e.g., a device now being marketed by Airmar Technology Corporation transmits a signal of 10 kHz at an average output of 194 dB re 1μPa at 1 m) are reported to have remained effective for at least two years. (Reference to brand names or companies is not intended to be a product endorsement.)

Pinnipeds are difficult to deter by acoustic means. They tend to accommodate reasonably quickly to loud noise, which may be explained either by threshold shifts in hearing or by "habituation," perhaps both. The new high-intensity AHDs have greater potential for causing hearing damage and for affecting non-target species. They therefore should be used cautiously until their effectiveness and potential side-effects are determined.

A problem involving depredation by killer whales on longline catches of sablefish (black cod) in Prince William Sound and the Bering Sea was also discussed briefly. It was suggested that changes in fishery practices and gear modifications were more likely than the use of AHDs to resolve this conflict.

General Issues

Workshop participants concluded that there was reasonable evidence that pingers significantly reduce the bycatch of harbor porpoises in gillnets and that AHDs, when properly deployed and of sufficient power output at appropriate frequencies, may be effective in reducing levels of pinniped depredation on fish. Also, it was recognized that pingers, possibly in combination with acoustic reflectors of some kind, may prove useful in reducing bycatch of other marine mammal species in other types of fisheries. Participants repeatedly emphasized, however, that artificial sound should be introduced into the underwater environment only when the costs and benefits of doing so are clearly understood and only after the potential ecological consequences have been carefully considered. The state of knowledge about marine mammal hearing abilities and behavior in response to various types of sound is limited. It is therefore extremely difficult to evaluate either the long-term effectiveness or the side-effects of any acoustic deterrent device. Much more research and monitoring is required before such evaluations can be made with a high degree of confidence. A number of suggestions were made regarding the potential future use of acoustic deterrent devices.

To meet the intent and provisions of the MMPA, without at the same time causing severe economic distress in fishing communities, approaches to management should be both inclusive and adaptive. Much of the responsibility for developing and implementing solutions to the problems of marine mammal-fishery interactions resides with the fishing and aquaculture industries themselves. Thus, fishermen and fish farmers need to be included in the planning and conduct of research, the interpretation of results of field experiments, and the development of management measures. Moreover, management regimes need to be adaptive in nature. In other words, regulatory measures need to be updated routinely to incorporate new knowledge and new technologies. Long-term monitoring is an essential element of adaptive management. Innovation should be supported and encouraged, and rigorous testing should be required before new technologies are deployed as part of fishery and marine mammal management programs.

INTRODUCTION

1.0 Bycatch of marine mammals in fishing gear occurs throughout the world (Northridge 1984; Perrin et al. 1994). In some instances, bycatch of marine mammals in fisheries is causing or contributing to population declines and preventing the recovery of depleted stocks.

1.1 Much public attention has focused on the bycatch of dolphins in tuna purse seines, humpback whales in cod traps, and various species in set and drift gillnets. Many other kinds of fishing gear and methods also have marine mammal bycatch.

1.2 Often, marine mammals may be caught purely by accident because their swimming path intersects a net or trap in the water. In such cases, bycatch might be avoided if the marine mammals could be made aware of the gear's presence. Marine mammals are also sometimes attracted to fishing gear because of opportunities to remove bait or caught fish from it. They may have learned to associate fishing vessels or gear with food. In these cases, bycatch might be prevented by changing the acoustic signals produced by the gear and fishing operations, by fishing when marine mammals are not present in the area, or by deterring them, somehow, from approaching the gear.

1.3 Another concern, quite apart from the effects of bycatch on marine mammal populations, is how to protect valued fishery and aquaculture resources from the depredations by marine mammals. Pinnipeds, in particular, frequently remove caught fish from nets, hooks, or traps and attack fish that are being raised in pens. The damage often extends to gear as well (e.g., torn nets and lines). Some pinnipeds converge on areas where anadromous fish stocks aggregate or where the movements of fish are naturally or artificially constrained (e.g., below falls or fish ladders). In such situations, the pinnipeds' competitive interactions with fishery operations and their impacts on recovery, enhancement, or restocking efforts are highly visible. In some areas and circumstances, odontocete cetaceans remove bait or catch from fishing gear.

1.4 Because many marine mammals use sound to communicate, sense their surroundings, and locate and capture prey, scientists and fishermen have sought to develop acoustic methods to prevent or reduce harmful marine mammal-fishery interactions. The main approaches have involved (a) broadcasts of killer whale vocalizations; (b) alteration of the acoustic reflectivity of gear to make it more detectable by marine mammals; (c) attachment of mechanical or electronic noise-makers to gear so that marine mammals will be alerted to its presence; and (d) placement of high-energy sound sources on or near fishing gear and aquaculture facilities to cause approaching marine mammals to experience pain or discomfort (Jefferson and Curry 1994). Unfortunately, none of the studies to date has provided unequivocal evidence that a particular sound generator or reflector will both (a) prevent or significantly reduce incidental takes of marine mammals in commercial fisheries and (b) have no associated adverse effects on fish catches, the "targeted" marine mammals, or other biota. Likewise, studies using natural sounds and high-energy sound generators have failed to produce unequivocal evidence that they both (a) prevent or significantly reduce marine mammal depredation on caught or penned fish and (b) have no associated adverse effects on fish catches, penned fish, the "targeted" marine mammals, or other biota.

1.5 In the United States, the National Marine Fisheries Service (NMFS) has lead-agency responsibility for assessing and, when necessary, preventing or mitigating the adverse effects of marine mammal-fishery interactions. Since the early 1990s, the NMFS has received requests from scientists, fishermen, and fishery groups for financial support and authorization to test or use acoustic deterrent devices to prevent or reduce the adverse effects of interactions. The NMFS has had difficulty responding to these requests, in part because of uncertainties about the design and results of previous studies and in part because not enough is known about the behavior and hearing abilities of the marine mammals. Therefore, in 1995 the NMFS asked the Marine Mammal Commission (MMC) to organize and convene a workshop on acoustic deterrence. The information gathered at the workshop was to be used in the development of a national policy on the use of acoustic deterrents. It was also expected that the workshop would identify actions necessary to resolve critical uncertainties about the effectiveness of various devices and about their effects on target and non-target species.

1.6 Although the conveners and participants were well aware of the geographically broad relevance of the issues, the focus of the workshop was on problems in the United States. Thus, this report, while it will be of interest to many individuals and agencies, is aimed primarily at people within the NMFS who have responsibilities for implementing the Marine Mammal Protection Act and the Endangered Species Act. A sense of urgency has arisen from the 1994 amendment to the MMPA requiring that, for "strategic stocks" (see Appendix 1), fishery-caused mortality be reduced to less than the calculated potential biological removal level (PBR level; see Appendix 1).

1.7 The discussions at the workshop highlighted the need to define terminology as unambiguously as possible. A glossary of terms is provided as Appendix 1 of this report. Scientific names of species mentioned in the report are given in Appendix 2.

WORKSHOP ORGANIZATION AND ARRANGEMENTS

2.0 The workshop was held on 20-22 March 1996 at the Battelle Conference Center in Seattle, Washington. It was organized and chaired by R.J. Hofman and G.K. Silber of the

MMC and D. Wilkinson of the NMFS's Office of Protected Resources. Participants, listed in Appendix 3, included representatives of the fishing industry, environmental community, and manufacturers of acoustic deterrent devices, scientists with relevant expertise from seven countries and 21 academic and private institutions, and staff members of governmental agencies in the United States, Canada, and Australia. R.R. Reeves of Okapi Wildlife Associates, Hudson, Quebec, was contracted by the Commission to edit and draft portions of the workshop report. Funding for the workshop was provided by the NMFS.

2.1 Background documents sent to participants before the workshop are listed in Appendix 4. The workshop agenda is provided as Appendix 5.

WORKSHOP OBJECTIVES AND PROCEDURES

3.0 The objectives of the workshop were to:

1. evaluate the design and results of (a) studies done to determine the efficacy of acoustic deterrents in reducing interactions between marine mammals and fishery or aquaculture operations; and (b) studies of how marine mammals respond to, and are affected by, different types and levels of sound;

2. identify critical uncertainties about the effectiveness and effects of acoustic deterrents;

3. describe research and monitoring programs needed to resolve the uncertainties, and estimate the time, funding, special equipment, and logistic support required;

4. rank the identified research and monitoring programs according to the likelihood that they would contribute to the development of effective, non-harmful ways of mitigating marine mammal-fishery interactions; and

5. use available knowledge to suggest when, how, and under what conditions acoustic deterrents should be incorporated into marine mammal, fishery or aquaculture management regimes.

3.1 To help meet objectives 1 and 2, the MMC contracted with experts to prepare and present background papers on particular subjects. These were:

1. an overview of hypotheses concerning the causes of, and possible means for preventing or reducing, harmful marine mammal-fishery interactions -- Thomas A. Jefferson, Ocean Park Conservation Foundation, Aberdeen, Hong Kong;

2. an overview of what is known about the hearing capabilities of small cetaceans and how these animals use and respond to different types of sound -- Whitlow W.L. Au and Paul E. Nachtigall, Hawaii Institute of Marine Biology, University of Hawaii;

3. an overview of what is known about the hearing capabilities of pinnipeds and how these animals use and respond to different types of sound -- Ronald J. Schusterman, Long Marine Laboratory, University of California, Santa Cruz, California;

4. a review of research done to assess the possible use of sound reflectors and generators to prevent or reduce entanglement of large cetaceans in fishing gear -- Jon Lien, Whale Research Group, Memorial University of Newfoundland, St. John's, Newfoundland;

5. a review of research done to assess the possible use of sound reflectors and generators to prevent or reduce entanglement of small cetaceans in fishing gear -- Stephen Dawson, University of Otago, Dunedin, New Zealand;

6. a review of research done to assess the possible use of sound to prevent or reduce pinniped depredation on caught fish, fish returning to hatcheries or spawning grounds, and fish being raised in aquaculture facilities -- Peter D. Shaughnessy, CSIRO Division of Wildlife and Ecology, Canberra, Australia;

7. a review of efforts by fishermen and researchers to use sound to prevent or reduce depredation by killer whales and other cetaceans on fish caught on longlines -- Craig O. Matkin, North Gulf Oceanic Society, Homer, Alaska; and

8. a review of available information concerning the possible effects of acoustic deterrents on marine mammals and other biota -- Bernd Würsig, Texas A&M University, Galveston, Texas. (Würsig was unable to attend the workshop. His paper was presented by William A. Watkins.)

3.2 Two background papers, in addition to those prepared under contract to the MMC, were presented by other workshop participants. They were:

1. an overview of marine mammals and fisheries involved in adverse interactions in the United States and elsewhere -- Michael Payne, Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland; and

2. an overview of what is known about the hearing capabilities of large cetaceans and how these animals use and respond to different types of

sound -- William A. Watkins, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

3.3 Specific individuals had been asked, before the workshop, to comment on the presentations (commenters are identified in the workshop agenda -- Appendix 5). These experts made their comments immediately following the respective presentations during the first day of the workshop. In most cases, an outline or the written text of the presentation had been provided, in advance, to the invited commenters.

3.4 To help meet workshop objectives 2 and 3 (see 3.0, above), D.P. DeMaster of the National Marine Mammal Laboratory led a facilitated discussion during the second morning. Participants initially identified a broad range of issues and uncertainties, which were then grouped under seven general headings. These headings were:

1. guidelines or criteria for deciding when and under what conditions acoustic deterrents should be incorporated into fishery and aquaculture management regimes;

2. evaluating whether the use of low-intensity sound generators (pingers) was likely to remain effective in reducing the bycatch of harbor porpoises in sink gillnet fisheries, without having unacceptable adverse effects on fish catches or other biota;

3. evaluating whether pingers would be effective in reducing bycatch of marine mammals in other fisheries, without having unacceptable adverse effects on fish catches or other biota;

4. assessing the long-term effectiveness, and possible undesirable side-effects, of AHDs used to keep pinnipeds away from aquaculture facilities, hatcheries, and areas where valuable fishery resources are concentrated;

5. aspects of experimental design and analysis required to produce statistically meaningful results from field tests of acoustic deterrent devices;

6. basic research, engineering, and educational programs needed to resolve critical uncertainties. This was understood to include not just more science and technology, but also the development of ways to ensure that fishermen and operators of aquaculture facilities are well informed about and involved in seeking solutions to problems caused by interactions; and

7. other marine mammal conservation problems, not directly related to fisheries or aquaculture, that might be addressed using acoustic methods.

3.5 These seven subject areas were referred to small working groups for in-depth discussion. The groups were asked to (a) identify and agree on critical uncertainties, (b) describe the kinds of research needed to resolve them, and (c) determine the general circumstances when acoustic devices should or should not be incorporated into management regimes. Each group's report was expected to include:

1. a brief characterization of the problem, e.g., the fisheries or aquaculture operations involved, the nature of the interactions with marine mammals, and the relevant uncertainties;

2. a statement of the objectives of the project or task;

3. an explanation of the rationale for any engineering work, field trials, etc. needed to attain the objectives most cost-effectively. If relevant, this explanation was to include required sample sizes and methods for collecting and analyzing the data;

4. estimates and justifications for the required time, costs, special equipment, and logistic support;

5. an illustrative list of the fisheries or aquaculture operations that could benefit from, or be involved in, the work; and

6. criteria for judging the success of a particular project or task and for applying the results to management programs.

3.6 The working groups met during the afternoon and evening of the second day of the workshop. The above terms of reference were followed to differing degrees by the groups. The working group reports were presented and discussed during the final plenary session on the third day. These reports constitute the principal output of the workshop and are provided, in edited form, in Section 5, below.

3.7 In the two months immediately following the workshop, considerable exchange of views and information continued by phone, facsimile, and e-mail. Chairmen and rapporteurs of the working groups continued to oversee the completion of their reports. A draft of the entire workshop report, containing all of the edited working group reports, was circulated to participants in late May 1996. Their suggestions and corrections were taken into account in the preparation of this final version.

3.8 No formal attempt was made, during or after the workshop, to establish priorities among the many tasks identified. Participants viewed that process as primarily an agency (NMFS) responsibility.

BACKGROUND

Bycatch Issues

4.0 The bycatch of marine mammals in fisheries is a serious conservation problem. For many species and populations, it far exceeds any current threat from deliberate catching or killing. Although fishery bycatch was recognized as one of the problems facing marine mammals when the MMPA was enacted in 1972, it was not until the 1988 amendments to the Act that it became a principal focus of management efforts within the NMFS. By the late 1980s, bycatch in fisheries had also come to be recognized as a major problem at the international level. For example, a Workshop on Mortality of Cetaceans in Passive Fishing Nets and Traps, co-sponsored by the International Whaling Commission, the NMFS, and the MMC, as well as a variety of other agencies, was held at the Southwest Fisheries Science Center in La Jolla, California, in October 1990. That workshop galvanized interest in the bycatch issue and resulted in compilation of fishery and bycatch data from around the world (Perrin et al. 1994).

4.1 The MMPA amendments of 1994 infused efforts to find a solution to the bycatch problem in U.S. waters with a sense of urgency. Although bycatch of several stocks is estimated to exceed PBR levels, the most dramatic disparity between bycatch and PBR in the U.S. occurs in the case of the harbor porpoise population in the Gulf of Maine (Barlow et al. 1995: their Table 1). The annual bycatch has been on the order of 2000 while the estimated PBR level is about 400 (Blaylock et al. 1995). This means that the annual bycatch from this stock must be reduced by about 80% to achieve the take reduction required by the MMPA. Achievement of the MMPA's immediate take-reduction goals for some other stocks (e.g., bottlenose dolphins, pilot whales, and beaked whales) will also require management measures. Clearly, if fishery closures are to be avoided, another means of reducing bycatch of harbor porpoises and several other species will be necessary.

4.2 Until 1994, the use of sound to reduce the incidental mortality of small cetaceans in gillnet fisheries had met with scientific skepticism; most field trials had been flawed or inconclusive (for a recent review, see Jefferson and Curry 1994). However, controlled experiments in the Gulf of Maine sink gillnet fishery in autumn 1994 (Kraus et al. 1995) and the northern Washington coastal set-net fishery for chinook salmon in summer 1995 (Gearin et al. 1996) showed significant reductions in the bycatch of harbor porpoises in nets equipped with active pingers. In November-December 1995, the New Hampshire Gillnet Fishermen's Association, in cooperation with the NMFS, conducted an experimental fishery in which pinger usage was integrated into standard commercial gillnetting operations. No bycatch of harbor porpoises was recorded. The probability of catching zero porpoises on observed trips (48% of the total) by chance, given the level of effort and the data from previous years, was statistically negligible ($P < .01$) (Potter 1996)[1]. These results provided a basis for workshop discussions concerning the effectiveness and side-effects of pingers, the desirability of

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[1]The results of further experimental fisheries conducted in spring 1996, following the workshop, were not as encouraging. Catch rates in nets with pingers attached were similar to historic rates when pingers were not being used (Potter, personal communication).

incorporating their use into gillnet fisheries in other areas, and the need for additional research and experimentation.

Depredation Issues

4.3 Fishermen have traditionally found their own ways of coping with competitors and co-predators, often shooting marine mammals observed near fishing operations. The recent proliferation of aquaculture has coincided, at least in much of North America, with growth of some pinniped populations brought about by legislative and regulatory changes intended to promote the recovery, rather than continued "control," of depleted marine mammal populations. Recent collapses in wild commercial fish stocks, especially salmonid runs in western North American rivers, have greatly intensified the conflict between marine mammals and fishing interests, even though the collapses were caused by overfishing or habitat loss rather than by marine mammal depredations.

4.4 The MMPA Amendments of 1994 expressly prohibit the "intentional lethal take of any marine mammal in the course of commercial fishing operations." The amendments authorize fishermen and fish farmers to deter marine mammals from damaging their gear, catch, and cultured fish so long as the measures used do not result in the death or injury of marine mammals (MMPA §101(a)(4)). The amendments direct the NMFS and the Fish and Wildlife Service (FWS) to develop guidelines for safely deterring marine mammals and, for species listed as endangered or threatened under the Endangered Species Act, to recommend specific measures that may be used to non-lethally deter marine mammals. The Services may prohibit, after notice and opportunity for public comment, any forms of deterrence that have significant adverse effects on marine mammals[2].

4.5 No experimental data, comparable to those mentioned above regarding pinger use with gillnets, are available to evaluate the efficacy of AHDs in deterring pinnipeds. AHDs have been used in aquaculture operations since the early 1980s. Until recently, effectiveness was generally short-term. In most instances, the pinnipeds eventually became less responsive, due either to "habituation" or to changes in their hearing sensitivity, and the depredation resumed. In some cases, depredation may have increased because animals learned to associate the sound with a readily available source of food.

4.6 Recent advances in underwater acoustic technology have led to development of AHDs that transmit very high-amplitude signals at frequencies thought to be well within the range of pinniped hearing. Manufacturers have reported good results for two to three years, with no signs of "habituation" or declining effectiveness. The newer-generation AHDs are presumed to cause pain at short ranges and appear to be effective deterrents against depredation by pinnipeds.

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[2]In May 1995 the NMFS published for comment a proposed rule setting forth guidelines and prohibitions regarding the use of deterrents. At the time of the workshop, the FWS had taken no action and the NMFS had not yet published a final rule.

4.7 There is a need for definitive experimental evidence that they perform their intended deterrent function, and do not have unacceptable effects on non-target marine mammals and other biota. With regard to the second point, a study in British Columbia showed a possible avoidance response by harbor porpoises. The abundance of porpoises within a radius of 3.5 km (1.9 nautical miles) of an AHD was significantly lower during experimental periods (AHD activated) than during control periods (AHD deactivated) (Olesiuk et al. 1995). Thus, AHDs may have a biologically significant impact on harbor porpoises and other marine biota, which are not intended targets. Since many, if not all, of the signals from AHDs are probably within the hearing sensitivity ranges of large whales, the potential impact on these species also needs to be investigated. Although no impacts on the behavior, hearing, or physiology of fish and marine birds have been demonstrated, neither have appropriate studies been conducted to verify that the new high-intensity AHD systems do not have such impacts.

WORKING GROUP REPORTS

5.0 The working group reports reflect the combined insights and opinions of a group of experts. The group chairmen sought to achieve consensus and to address their respective topics in a balanced and comprehensive manner. All reports were nearly complete by the end of the workshop, although in some cases substantial dialogue among members and redrafting of the reports took place in the weeks after the workshop. The formats of the reports are not entirely consistent, and a certain amount of redundancy was unavoidable.

5.1 Working Group 1: Guidelines and Criteria for Decision Making

Barlow, Bowles, Dawson, Hofman (Chair), Kraus, Read, Reeves, Wilkinson, Williamson, Young

To help structure discussion, the chairman prepared a list of possible guidelines and criteria, based on the workshop presentations and discussions. This list was presented and discussed briefly during the plenary session on the second day of the workshop. The working group then met to review and revise the list to reflect the discussion.

The working group concluded, and the plenary concurred, that the following general guidelines and criteria should be used to help decide when, and under what conditions, active acoustic devices should be tested and used for management purposes. These guidelines and criteria are tailored for use in the United States (e.g., the categories of fisheries and the terms "environmental assessment" and "environmental impact statement" are derived from, and have precise meanings within, U.S. law), but they should be helpful to managers and administrators in other countries as well.

1. Anthropogenic sounds should be introduced into the ocean only when such introduction is necessary to accomplish a beneficial or potentially beneficial purpose, and when it is clear that such a purpose cannot be accomplished in a less intrusive way[3].

2. Acoustic devices should not be used for management purposes unless there is good reason to believe (e.g., there are significant empirical data showing) that their use will contribute significantly to solving the problem of concern. Such use should also be contingent on reasonable evidence demonstrating that there will be no unacceptable side-effects -- e.g., the safety of fishermen or others will not be jeopardized, the target or other species will not be harmed, and a significant decline in the fish catch will not result.

3. Some form of licensing or prior authorization should be required for operational (as opposed to experimental) use of high-output devices that reasonably might be expected to harm target or other species -- e.g., cause temporary or permanent hearing damage.

4. The registration forms used by U.S. fishermen participating in Category I and Category II fisheries should request information on the numbers and types of acoustic devices (e.g., pingers) used in the preceding year and expected to be used in the coming year.

5. In some instances, experimental or other data may provide good reasons for suspecting that a particular device or acoustic system would solve or contribute to solving a problem, yet substantial questions will remain concerning long-term efficacy and possible harmful side-effects. In these circumstances, use of the device or system for management purposes should be conditional on the implementation of an appropriate monitoring program. The monitoring program should be sufficient to verify that the device or system works as expected and has no unacceptable side-effects.

6. Obtaining authorization to test an acoustic device or system that reasonably might be expected to ameliorate a marine mammal-fishery conflict should be made as simple as possible, especially if the device or system is unlikely to have unacceptable side-effects.

7. Tests should not be haphazard or unstructured. They should be designed and carried out to optimize the likelihood of producing meaningful results in the shortest possible time and at the least possible cost.

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[3]During discussion of this point, it was noted that a general policy on the introduction of sound into the marine environment from all anthropogenic sources is needed. Although all participants shared this view, it was recognized that the workshop was not the appropriate forum for developing such a policy.

8. Whenever a proposed experiment or management program could have adverse environmental impacts, an environmental impact assessment should be done before any resources are allocated to the project. If the assessment indicates that significant adverse impacts are possible, an environmental impact statement should be done in accordance with applicable state and Federal law.

9. Impact assessments should be done by the responsible regulatory authority. The organization, industry, or individual desiring to test or employ a particular device or system should provide, or pay the cost of obtaining, the data and information needed for the assessment. They also should conduct or pay the cost of monitoring necessary to verify that the device or system works as expected and has no unacceptable side-effects.

10. Resource users, public interest groups, and industries that could be affected by policies and regulations regarding the use of acoustic devices and systems should be involved in identifying and evaluating the relative advantages and disadvantages of alternative actions.

5.2 Working Group 2: Gulf of Maine Harbor Porpoises and Gillnet Fisheries (Pingers)

Payne (Chair), Potter, Read, Reeves, Silber (Rapporteur), Swartz, Williamson

This group focused on the most critical marine mammal bycatch problem in U.S. waters: mortality of harbor porpoises in the Gulf of Maine sink gillnet fishery.

I. Description of the Problem

The harbor porpoise bycatch in the Gulf of Maine sink gillnet fishery exceeds the level considered sustainable by the population. Management measures taken to date, including time and area closures, while reducing the bycatch, have not reduced it to the calculated PBR level. Moreover, they have been difficult to implement.

Section 118 of the 1994 amendments to the MMPA requires that the bycatch be reduced to below the PBR level prior to 1 April 1997. Thus, if the fishery is to continue in its present form, the bycatch will need to be reduced by 70-80%, i.e., from approximately 2000 porpoises per year to approximately 400 per year by 1 April 1997.

II. Uncertainties

The core of any plan to reduce bycatch in the Gulf of Maine will be based, at least in part, on the significant results of the 1994 New Hampshire pinger experiment. This experiment demonstrated that the pingers could be effective in achieving the desired bycatch reduction in the sink gillnet fishery. Nevertheless, uncertainties remain about their continued effectiveness in this fishery through time, and about their potential effectiveness in fisheries that catch other species. The uncertainties are as follows.

1. Although it is clear that the pingers significantly reduced the harbor porpoise bycatch in the experiment, it is not clear why they worked. For example, it is not clear whether porpoises were alerted or repelled by the sounds made by pingers; their prey responded by moving away from the sounds and the porpoises followed; or other factors were involved. In addition, it is not clear what characteristics of the sound were responsible for the observed results. Despite these uncertainties, there is no doubt that something about the pingers rather than, for example, a natural change in porpoise distribution or behavior, caused the observed reduction in bycatch. The fact that porpoises were taken in the control nets at the historic, or expected, rate indicates that substantial numbers were present in the area at the time of the experiment.

2. It is not clear if, and to what extent, the results of the 1994 New Hampshire experiment can be extrapolated to other fisheries and bycaught species. Because of the many variables (e.g., how gear is fished, how the marine mammals of concern are distributed spatially and temporally, environmental factors), it would be unwise to assume that identical, or even similar, results can be achieved in other situations. Therefore, full-scale operational use of pingers should not be extended to other fisheries and bycaught species without prior testing. If pingers are used in other fisheries, well-designed test studies and monitoring programs should accompany the use so that the effects and efficacy of the pingers can be evaluated. In this regard, it is noteworthy that the experimental use of pingers resulted in a significant reduction in the harbor porpoise bycatch in the northern Washington coastal set-net fishery in 1995 (Gearin et al. 1996; see footnote 1).

3. Gillnet gear is fished differently, depending on the target species and other factors. Even within the "Gulf of Maine sink gillnet fishery," various gear types and techniques are used. Pingers may not have the same effects when used on all types of gillnet gear and with all techniques of gillnet deployment. Although baseline porpoise bycatch rates are known to vary among the different components of the Gulf of Maine fishery, a full analysis of this variability has not been done. The results of such an analysis might be usefully incorporated into any strategy for expanding the use of pingers in the Gulf of Maine fishery. The same type of uncertainty is likely in other gillnet fisheries as well.

4. The catch of 25 porpoises in the control nets in the 1994 experiment suggests clearly that the animals were in the area and either were avoiding or for other reasons were not being caught in the pinger-ensonified nets. If they were avoiding the ensonified nets, it is possible that they will stop doing so or that pinger use will displace porpoises from essential foraging areas or other types of essential habitat. These possibilities mean that long-term monitoring of the bycatch and of porpoise distribution and abundance should accompany any widespread use of pingers on fishing gear.

5. As noted above, the effectiveness of pingers may diminish as porpoises become habituated, or desensitized (e.g., due to changed hearing thresholds), to the stimulus. One indication that habituation or desensitization could be occurring would be an increase in the bycatch rate. An increase in the bycatch rate alone, however, would not be sufficient to establish that habituation or desensitization was the cause. A variety of other factors could be involved, e.g., pinger malfunction or increase in the porpoise population. Thus, a monitoring and research program is needed both to detect any change in the bycatch rate and to provide the basis for determining the cause.

6. The effects, if any, of pingers on other biota are uncertain. Pingers, particularly when deployed over large areas for long periods of time, may cause significant distributional, physiological, and behavioral changes in large and small cetaceans, pinnipeds, fish, and other marine organisms.

7. Uncertainty and variability in the seasonal and annual abundance, distribution, and bycatch of harbor porpoises will be factors in interpreting the results of further pinger research. Such uncertainty and variability need to be accounted for in a robust management plan that entails the routine use of pingers. For example, harbor porpoise bycatch in the Gulf of Maine sink gillnet fishery was higher in the fall than in any other season during 1991-94. However, the particular month of highest bycatch rate has varied between September and December throughout this period. The areas and times in which pingers are to be required, as well as any interpretation of their effectiveness, will depend on better knowledge of the within-season and inter-seasonal movements, distribution, and abundance of the animals.

III. Certainties

Several things seem reasonably certain:

1. The legal requirements and the scale of the problem to be solved are clear.

2. The fishermen have demonstrated a willingness and commitment to work to solve the bycatch problem in their fishery.

3. The areas and season of greatest bycatch are well documented (although the precise time period is variable).

4. A gross understanding exists of seasonal trends in harbor porpoise distribution. It is important to acknowledge, however, that much uncertainty surrounds the intra- and inter-seasonal movements of individual animals. Satellite tracking now underway (by A. Read and colleagues) should reduce this uncertainty.

3. If application of pingers throughout the fishery achieves a level of bycatch reduction comparable to that of the 1994 experiment, the PBR goal could be reached. It will depend on the continued widespread support and compliance of the entire gillnet fleet. The potential for large-scale fishery closures, in the event that the take-reduction goal is not achieved, is likely to be sufficient motivation for the industry to ensure that pingers are used as prescribed and that participation in the pinger program is complete.

4. If the PBR goal is achieved in the first year, repeat the same strategy in subsequent years. If it does not prove to be effective (i.e., the bycatch at the end of the season exceeds the PBR level), implement an alternate approach. Any alternative likely would need to include lengthy closures, possibly covering large geographic areas. The closures could be modeled on the existing area-closure program outlined by the New England Fishery Management Council, with the timing of closures following the recommendations of the Council's Harbor Porpoise Review Team.

5. A survey of harbor porpoise abundance should be conducted in 1996 to provide an additional abundance estimate to compare with those obtained in 1995 and previous years, and possibly obtain a trend estimate.

6. The research and monitoring program should include:

   (a) At least 6% observer coverage on vessels fishing.

   (b) Studies of the fine-scale distribution of porpoises in areas where pingers are used, to look for signs of displacement or other effects.

   (c) Detailed behavioral studies of the responses of porpoises, herring (one of the porpoises' prey), and other species (e.g., baleen whales) to the sounds of pingers.

VI. Other North American Gillnet Fisheries in which a Similar Strategy May Be Appropriate

Several other gillnet fisheries in North America have harbor porpoise bycatch rates comparable to that of the Gulf of Maine sink gillnet fishery. These include the northern Washington set-net fishery, in which a controlled experiment with pingers in 1995 had results similar to those of the 1994 New Hampshire experiment (Gearin et al. 1996); a Canadian gillnet fishery in the Bay of Fundy (southeastern Canada); and various set-net fisheries in British Columbia and southeastern Alaska. If pingers are deployed in these fisheries to reduce the porpoise bycatch, such deployment should be accompanied by a monitoring program, as described above. Other gillnet fisheries off the U.S. east coast south of the Gulf of Maine almost certainly take harbor porpoises, but the scale of this bycatch is unknown (Blaylock et al. 1995).

VII. Criteria for Successful Implementation of the Pinger Program in the Gulf of Maine Sink Gillnet Fishery

1. The MMPA-mandated reduction in porpoise bycatch is achieved on schedule.

2. Large-scale fishery closures are avoided, and the fishery is maintained.

3. Fishermen adopt the pinger program as their solution to the porpoise bycatch problem and thus ensure that it is fully and consistently implemented.

4. Data are available to demonstrate that other biota are not adversely affected by the large-scale use of pingers.

5.3 Working Group 3: Other Species and Other Gillnet (Mainly Drift Gillnet) Fisheries (Pingers)

Barlow (Chair), Dawson, Gearin, Hanan, Kraus, Melvin, Northridge, Read, Wilkinson (Rapporteur), Yi

This group's mandate was to suggest approaches for evaluating the efficacy of pingers in gillnet fisheries other than those in which the harbor porpoise is the main bycaught species of concern. The group initially focused on well-known U.S. fisheries. It was assumed that the principles applicable to these fisheries might also apply to other fisheries.

I. Possible Target Fisheries and their Characteristics

1. West-coast drift gillnet fishery for swordfish and sharks

About 150 vessels, with crews of 2-4, are involved. The fishing is done at distances of 5.6-370 km (3-200 nautical miles) from shore, on trips lasting 5-14 days. The nets are 36-61 cm (14-24 inch) mesh, 1.9 km (1 nautical mile) long, and 61-92 m (200-300 feet) deep. They are suspended 6-18 m (20-60 feet) below the surface. Nets are set at dusk and retrieved at dawn. The boats are attached to the nets overnight. The fishing season is from 14 August through the end of January.

The fishery is generally regulated by the State of California (6 boats operate off Oregon). Its ex-vessel value is about $15 million.

The bycatch annually includes approximately 300-400 common dolphins and smaller numbers of beaked whales, pilot whales, various other delphinids, Dall's porpoises, sperm whales, and some pinnipeds (Barlow, personal communication). The take rate is about 1 marine mammal per 10 sets. Observer coverage has been about 15%.

2. East-coast drift gillnet fishery for swordfish, tuna, and sharks

This fishery is generally similar to the one on the west coast described above, but it is much smaller and of shorter duration. Less than 20 vessels are involved. The season is open only for about 10 days in summer (until the quota on swordfish is reached).

The nets are 50 cm (20 inch) mesh, 2.5 km (1.3 nautical miles) long, and 18-25 m (59-82 feet) deep. They are fished at the edge of the continental shelf. The total number of sets per season is approximately 200.

The bycatch annually includes approximately 400 common dolphins, 60 pilot whales, smaller numbers of other delphinids, more than 30 beaked whales, and a few northern right whales, humpback whales, and sperm whales (National Marine Fisheries Service 1995). The take rate is more than 1 marine mammal per set. Observer coverage has been good (50-100%).

3. Mid-Atlantic (central East Coast of U.S.) coastal gillnet fisheries

These are small-scale fisheries that operate in state waters from New Jersey to Florida. Target species include weakfish, croaker, spot, shad, bluefish, and striped bass. More than 3000 fishermen participate in these fisheries. The gear consists of bottom-anchored gillnets. Regulations vary from state to state.

Little information is available on fishing effort or marine mammal bycatch. Most of the information on takes is from stranding data. The bycatch is known to include harbor porpoises, bottlenose dolphins, and harbor seals. The mortality rates of harbor porpoises and bottlenose dolphins may be above the PBR levels (see Blaylock et al. 1995).

There has been little observer coverage to date. Obstacles to implementing an effective observer program include the small size of many of the vessels, the large number of participants in the fisheries, and the presumably low bycatch rate.

It is important to note that the State of Virginia is reported to have already purchased pingers for fishermen.

II. Testing the Effectiveness of Pingers

1. Variables applying specifically to the west-coast driftnet fishery

(a) The depth of the nets makes them difficult to ensonify. Most entanglements occur in the upper two-thirds of the net, but they may occur in other parts of the net as well.

(b) Because of the length of trips and the geographic extent of the fishery, each boat will have to be its own control and deploy both live and dummy pingers.

(c) The species diversity in the bycatch makes acoustic frequency selection both important and somewhat complex. For some species (e.g., beaked whales and *Kogia* spp.) little is known about hearing capabilities. A pinger with a frequency sweep could prove useful for all species, but a "noisy" signal with harmonics would be easier to incorporate and might be equally effective. From what is known about odontocetes, all species should be able to hear in the frequency range of the currently standard pinger (fundamental frequency $\approx$ 10 kHz). While there might be species differences in detection ranges, particularly at high frequencies, the goal -- detection of the ensonified net from far enough away to avoid entanglement -- should be adequately met by existing pingers. Thus, additional pinger development should not be necessary for an initial experiment in this fishery.

2. Specifications and protocol for studies in the west- and east-coast driftnet fisheries

(a) *Salt-water switch.* Use the available pingers with a salt-water switch.

(b) *Pinger placement.* Pingers should be placed no more than 100 m apart. They should be placed on both the headrope and the leadline of nets used on the west coast, so that the net is totally ensonified. The placement of pingers should be alternated between headrope and leadline.

In the east coast fishery, pingers should be placed on the leadline.

(c) *Randomization.* Deployment of active and dummy pingers should be randomized between sets on the same vessel rather than between vessels to avoid possible geographic bias.

(d) *Power analysis.* In order to generate meaningful results, sample size and observer coverage should be determined in advance, using power analysis. The target bycatch level should be the PBR level for each species. However, for some species (e.g., beaked whales), the numbers caught are likely to be too small to obtain adequate sample sizes. In those cases, the study should be structured to detect a 50% reduction in total cetacean mortality, with particular attention paid to those species for which catch has exceeded PBR.

(e) *Passive devices.* Simultaneous use of active and passive deterrents might have potential, but additional work on passive devices and combinations is needed. There is concern that simultaneous use could confound interpretation of results.

(f) *Pinger availability.* Consideration should be given to pinger availability and supply. Substantial lead time may be required for pinger manufacture. Since about 500 active and an equal number of dummy pingers are needed for each experiment, it might be desirable to consider transferring the pingers from the east to the west coast.

(g) *Blind controls*. Because of difficulties created by the length of trips and the need to re-use pingers on consecutive sets, a double-blind experiment might not be possible. If so, a single-blind experiment, with the observers knowing whether the pingers are active, must be considered adequate. To keep the structure of experiments comparable on each coast, every effort should be made to achieve single-blind controls.

Note: Because of similarities in the fisheries and the bycaught species, experimental results from one coast may have some degree of applicability to the other coast.

3. U.S. mid-Atlantic coastal gillnet fisheries

(a) Much more needs to be known about these fisheries before any investigation of the efficacy of acoustic deterrents can reasonably be initiated.

(b) Despite the difficulties, some sort of observer program is imperative. The possibilities of using observers on shore or on board independent vessels should be explored. Also, aerial surveys could provide information on fishing effort and the presence of marine mammals in the fishing areas.

(c) Habituation (decreased responsiveness; see Appendix 1) or desensitization (hearing threshold shifts) could be particularly important in these fisheries because some populations of marine mammals are probably resident rather than migratory.

III. Possible Approaches to Testing Pinger Efficacy When Field Trials are not Feasible

Two approaches might be considered in situations where, for example, uncertainty is caused by the inadequacy of information about the fishery (e.g., mid-Atlantic coastal gillnet fisheries) or catch rates are so low that observer programs would provide little data. They could be used in areas with resident (and preferably fairly large) cetacean populations.

1. Deploy a pinger array as is normally done on a gillnet and monitor the behavior of wild dolphins or porpoises as they encounter the array. Such an experiment would allow an evaluation of whether animals avoided the ensonified area, and, if they did, at what range their behavior changed. If left in place for a longer period, it might be possible to evaluate the habituation problem by observing resident animals.

2. Test the hypothesis that pingers elicit echolocation signals which aid cetaceans in detecting and avoiding nets. In an experiment, deploy a pinger in the vicinity of an echolocation click detector/logger. Echolocation clicks could be counted over long control (silent) and experimental (pinger on) periods.

IV. Summary

Experiments with pingers in the east- and west-coast driftnet fisheries should be initiated as soon as possible. On the other hand, substantially more information about the coastal gillnet fishery (or fisheries) in the mid-Atlantic region is needed before a useful experiment can be designed and conducted there.

5.4 Working Group 4: Use of Acoustic Harassment Devices to Reduce Predation by Pinnipeds on Salmonids and Other Fish Species

Boutillier, Bowles, Christensen, Ford, Fraker, Gentry (Chair), Harvey, Mate, Morris (Rapporteur), Schusterman, Shaughnessy, Young

Four separate kinds of interaction between pinnipeds and fisheries or aquaculture operations were considered by this group, namely:

* bottlenecks or "choke points" where wild salmonids aggregate in response to human-made structures or natural river physiography;

* aquaculture facilities where pen-raised salmonids attract pinnipeds;

* the salmon drift gillnet fishery, mainly in Oregon rivers; and

* the commercial sport-fishing industry -- party (head-boat) fishing, which targets salmonids and other species, and salmon trolling in California.

AHDs have been used, at least experimentally, in each situation to keep pinnipeds away (see Mate and Harvey 1986).

The group realized that the term AHD might not always be appropriate, since a particular device might actually be designed to cause fright, annoyance, or pain rather than "harassment," *per se*. The term AHD has been used throughout the working group report (and the workshop report) to distinguish the generally high-amplitude devices used to deter pinnipeds, from the generally low-amplitude "pingers" used to prevent bycatch of marine mammals (mainly cetaceans) in fisheries.

I. Key Observations

1. As the 1995 Gulf of Maine Task Force on Pinniped and Aquaculture Facilities concluded (Task Force 1996), acoustic devices cannot be expected to provide 100% protection from pinniped depredation.

2. Because sound appears not to be particularly aversive to pinnipeds except at very high intensities, it should not be used as the measure of first resort in resolving fishery conflicts. Simpler, cheaper methods having less impact on surrounding biota -- e.g., not locating fish farms near pinniped rookeries and constructing physical barriers to keep seals away from fish pens -- should be

used first. AHDs should be used only to supplement these. AHDs should be used only after other non-lethal (or otherwise less intrusive) measures have been found to be ineffective.

3. The possible effects of sound on non-target species should be the first concern when (a) using AHDs, (b) escalating efforts to drive away recalcitrant individual animals, and (c) choosing the site for new aquaculture pens.

4. The problems considered here involve primarily four pinniped species: California and Steller (northern) sea lions, harbor seals, and gray seals. Thus, research intended to improve the effectiveness of AHDs in North America need consider only a few species.

5. The number of recalcitrant individuals that cannot be deterred by high-intensity sounds is usually small. The lack of effectiveness in these cases could be due to impaired hearing, habituation, learned avoidance behavior, or other factors. Representative animals should be studied to determine why they are not deterred by high-intensity sounds.

6. The question of whether lethal means should be used to remove recalcitrant individuals was beyond the scope of the workshop and not addressed.

7. When AHDs fail to keep pinnipeds out of an area, mitigation should not necessarily be sought by increasing intensity or operating time. Most current AHDs already produce at or near their maximal practical levels. Increasing the total sound energy delivered by increasing operating times or intensity could cause hearing damage, which must be considered an undesirable, and indeed counterproductive, result.

   It should be recognized that in at least some cases, the apparent failure of AHDs to deter pinnipeds may be a consequence of improper maintenance and deployment of transducers. For example, the user may be trying to protect an area that is too large to be adequately ensonified or may have placed the AHDs where transmissions may be blocked. These possibilities should be considered before concluding that a particular device is ineffective. Tests should be done when AHDs are installed to (a) ensure that they are working properly, and (b) measure received sound levels at the distances and in the areas where they are expected to deter pinnipeds.

8. The effectiveness of AHDs is influenced by the "personality" of pinnipeds. Pinnipeds are highly exploratory, persistent, and hard to frighten with most sounds. Growth rates of some local populations of the four pinniped species have been substantial (5-13% per year). In areas where pinniped populations are growing, increased interactions with fisheries and aquaculture operations can be anticipated.

9. The nature of sound transmission is highly site-specific. Transmission loss depends on slope, depth, and composition of the bottom, temperature, salinity, and many other factors. Because of the number of variables that affect transmission loss, the strength and effectiveness of the signal reaching the animal usually cannot be predicted precisely. Nevertheless, the strength of the received signal, not the source level, should be the main consideration in assessing an AHD's effect on target animals and its likely impact on other biota.

10. Research is needed on the effects of exposure to sound on the hearing abilities of marine mammals (temporary and permanent threshold shifts). It is also needed on the physiological and behavioral consequences of long-term, chronic exposure to sound. Studies of the effects of exposure to AHD sounds need to include non-target species (e.g., other marine mammals, fish, turtles, invertebrates) as well as the target species. The possible effects of AHDs on harbor porpoise and other strategic stocks are of special concern because changes in the distribution of harbor porpoises around experimental AHDs have already been observed.

II. Means of Increasing the Effectiveness of Sound as a Deterrent

Given that sound intensity cannot be increased much beyond present levels, what else can be done to increase the effectiveness of sound as a deterrent? The following list was developed by the Working Group.

1. Use hazing by humans.

2. Pay careful attention to pen location and construction, with the paramount goal of keeping animals naive to penned sources of food. Predator fences, correctly installed and tensioned, should be used in nearly all cases and perhaps be required.

3. Protect areas that are as small as possible in settings that confine the sound.

4. Use sounds only where large numbers of fish are being taken.

5. Use sounds to prevent depredation on free-ranging fish only where fish aggregations are temporary and where predators are not aggregated for some purpose other than feeding (e.g., resting, nursing, breeding).

6. Use a mild warning tone before the aversive sound is produced to try to develop a conditioned response to the tone, allowing the aversive sound to be used only intermittently. The ability to develop a conditioned response will depend in part on the aversiveness (e.g., suddenness and intensity) of the sound. Ten or more repetitions might be necessary before the conditioned response is developed. The aversive sound will have to be produced periodically to prevent the conditioned response from being extinguished. If

successful, conditioning animals to respond to a low-intensity warning signal would (a) reduce the possibility of causing hearing damage; (b) lessen the possibility of affecting non-target species; and (c) reduce electrical power requirements. The effectiveness of any conditioning technique will depend in part on the strategy used by the animal to find the fish that are being protected. Animal search strategies are still largely unknown.

While sounds of appropriate frequency, timing, and intensity can be used to condition animals in the laboratory, psychologists do not consider them to be especially effective negative reinforcers. As a consequence, such sounds are used in conditioning experiments only in conjunction with aversive stimuli. It is possible that noise will prove to be more effective as a negative reinforcer for marine mammals, which depend on sound for much of the information that they get about their environment. This possibility, however, is only a speculation at present.

7. Produce sounds only when the predator approaches the area being protected. Predator detection is central to the success of conditioning. The onset of the aversive sound should have particular properties (see point 10).

8. Tailor the aversive sound to the predator of concern. Establish what kinds of sound are most aversive to a given species and simulate them with the AHD. Acoustic features that can be manipulated include absolute level, signal-to-noise ratio, duration, onset time, rate, bandwidth and center frequency, modulation rate (FM and AM), and duty cycle. The sounds can be tailored to features of the animal's perception, such as similarity to biologically significant sounds, timbre, and deviation from expectation. A good AHD will arouse the animal and exceed its comfort range (i.e., annoy it or cause pain). The possibility that AHDs deter a predator by masking sounds that it is listening for should be investigated (see point 10).

9. Where possible, use directional rather than omnidirectional sounds.

10. Prevent habituation in the first place, and thus avoid the problem of overcoming habituation after it has begun. More research is needed on this phenomenon and its role in foiling acoustic deterrence.

    For a sound to drive a hungry animal away from a food source, it must be aversive enough to override the feeding drive. The sound must be uncomfortably intense; it must stimulate reflexive movements, like the acoustic startle response; and/or it must effectively mask sounds on which the animal depends for locating the food source. Thus, the aversive sound should be as uncomfortable as possible for the target animal, without injuring it. Unfortunately, the more effective the sound, the more likely it is to have undesirable effects on non-target species, and the more likely that it will be injurious to the target animal with protracted exposure.

The most successful AHDs currently in use produce sounds that increase from ambient sound level to the maximum intensity (194 dB RMS SPL re 1 μPa) over a period of 70 seconds to "warn" animals off. The maximum intensity may be near what will cause hearing impairment. Any increase in sound intensity could increase the risk of hearing impairment. If needed, the next best way to increase the aversiveness of the sound is to increase the onset rate. This can stimulate the acoustic startle response, a reflex that is itself aversive. The onset rate should be rapid, perhaps as little as 200 ms. The optimal rate may be on the order of 50-100 dB per second: fast enough to stimulate the startle response, but not so abrupt that it will immediately cause acute hearing damage. Intense sounds with onsets < 1 ms can cause acute hearing loss after a single exposure, and they are not as aversive. Obviously, such types of sound should never be used. This point also applies to impulses from seal bombs and other explosive devices detonated close to an animal.

III. Situations in which AHDs are not effective or are contra-indicated include those where:

1. the conditions for sound propagation are poor within the desired effective range;

2. the probability of adversely affecting harbor porpoises and other non-target species is high;

3. fish are not well aggregated or are not somehow constrained in their movements (e.g., by having to pass through a constricted area); and

4. use would prevent or interfere with access to normal haul-out sites or other important habitats.

IV. Aggregation Points for Wild Salmonids

On the American west coast from central California through Alaska and on the east coast from Maine through the Canadian Maritime provinces, many runs of salmonids have declined for a variety of reasons, most importantly overfishing and habitat degradation. In some instances, pinniped predation on either out-migrating smolts or returning adults may be one of the factors retarding the recovery or enhancement of the salmonid populations. In most settings, the complexities and vagaries of the food web confound attempts to demonstrate that the pinnipeds have a deleterious effect on the fish stock. However, in some rivers natural or human-made features create "choke points" where it is easier to quantify the effects of pinniped predation. AHDs might be used at such sites to reduce pinniped predation on the fish. The success or failure of such use might be measured by monitoring changes in the number of fish passing the points.

V. Culturing of Salmonids and other Finfish

The culturing of finfish, especially salmonids, is proliferating in North America. In some areas, the economic value of cultured fish is similar to or greater than that of wild fish.

Many fish farms suffer attacks by pinnipeds: mainly California sea lions and harbor seals on the west coast; harbor and gray seals on the east coast. Losses from attacks take several forms: fish are killed outright; injured fish have reduced value; injury and descaling make fish more susceptible to disease; stress affects the growth rates of fish and increases their susceptibility to disease; and damage to pens allows fish to escape and costs time and money to repair. The escape of fish causes an economic loss to the owner and poses a threat to indigenous stocks by potential genetic contamination. Escaped fish also may transmit diseases to wild stocks, compete with wild fish for food and spawning sites, and disrupt redds of wild fish.

Despite some encouraging early results, AHDs used in the 1980s were not effective in controlling depredation by pinnipeds (Mate and Harvey 1986). Recently-developed AHDs (such as those being sold by AirMar Technology Corporation) are reported to have been effective at fish farms in Maine for two years or longer (Task Force 1996) and should be tested further in problem areas. The effectiveness of AHDs can be measured in economic terms, but the effects on non-target biota are largely unknown. As noted earlier, some data show detectable changes in harbor porpoise distribution in response to experimentally activated AHDs in western Canada (Olesiuk et al. 1995).

The group reviewed and agreed with the main conclusions of the report of the Gulf of Maine Aquaculture-Pinniped Interaction Task Force regarding the use of AHDs (Task Force 1996), that the NMFS should:

1. support research on the effects of AHDs;

2. support, through grants or directed research, innovative work on the development of approaches to mitigating or eliminating unwanted side-effects and to reducing the costs of purchasing and operating AHDs;

3. support the development of innovative predator control strategies, including pen design and new technologies, that could eliminate the need for AHDs;

4. conduct workshops to review the latest and best information on AHDs and to facilitate communication between aquaculture practitioners on the one hand and animal behaviorists, manufacturers, and acousticians on the other; and

5. continue to ensure that all interest groups, including proponents of salmon aquaculture and pinniped protection, are involved in the development of policies pertaining to the use of acoustic devices.

VI. Salmon Gillnet Fisheries

Harbor seals and California sea lions take salmon caught in gillnets along the northwest coast of North America. They also cause significant net damage. The fisheries are mainly in rivers, although some fishing is done offshore. In rivers, the nets (100-300 m (328-984 feet) long) are drifted downstream attached to a vessel. The fishing season is short (several weeks). The loss of and damage to fish is economically significant in some areas, and some marine mammal bycatch occurs. For example, approximately 100-200 harbor seals are killed in these fisheries annually. It is possible that AHDs could be developed that would reduce bycatch, gear damage, and the loss of and damage to caught fish. However, since the fishing operation is moving, contraindications 1-3 (section III, above) may apply. There are some concerns that acoustic deterrence may displace other fish (e.g., non-salmonids, especially juveniles in estuaries).

VII. Sport-Fishing Party Boats and Salmon Troll Fisheries

A variety of commercial sport-fishing charter boats, targeting bottom fish species and salmon (trolling), operate on both the east and west coasts of North America. California sea lions and harbor seals take caught fish off the lines. On the west coast the problem is quite severe in some areas, especially southern California where 40% or more of catches can be lost. Cracker shells and seal bombs have been used to drive pinnipeds from the immediate fishing area, but these are dangerous for the operator and give only brief (5-7 min) protection. Electronic AHDs might be developed which could keep pinnipeds away and prevent or reduce predation for longer periods. However, the area to be ensonified is not enclosed, fish are not aggregated, and other marine biota are exposed to risk (see section III, above). Furthermore, if the fishery or the use of AHDs proliferates, the concentration of such devices in large areas, or in sensitive habitat for long periods, could be detrimental to non-target marine biota.

5.5 Working Group 5: Statistical Approaches for Evaluating the Effectiveness of Acoustic Deterrents

DeMaster (Chair), Jones, Laake, Matkin, Zeh

A detailed outline of statistical design features was prepared, followed by comments on retrospective and *ad hoc* studies and on various other statistical considerations. Aspects of this group's report having to do with bycatch studies should be read in conjunction with the report of Working Group 3; aspects having to do with depredation studies should be read in conjunction with the report of Working Group 4. The group recommended that the following be done or considered to produce statistically meaningful results.

I. Develop testable hypotheses, incorporating historical data and information from fishermen and other sources.

II. Design experiments to address a number of different hypotheses, e.g.:

1. species-specific bycatch rates for marine mammals, seabirds, and fish are independent of treatment *y*;

2. depredation rate of species *x* is independent of treatment *y*;

3. rate of depredation by "naive" animals is equal to that by "experienced" animals;

4. rate of depredation by species *x* is constant over time, given treatment *y*;

5. rate of depredation on fish under conditions of acoustic treatment is lower than that under conditions of physical barriers (e.g., predator nets);

6. distribution of species *x* is independent of treatment *y*;

7. catch rate of target (fish) species is independent of treatment *y*; and

8. hearing thresholds of target (fish) and bycaught (mammal) species are independent of treatment *y*.

III. Factors to consider include:

1. a double-blind protocol is preferable whenever possible; at a minimum, the fishermen should be unaware of which gear is treated and which is control;

2. temporal use of treated and control gear should be randomized;

3. alpha-level for Type 1 error should be set prior to experiment (at 0.05-0.1);

4. power should be at least 0.7 to limit the chance of Type 2 error; and

5. sample size should be large enough to get a reasonable likelihood of detecting a biologically meaningful effect.

IV. Quantifiable parameters to estimate (or measure) in bycatch experiments and monitoring studies:

1. bycatch rate, by species (mammals, seabirds, fish) -- organisms killed per unit effort;

2. percent incidence of hearing damage;

3. sound levels (ambient and anthropogenic) at measured distances and depths from net;

4. amount and composition of catch of target species;

5. rate of depredation on catch of the target species (as a way of assessing the "dinner-bell effect");

6. output of a representative, random sample of pingers (amplitude by frequency plots);

7. output of pingers in the vicinity of bycaught marine mammals; and

8. distribution of marine mammals, fish, and seabirds in relation to fishing gear.

V. Quantifiable parameters to estimate (or measure) in depredation experiments and monitoring studies:

1. rates of scarring or other damage on fish at ladders (or other passage facilities);

2. rate of mortality of penned fish caused by marine mammals;

3. sighting rates of pinnipeds and other marine mammals in the vicinity of fish pens, fish ladders, etc.;

4. the number of individual animals in the vicinity of fish pens, fish ladders, etc. if possible;

5. sound levels (ambient and anthropogenic) at specified and measured distances and depths from fish pens, fish ladders, etc.; and

6. distribution of marine mammals, seabirds, and fish in the vicinity of fish pens, fish ladders, etc.

VI. Additional information needs:

1. percent incidence of hearing threshold shifts in marine mammals, seabirds, and fish, in relation to frequency, duration, amplitude, and type of sound;

2. percent habituation or aversion responses in marine mammals, seabirds, and fish, again in relation to frequency, duration, amplitude, and type of sound;

3. characteristics of signals that are aversive to individual marine mammal species;

4. development of a paradigm for studying the behavior of free-ranging pinnipeds in the vicinity of AHDs.

VII. Comments on retrospective and *ad hoc* studies:

Designed experiments are more reliable than opportunistic trials and are thus preferred for evaluating the effectiveness of acoustic deterrents. However, retrospective and *ad hoc* studies (e.g., records of predation at aquaculture sites before and after the installation of AHDs) can be used to judge whether acoustic deterrents are likely to be successful in a comparable situation. They can also be used to identify factors that are potentially important in influencing the fishery-marine mammal interaction.

The validity of conclusions from such studies will depend on the quality of the records that were kept and on how the study was implemented. Such studies generally have focused on bycatch or depredation rates, so they are not useful for assessing indirect effects on the marine mammals or other biota (e.g., hearing loss, displacement from critical habitat).

VIII. Statistical considerations:

For trials using pingers to reduce bycatch, the primary measure of outcome will usually be the proportion of nets (or strings of nets) in which marine mammals were caught. The unit of fishing capacity -- strings in this case -- should be standardized. Results will usually be summarized in 2-way tables like the following:

	No. of strings without bycatch	No. of strings with bycatch
With pingers	A	B
Without pingers	C	D

where A, B, C, and D are the numbers of strings in the respective cells. Both B and D will often be small, so Fisher's exact test, an exact binomial test, will be needed. Although sophisticated analyses may consider covariates such as soak time, this is not essential in a randomized trial, so power calculations can be based on this simple analysis.

Casagrande et al. (1978) and Conlon and Thomas (1993) discuss algorithms for determining sample size in the treatment (with pingers) and control (without pingers) groups, to provide specified power to detect a specified difference with a test at a given alpha level. The required sample size can also be determined by simulation. It would be useful for the regulatory agency (the NMFS in the United States) to have a computer program available to make these calculations. Such a program could be provided for use by anyone designing a study of this kind.

When a power calculation shows that the required sample sizes are not feasible in a particular fishery, a sequence of experiments over several years may be needed. Alternatively, historical controls may be used, although they are less desirable because of the possibility that environmental variability and temporal changes in the fishery will confound results. Finally, the results of small studies of several similar fisheries might be combined to make an overall inference about significance.

In some circumstances, it may not be adequate to simply detect a difference of a specified magnitude between treatment and control. To determine whether the acoustic deterrent is capable of reducing the bycatch to below the PBR level, for example, it may be necessary to estimate the difference with considerable precision. This may require larger sample sizes than suggested by a simple power calculation (see Goodman and Berlin 1994). Estimation of bycatch with acceptable precision must also be considered when determining how much observer coverage is needed for long-term monitoring once a management program involving the acoustic deterrent has been put into place.

Trials to test the effectiveness of acoustic devices in deterring predators will probably require a different design from that used for testing the effectiveness of pingers in reducing bycatch. Some sort of paired "on versus off" design will usually be needed. Retrospective studies of aquaculture operations in which AHDs have been used can provide valuable information on (a) expected effectiveness of a device, (b) required duration of "on" and "off" periods for measuring effects, (c) how long a "washout period" is needed after an "on" period to return to control conditions, and (d) what outcome measures are most useful (e.g., number of fish mortalities per pen of a given size). Designed studies will require power calculations based on paired *t*-tests rather than on analysis of 2-way tables if the most appropriate outcome measures are best treated as continuous rather than categorical. It is not altogether clear in AHD studies what the appropriate experimental unit should be, whereas in pinger experiments it seems clear that the experimental unit is a set (or haul in the case of trawls) of a given piece or unit of gear.

5.6 Working Group 6: Basic Research, Engineering, and Education

Au, Goodson, Jefferson, Kastelein, Ketten, Lien, Nachtigall (Chair), Popper, Thomas, Watkins

During plenary discussions, it was noted that there were many uncertainties concerning the behavior and hearing capabilities of marine mammals, the operational characteristics of pingers and AHDs, and the nature and operations of commercial fisheries (e.g., factors that determine when, where, and how various types of gear are deployed and retrieved). These uncertainties contribute to the difficulty of determining, *a priori*, how different species of marine mammals may react to or be affected by different sounds. They also make it difficult to design and interpret the results of experimental trials. It also was noted that many fishermen lack understanding of the possible biological impacts of their bycatch, that many environmental groups lack understanding of the social and economic impacts of gear damage and fish loss caused by marine mammals, and that many scientists lack understanding of fishing gear and practices.

After developing a long list of uncertainties, the members of this Working Group chose to partition their efforts according to four discrete areas of interest and expertise (1) social science and policy, (2) bioacoustics, (3) technology development, and (4) animal behavior. Each item in the list was addressed by one or more subgroups. The Working Group's report is, accordingly, a series of four subreports.

The overall intention was to identify areas of needed research and to suggest ways that this research might best be designed. The result is, in a sense, a "shopping list," with no indication of priorities.

Subgroup 1: Human dimensions and policy aspects (Jefferson, Lien)

This subgroup started from the premise that it is as important to understand the human dimensions of fishery-marine mammal conflicts as it is to understand the biological aspects. A greater focus on understanding and effectively dealing with the human dimensions should improve the chances of resolving the conflicts. Areas of needed inquiry or attention include:

I. Public education

Often, fishermen and the general public lack a clear understanding of the goals and objectives of marine mammal bycatch reduction measures. For example, the rationale behind the PBR concept, and the methods for calculating that level, are not known to many people. The resultant lack of understanding often impedes acceptance of measures necessary to achieve the PBR goal. The public, and especially people directly involved in the fishing industry, need to be better informed about the importance of bycatch reduction practices and methods, proper (and improper) use of acoustic deterrent devices, and the scientific rationales regarding causes and solutions.

II. Including affected groups in decision making

Fishery management may take the form of rules and regulations developed by government officials. These measures may be imposed on the fishing industry without clear consideration of the possible socio-economic consequences. Understandably, such top-down management leaves fishermen feeling alienated, resentful, and reluctant to cooperate. The chances of successful management (i.e., a sustainable fishery) are greatly enhanced if there is an open dialogue and both fishermen and other interested parties are consulted for their input early in the process.

Mutually agreed management objectives are critical for achieving long-term conservation goals. Better methods of involving interested groups in the decision making process must be identified, evaluated, and implemented.

III. Adaptive management

Given the complexity of the problems, fishery-marine mammal conflicts are best managed adaptively. In other words, management measures need to be subject to continual review and revision in the light of new knowledge, changed circumstances, and shifting priorities. The costs and benefits of management practices need to be evaluated on an ongoing basis. This means evaluating old and new technologies, monitoring effectiveness of the existing management regime, and regularly examining and re-evaluating the options. Adaptive management does not just happen: it requires dedicated forethought and planning.

IV. Untapped information sources

Extensive information on marine mammal bycatch exists, but much of it has not yet been used to its fullest potential. Sources include fishermen's knowledge and several large data sets in government files. Examples of the latter are the 1978-87 data from the observer program of the North Pacific Japanese salmon driftnet fishery, and the 1989-91 data from the North Pacific squid driftnet fishery. Analyses of factors related to bycatch from these data could improve understanding of what influences incidental catch rates and, perhaps, provide guidance about how to modify fishing practices in order to reduce bycatch. Many obstacles may need to be overcome to obtain such data, but the potential for insight makes it worth the effort.

V. Additional topics that need to be addressed

1. The purpose (objectives and goals) of the use of acoustic deterrent devices needs to be clear and should, if at all possible, be accepted by affected groups.

2. All aspects of noise pollution and its effects, not just on marine mammals but on entire ecosystems, need to be addressed.

3. Non-acoustic methods of bycatch reduction and predator control should be considered before acoustic methods are used. Changes in fishing techniques or aquaculture structures (e.g., better siting decisions) might resolve some conflicts better, or more nearly permanently, than acoustic fixes. Some problems have no technical solution and thus require other approaches.

4. Better communication among fishermen, conservation groups, scientists, and resource managers is needed. Open forums that foster a free exchange of ideas and information should be encouraged. Most graduates of fishery science and biology programs are ill-equipped to deal with the human dimensions of issues, and this needs to change.

5. Some acoustic methods may work at first but become less effective over time. Monitoring of a method's effectiveness needs to be accompanied by contingency planning -- i.e., what is to be done if a system fails to work as expected?

Subgroup 2: Bioacoustics (Au, Ketten, Nachtigall, Popper)

This subgroup considered the following critical data insufficiencies and what is needed to overcome them:

I. Insufficient information on the hearing capabilities of bycaught marine mammal species (e.g., harbor porpoises); intra- and inter-species differences in normal hearing ranges; incidence of hearing loss from disease or damage in wild populations.

Statement of Problem:

Effective design of acoustic deterrent devices requires, among other things, knowledge about the sounds that the animals can most readily detect. Very limited data are currently available on the hearing ability of the harbor porpoise. Thus, basic information is still needed about what this species can hear.

Only limited understanding exists about the hearing abilities of pinnipeds and most odontocetes. In many instances, what is known is based on data from a single specimen. While such data are certainly useful, they are not adequate. Virtually all mammalian species show individual variation in hearing ability, depending on an animal's age, acoustic history (e.g., whether it has been exposed to intense sounds), and, in a few cases, sex. Clearly, the signal of an acoustic deterrent needs to be within a frequency range that is detectable to the widest possible span of individuals in the target population. Not only is it necessary to know what sounds are detectable by the largest number of animals of a particular species, but also whether there is a common signal that is likely to be effective for several different species. Experiments are needed on multiple species and individuals and on individuals of different ages and sexes.

Suggested Approach:

1. Conduct basic behavioral and evoked-response experiments, and anatomical studies to develop an understanding of hearing in the relevant species (i.e., those most involved in and affected by fishery interactions).

2. Design and conduct behavioral studies to measure hearing capabilities (audiograms), critical ratios, and directional hearing.

3. Use evoked potentials and anatomical methods to analyze variations in the auditory systems, particularly of those species whose hearing cannot be studied through behavioral experiments.

In each case, multiple animals should be studied to determine the intra-species variation in hearing capabilities, especially as it relates to age, sex, and disease or impairment.

II. Insufficient information on the hearing capabilities and behavioral responses of non-mammal bycaught species (turtles, birds, fish) and of fish species targeted by fisheries.

Statement of Problem:

Non-mammalian species, including birds and turtles, are often bycaught in fisheries. Acoustic methods are of potential use in scaring these animals away, or in warning them of a net's presence (though none of these species is known to be able to detect nets by echolocation). As with marine mammals, it is not possible to determine *a priori* what stimuli are likely to be effective unless something is known about the hearing capabilities of these animals. Data on hearing capabilities are, to our knowledge, insufficient for all species of marine birds and turtles.

Many species of fish, both those that are the targets of fisheries and those that are found in regions where fishing occurs, may be attracted by the sounds used to deter mammals. They also may be repelled or affected physically by these sounds. The sounds could potentially repel targeted fish if they were capable of detecting the sounds. (Note: Recent data indicate that cod and herring may be able to detect ultrasound.)

Better information is needed about the detection capabilities of fish so that either (a) sound sources can be designed that will not alter fish behavior, or (b) sounds can be designed that are not detectable by the fish.

Suggested Approach:

1. Determine hearing capabilities of non-mammalian species that are caught incidentally in fisheries and that might be affected adversely by acoustic deterrents.

2. Use study techniques appropriate to each species, but use behavioral paradigms whenever possible.

3. Use evoked potentials when behavioral studies are not possible.

4. Include measurements of hearing sensitivities (audiograms) and critical ratios.

5. Study anatomy to help understand the mechanisms of sound detection.

III. The echolocation capabilities of bycaught odontocete species, and how those capabilities might be used to avoid artificial barriers such as nets, are largely unknown.

Statement of Problem:

Odontocete cetaceans can use echolocation to sense their environment, potentially including the presence or absence of fishing gear. Without a comprehensive understanding of the echolocation capabilities of the bycaught species, it is difficult to design gear that is readily detectable, and thus decrease the chances of animals being bycaught.

Suggested Approach:

1. Determine whether a particular odontocete species caught commonly in fishing gear has an echolocation capability.

2. Assuming that it does, investigate that species' ability to detect nets of different mesh size and composition -- e.g., obtain basic information about the species' echolocation system, such as frequencies, beam widths, functions in noise, etc.

IV. Little information is available on how wild odontocetes use echolocation.

Statement of Problem:

Although echolocation has been demonstrated for several odontocete species in a laboratory setting, there have been few demonstrations of the use of echolocation by wild animals. In fact, the limited data on wild odontocetes suggest that most of the time they are not echolocating. Very little is known about when, why, and how these animals use echolocation in nature, and this raises important questions. For example, were bycaught animals caught because they were not searching for targets at the time of capture or because they were unable to detect the net or failed to recognize it as potentially life-threatening? Depending on the animal's "normal" behavior, it might be possible to find a signal that tells an odontocete to "turn on" its echolocation system.

Suggested Approach:

1. A method needs to be developed to determine whether foraging animals and animals near nets are using echolocation. This will be difficult since echolocation signals are highly directional. Receiving hydrophones will have to be within the beam width to detect the signal.

2. Because animals often forage in large groups, a method needs to be developed to differentiate the echolocation signals from different individuals. Only in this way will it be possible to determine whether all animals in a group are echolocating, or, alternatively, whether just a few animals are echolocating for the group.

V. For most marine species, very little is known about damage to hearing caused by underwater sound.

Statement of Problem:

It is well known that sound can damage vertebrate ears. However, virtually nothing is known about the combined effects of frequency, duration, and amplitude on the auditory system of aquatic vertebrates.

Suggested Approach:

1. Conduct experiments with mammals and non-mammals to determine what types of sound cause temporary and permanent threshold shifts.

2. Examine bycaught animals to evaluate whether the condition of their auditory system could have been a factor in making them vulnerable to entanglement or entrapment. It has been suggested that many bycaught animals may be individuals with impaired hearing. If true, this would have serious implications for the use of acoustic deterrents.

3. Any dead or captive animal suspected of having been exposed to high-amplitude devices should be evaluated for evidence of damage to its auditory system. Such evaluation can be done by studying the animal's behavior, evoked potentials, and/or, in the case of a dead specimen, its ear anatomy. In this regard, it was noted that California sea lions captured or killed to prevent predation on steelhead trout migrating through Ballard Locks would be good candidates for such studies.

4. For species that are not endangered, a complete series of experiments should be done to establish the acoustic parameters of sounds that produce characteristic stages of ear damage (i.e., temporary versus permanent threshold shifts). This means a connected series of behavioral, evoked potential, and full anatomical analyses.

VI. Almost nothing is known about the hearing of mysticete cetaceans.

Statement of Problem:

Although mysticetes certainly use sound for communication, their hearing capabilities in relation to behavior are completely unknown. The hearing ranges of several species can be inferred from their sound production and from their inner ear anatomy. However, these provide only indirect suggestions as to bandwidth and sensitivity, parameters critical to the design of signals to alert mysticetes to the presence of fishing gear.

Suggested Approach:

Controlled experiments to study mysticete behavior relative to different sounds are unlikely to be possible in the foreseeable future. It may nevertheless be possible to measure auditory brainstem responses of live-stranded whales, and this could provide some idea of these animals' hearing bandwidths and sensitivities. Considering the importance of information on hearing to the development of bycatch mitigation measures, a major effort should be made to obtain relevant data from live-stranded or gear-entrapped animals whenever possible.

Subgroup 3: Technology development (Goodson, Watkins)

This subgroup identified a series of concerns and considerations, presented below in the form of an annotated outline.

I. Acoustic characteristics of devices -- Before a device is approved for general use, the manufacturer should supply polar plots of directivity and data on waveform, repetition rate, mark/space ratio (see Appendix 1), sound spectrum, source level, and tolerances that are to be maintained during manufacture, and expected performance change during the device's normal operating life. Changes in specifications or simple spreads in performance due to component tolerances could affect a device's acoustic characteristics and, in turn, its effectiveness. Example: The presence or absence of harmonics elicited radically different behavior by a captive harbor porpoise during a pinger experiment.

II. Noise pollution -- An assessment should be made of the shape and extent of the ensonified area surrounding any acoustic device. This area would be defined by the distance at which detection above ambient noise is possible. Such a threshold plot would be useful for planning placement of fish pens and fishing gear and establishing "quiet" (below ambient noise) safe passage zones between them. It is suggested that the sea state zero noise floor (at the frequency of the sound generated) be used to define this threshold until more is known about the minimal sound pressure levels which actually induce responses in the behavior of the mammal species at risk.

III. Detection of targets (subjects) -- For optimal functioning of a device, a method of automatically detecting and activating the device when marine mammals are near the fishing or aquaculture equipment ("smart" technology) needs to be developed. Examples:

1. acoustic detection of vocalizing animals (e.g., ones that are making social calls or echolocating); and

2. video imaging to extract visual cues (e.g., of animals approaching a static net at a fish farm).

The benefits of a target (subject)-activated or on-demand system include: less potential for habituation by the target species; less acoustic pollution of the local environment; and extended life of battery-powered systems. De-activation may be desirable for "out of season" conditions (better economics; makes de-rigging of alarms unnecessary).

IV. Signal suitability -- Transmitted signals should correspond to the sensitive part of the target animal's hearing.

1. Audiograms are needed for most marine mammal species. (Characteristics of the hearing ability of relevant fish species also need to be determined so that negative effects on them can be avoided.)

2. Determine signal waveforms best suited to (i) gaining the animal's attention, and (ii) creating an aversive response (if desired).

3. Optimize mark/space ratio -- unnecessary exposure may induce habituation and increase risk of hearing loss.

V. Oceanic conditions affect acoustic propagation from devices.

1. High sea states and rain increase background noise levels and induce aeration effects, which mask and severely attenuate acoustic signals underwater.

2. Possible trade-offs among alarm frequency, waveforms, and detection range need to be examined.

3. *In situ* recordings are essential for such examinations.

VI. Optimize the target strength and resonant characteristics of passive reflectors. Passive devices, intended for use in conjunction with active alarms, may be designed at specific frequencies keyed to species. These could augment the effectiveness of the active alarms.

1. Determine maximal prey size for each odontocete species. Use it to peg the minimal acoustic target strength of the reflector, which should exceed the acoustic characteristics of the largest typical prey.

2. Such size information can be obtained by examining stomach contents of bycaught animals.

3. Targeting behavior of odontocete sonar suggests that during fish interception, echo returns from beyond the target range are not being processed.

4. Inter-element (reflector) spacing needs to be optimized for each odontocete species.

5. Passive reflectors can incorporate resonant characteristics that can be stimulated by pingers.

VII. Malfunctioning equipment may produce "gaps" in the perceived acoustic obstruction, thus enhancing the probability of bycatches at such points. Device failures need to be detected as they occur.

1. In order to monitor deployment, alarm signals should be used which contain fundamental (or harmonic) components that can be detected using a standard (50 kHz) fish echo-sounder. Chirp transmissions are detectable on a wide range of echo-sounding equipment.

2. Go/no-go testers should be supplied by device manufacturers to allow easy detection of devices that are not functioning properly.

3. Devices should be deployed with spacing that provides acoustic overlap and allows one defective device to be tolerated.

VIII. Alternative technologies

1. In the context of aquaculture, adaptive sonar beam-forming techniques could provide high-intensity deterrent sounds targeted directly at the predator. They could similarly provide quiet zones with "nulls" in the projected sound pattern allowing unimpeded movement around pens.

2. Devices triggered by the presence of a predator (or a potential bycatch victim) are technically possible and might be mass produced economically.

Subgroup 4: Behavior (Kastelein, Thomas)

Knowledge of the behavior of marine mammals will facilitate the development of effective bycatch deterrence strategies[4]. This subgroup attempted, systematically, to develop a list of statements about behavior relevant to deterrence. Suggested approaches to research were appended to each statement. The idea was that this outline should be consulted problem-by-problem, and thus used as a guide to research on behavior that could be of relevance. Priorities would depend on the nature of the problem and on the availability of resources.

I. Influences of natural history on susceptibility to bycatch

Statement: Each species of marine mammal has its specific natural history, and this will influence that species' bycatch probability.

Approach: Analysis of a species' natural history might provide insights that could facilitate mitigation. The research objectives should be related to a specific bycatch problem.

1. *Age* may influence susceptibility to bycatch. In some species, individuals are probably most vulnerable during the transition from suckling to solid food, when they begin investigating their environment independently. Older animals, with impaired sensory abilities, might also be especially susceptible to bycatch. Acoustic devices are probably less effective at deterring these individuals.

2. *Sex* may be a factor. In some species, the sexes are spatially segregated, at least during part of the year, and the two sexes may use different foraging strategies, areas, and prey species.

3. *Social system* may play a role. For example, males may behave differently, in relation to fishing operations, than females, particularly those with calves. Social interactions, such as mating, could distract the animals so that they fail to notice nets. The size and composition of a group could affect the probability of entanglement.

4. *Individuality* may be important. Strong individual differences are typical of at least some marine mammal species. An animal's previous experience in general, and particularly around fishing operations, may influence the way it responds to acoustic deterrents.

II. Implications of behavior in relation to bycatch

Statement: An animal's behavior is likely to affect its bycatch probability and, in turn, to help determine which form of mitigation will be effective.

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[4]Knowledge of behavior as described by this subgroup also would facilitate development of techniques for preventing marine mammal depredation on both cultured and wild fish.

Approach: Careful monitoring of wild animals around fishing operations can improve understanding of the factors that affect bycatch. Information is needed about the following.

1. *Manner or context of entanglements* -- Do the animals blunder into nets? Do they patrol along them? Do they investigate fish in the net? Do they sometimes escape after being entangled?

2. *Behavior around barriers* -- Do the animals reduce their swim speed? Do they try to go underneath, around, over, or through nets? How far are they willing to travel to get past a barrier safely? Through what size opening in a barrier are they willing to venture?

3. *Use of echolocation in the wild* -- Which individuals echolocate? How often? Under what circumstances? How far do they swim before producing another echolocation signal? Are there circadian or seasonal differences? At what distances can the animals detect gear acoustically and visually, and under what circumstances?

4. *Effects of varying oceanic conditions* -- How do factors such as wind speed and direction, sea state, depth of the surface layer, salinity, and water temperature affect the behavior of the animals and the effectiveness of any deterrent device? (At least some of these factors may be integrated as "ambient noise.")

5. *Reasons that marine mammals are near fishing gear* -- Are they feeding on the target species of the fishery? Do they follow depth contours in pursuit of prey, a strategy matching that of fishermen that leads, inevitably, to geographic overlap? If marine mammals are feeding near fishing gear, they could be interested in species other than those targeted by the fishery. Are marine mammals present in the fishing areas when no fishing gear is present?

III. Behavioral responses to various acoustic devices

Statement: Characteristics of sounds can vary in many respects, such as frequency, duration, amplitude, duty cycle, psychoacoustic character (see Appendix 1), and onset time.

Approach: Careful examination of how various sounds affect the behavior of particular species may help identify the optimal characteristics of an acoustic deterrent. Many possible effects can be investigated using captive animals.

1. Characteristics of the most aversive signals

   (a) Psychoacoustic character

   (b) Duty cycle

   (c) Amplitude relative to response threshold

2. Immediate effect of acoustic device

    (a) Deters the animal

    (b) Makes the animal attentive to its surroundings

3. Effect of acoustic device over time

    (a) Accommodation

    (b) Habituation

    (c) Remains effective

IV. Behavior of fish that are targeted by the fishery

Statement: Acoustic devices used to reduce marine mammal bycatch could have negative effects on the fishery.

Approach: Catches of target fish species should be carefully monitored so that catches in sets with acoustic devices (treatment) can be compared with catches in sets without devices (control). The following can then be investigated:

1. rate of harvest;
2. avoidance or attraction effects of the device;
3. physiological and anatomical effects, such as stress, hearing impairment, and changes in growth or reproduction.

Points (2) and (3) might best be addressed in the laboratory.

V. Behavior of animals (other than mammals) not targeted by the fishery

Statement: Acoustic devices can have negative effects on non-target species in addition to marine mammals (e.g., turtles, diving birds, fish, crustaceans).

Approach: The behavior of such non-target species near fishing gear should be carefully monitored. Data should be collected so that behavior near ensonified gear can be compared with that near control gear. Catch data should be handled in the same way as indicated in point IV (above).

5.7 Working Group 7: Other Possible Uses of Sound for Marine Mammal Conservation

Ford (Chair), Kraus (Rapporteur), Watkins

Sound might be used to address problems in marine mammal conservation and management in addition to those involving interactions with fisheries and aquaculture operations. They were not discussed in detail at the workshop, but this small working group met briefly and provided a list of possibilities.

I. Reduction of the frequency or severity of vessel collisions with whales. This problem is most acute in the case of northern right whales along parts of the eastern North American seaboard. Nearly 30% of the documented mortality in this critically endangered population is due to ship strikes. The magnitude of the vessel-collision problem is still being defined for other cetacean species and populations.

The vulnerability of whales to collisions with ships may involve:

1. localization problems (the animal hears the vessel but cannot judge where it is);

2. confusion problems;

3. lack of awareness (on the part of both the whale and the vessel operator); and

4. a poor learning curve since mechanized, high-speed ships are a relatively new feature in the ocean.

Among the types of data needed to address this problem are data on:

1. acoustic characteristics of ships;

2. kinds of sounds that would alert the animals; and

3. kinds of sounds that would "scare" the animals away from the vessel's path (investigate through, for example, playback experiments and a literature review).

II. Reduction in the frequency that Florida manatees are struck by vessels and crushed in flood-control structures. Factors similar to those mentioned above for right whales would apply.

III. Temporary displacement of marine mammals from sites where underwater construction, demolition, or military exercises are planned. An acoustic stimulus possibly could keep or drive the animals away, or alternatively attract them to a safer area.

IV. Temporary displacement of marine mammals from the location or path of an oil or toxic chemical spill or from the site of a planned, loud acoustic event (e.g., a ship shock trial). Same comment as in point III.

V. Assistance in extricating marine mammals from particular types of entrapment (e.g., killer whales from Barnes Lake, southeastern Alaska; "Humphrey" the humpback whale from the Sacramento River; narwhals from an inlet in Repulse Bay, Canada).

PRINCIPAL WORKSHOP FINDINGS AND CONCLUSIONS

6.0 Many uncertainties surround all aspects of acoustic deterrence applied to marine mammals. This means that much more research and monitoring is essential if the problems of marine mammal interactions with fisheries and aquaculture operations are to be addressed responsibly and in a manner consistent with the MMPA. Of particular concern is the paucity of information about marine mammal hearing thresholds and how the animals use and respond to sound. There is an immediate need for research on how marine mammals behave around fishing gear, on how and when they use echolocation, and on their hearing thresholds (audiograms).

6.1 A basic principle that must underlie all use of acoustic deterrent devices to resolve marine mammal conflicts with fisheries and aquaculture operations is that any introduction of artificial sound into the underwater environment is potentially harmful to marine mammals and other biota. The physical, psychological, and ecological disbenefits will usually be less obvious and less easily measured than the economic benefits. This is particularly true in view of the potential for cumulative and synergistic impacts of each new acoustic device or system.

6.2 Other management strategies, not involving the introduction of artificial sound into the underwater environment, should always be sought, even after an acoustic solution appears to have been found. Also, it should be kept in mind that solutions which work in an industrialized country may be impractical in less developed countries where low-cost, low-maintenance solutions are the only kind that have any hope of being used.

6.3 The responsibility for resolving conflicts between marine mammals and fisheries or aquaculture operations needs to be shared among resource users (fishermen and fish farmers), resource managers (governmental officials), and resource consumers (including the general public). Management strategies need to be inclusive and adaptive, as outlined in the report of Working Group 6, Subgroup 1.

6.4 It is unrealistic to expect statistically meaningful experiments to be conducted for all potential target species and for all fishery or aquaculture contexts in which the use of acoustic deterrent devices may be contemplated or tried. The results of experiments done with particular species in particular contexts should be used to make inferences about applicability to other species and contexts. Such inferences should be made cautiously, and monitoring programs should be conducted to determine efficacy and side-effects.

6.5 In view of the promising results from the 1994 New Hampshire and 1995 Washington experiments, pingers might be used experimentally in situations for which their effectiveness in reducing bycatch is untested. This includes different types of fisheries as well as similar fisheries that involve bycatch of species other than the harbor porpoise. All participants agreed that it would be inappropriate for either fishermen or managers to act on the assumption that pingers will be effective universally. The importance of obtaining direct evidence for each type of fishery, and each bycaught species of concern, must not be ignored. For example, in the case of the critically endangered vaquita, an endemic species of the upper Gulf of California, Mexico, it must not be assumed, without direct supportive evidence, that the use of pingers in the gillnet fisheries in this region would reduce the bycatch of vaquitas. If it is assumed, based on experience with other fisheries and species, that pingers will solve the vaquita bycatch problem, and the assumption is wrong, the resumption of fishing with pinger-equipped nets could lead to extinction of the vaquita.

6.6 It is appropriate to proceed with the full-scale integration of pingers into the management regime for the New England sink gillnet fishery provided that the regime includes observer and monitoring programs adequate to verify that the bycatch remains acceptably low and that no non-target species is affected adversely[5].

6.7 The use of pingers is appropriate in other similar gillnet fisheries in which the harbor porpoise is a major bycaught species of concern (see footnote 5). However, such use should always be conditioned on a monitoring program to validate expectations.

6.8 Experiments should be conducted as soon as possible to determine if pingers could prevent or substantially reduce marine mammal bycatch in the driftnet fisheries off the U.S. east and west coasts. It is important that these experiments be designed according to the specifications laid out in the reports of Working Groups 3 and 5, using blind controls and *a priori* assessment of statistical power.

6.9 Before any but experimental use of pingers is begun in the many gillnet fisheries along the eastern U.S. seaboard south of the Gulf of Maine, an observer program should be conducted to determine the operational characteristics of the fisheries and obtain data needed to assess the species and numbers of marine mammals and other non-target species being caught incidentally.

6.10 A major, continuing concern related to those acoustic deterrent devices that seem to be effective, including both pingers in reducing the bycatch of harbor porpoises and AHDs in reducing the depredation of fish by pinnipeds, is that the actual mechanisms involved in making them effective are unknown. Effectiveness probably varies not only by species, but also with respect to an individual animal's experience, age, social status, and sex, and possibly location, weather conditions, and time of year. Uncertainty about the details of cause and effect means, among other things, that reliable predictions cannot be made of how

[5]This conclusion might have been different had the workshop been held after the experimental fishery in the spring of 1996 in which significant numbers of harbor porpoises were caught in nets with pingers attached.

long a device will continue to have the desired effect. Attempts to extrapolate the results from studies of one species or fishery to another are confounded by this same uncertainty. Moreover, it adds to the difficulty of assessing the likely nature and magnitude of side-effects on both target and non-target species.

6.11 Another major concern is that the side-effects of acoustic deterrent devices on non-target organisms are unknown. Conclusive studies have not been done to investigate these. An experimental study of the effects of AHDs showed that harbor porpoises were displaced by at least a few kilometers when the AHDs were activated (Olesiuk et al. 1995) (possible effects on other non-target species were not assessed). Studies on the effects of the latest generation of high-amplitude AHDs on marine mammals, fish, and other organisms are badly needed. It is important to recognize that the powerful signals produced by AHDs are probably well within the hearing ranges of most (possibly all) species of marine mammals, including endangered baleen whales.

6.12 Studies to date in commercial fisheries provide no evidence that the addition of sound reflective materials to nets will, by itself, cause a reduction in bycatch. Some participants urged that discrete passive sonar reflectors might be usefully deployed in combination with pingers, but this possibility requires testing before large-scale, non-experimental application of reflectors is considered.

6.13 The *ad hoc* development and proliferation of AHDs over the last 15 years have been accompanied by little controlled experimentation and effects monitoring. Opportunities for empirical investigation of changing responsiveness on the part of pinnipeds have therefore been lost. Also, in many areas, side-effects on non-target organisms may already have occurred without documentation. It is important that this situation be reversed and that rigorous experimental studies be conducted, taking account of the methodological considerations in the reports of Working Groups 4 and 5.

6.14 Experiments should be done to determine if animals can be conditioned, using occasional aversive stimuli, to stay away from aquaculture facilities and fishing gear. When trying to generate a conditioned response on the part of offending pinnipeds, there is a risk that commitment to one particular approach will preclude future options. This means that any measure taken should be preceded by careful design and testing.

6.15 In all investigations of acoustic deterrents, propagation characteristics need to be considered. Actual measurements of sound fields are necessary to evaluate the distances at which the sounds are likely to be perceived by target and non-target animals. Optimal deployment of acoustic devices depends on site-specific propagation conditions, which are themselves influenced by factors such as weather, vessel traffic, and biological background noise.

6.16 It is important to recognize that single solutions are unlikely to be universally applicable. Also, it should not be assumed that any given approach will remain effective indefinitely. Thus, it is incumbent on both the private and public sectors to maintain an ongoing commitment to support innovative research and development in the pursuit of ways to achieve bycatch reduction and the safe control of depredation.

6.17 Incidental mortality in fishing gear can be a serious problem for baleen whale populations, particularly northern right whales and humpback whales. Low-frequency "clangers" have helped reduce the incidence of humpback collisions with cod traps in Newfoundland and should be considered in other areas where whales are caught in fishing gear.

6.18 Although marine mammals are caught incidentally in trawl fisheries, the scale of this bycatch is generally lower than that in gillnet fisheries. Thus, the workshop did not address trawl fisheries as a priority.

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APPENDIX 1.

GLOSSARY OF TERMS

Acoustic deterrent device - A sound-producing or sound-reflecting device used to make marine mammals aware of, or to repel them from, an area or structure (e.g., a net, pen, or trap). Both passive reflectors and sound generators are included within the definition.

Acoustic harassment device (AHD) - A sound-generating device which, because of some combination of intensity, frequency, or other characteristic(s), is aversive to marine mammals and keeps or drives them away from an area or structure.

Category I fishery - Under a classification scheme established by the NMFS regulations implementing the 1994 Amendments to the Marine Mammal Protection Act (Section 118), a U.S. fishery which is responsible by itself for the annual mortality or serious injury of 50% or more of a marine mammal stock's PBR level (see below for a definition of PBR level).

Category II fishery - A U.S. fishery which is responsible by itself for an annual take of 1 to 50% of the PBR level for a marine mammal stock, and when that stock's total annual mortality and serious injury caused by commercial fisheries exceeds 10% of its PBR level.

Depredation - In the present context, understood to mean something akin to "facilitated predation," in which an animal "attacks" or "raids" (plunders) something already caught or otherwise claimed by people.

Habituation - A gradual waning in responsiveness to repeated or continuous stimuli that are not reinforced by negative consequences, or at least by consequences that are intolerable. Habituation might be said to represent increased tolerance toward an aversive stimulus.

Mark/space ratio - The ratio between the duration of an acoustic pulse and the time between pulses. It indicates the rate at which acoustic power is being delivered into the environment. Changes to the mark/space ratio directly affect the battery life of battery-operated systems. A 300 ms signal repeating every 4 seconds has a mark/space ratio of 1:13.

Pinger - In general, a small, low-intensity sound-generating device intended to function as an "active acoustic alarm." The current standard pinger, as used in the landmark experiment in New Hampshire in 1994 (Kraus et al. 1995), emits a fundamental signal at 10 kHz with harmonics to at least 60 kHz, with a source level at 132 dB re 1 μPa at 1 m. The signal lasts for about 300 ms and repeats every 4 seconds. This pinger was designed specifically to deter harbor porpoises from becoming entangled in gillnets.

Psychoacoustic - This term refers to the psychological effect of a sound. For example, the high amplitude and frequency modulation of an ambulance siren stimulates a flight/alarm response in humans. A sound of equal amplitude, but without frequency modulation, would not necessarily stimulate this response.

Potential biological removal (PBR) level - Defined in the Marine Mammal Protection Act Amendments of 1994 as "the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population." For details of how PBR is calculated, see Barlow et al. (1995).

Reflector - A passive sonar reflector, analogous to "cat's eyes" built into a road to reflect car headlights back to the driver. It works on the same principle as devices on boats that reflect radar and thus make the boats "more visible" to radar. Reflectors fastened to nets are intended to make nets more detectable to echoranging animals, i.e., increase the "target strength" of the nets.

Strategic stock - A marine mammal population that is either (a) listed as endangered or threatened under the U.S. Endangered Species Act, or is declining and likely to be listed in the foreseeable future; (b) designated as depleted under the Marine Mammal Protection Act; or (c) subject to human-caused mortality greater than the estimated PBR level.

APPENDIX 2.

COMMON AND SCIENTIFIC NAMES OF SPECIES MENTIONED IN THIS REPORT

Beaked whales, whales in the family Ziphiidae
Bluefish, *Pomatomus saltatrix*
Bottlenose dolphin, *Tursiops truncatus*
Cod, *Gadus* spp.
California sea lion, *Zalophus californianus*
Chinook salmon, *Onchorhynchus tshawytscha*
Common dolphins, *Delphinus* spp.
Croaker, *Micropogonias undulatus*
Florida manatee, *Trichechus manatus latirostris*
Gray seal, *Halichoerus grypus*
Harbor porpoise, *Phocoena phocoena*
Harbor seal, *Phoca vitulina*
Herring, *Clupea* spp.
Humpback whale, *Megaptera novaeangliae*
Killer whale, *Orcinus orca*
Mesoplodonts, cetacean species in the genus *Mesoplodon*
Narwhal, *Monodon monoceros*
Northern right whale, *Eubalaena glacialis*
Pilot whales, *Globicephala* spp.
Sablefish (black cod), *Anoplopoma fimbria*
Shad, *Alosa sapidissima*
Sperm whale, *Physeter catodon*
Spot, *Leiostomus xanthurus*
Steelhead trout, *Oncorhynchus mykiss*
Steller (Northern) sea lion, *Eumetopias jubatus*
Striped bass, *Morone saxatilis*
Swordfish, *Xiphias gladius*
Vaquita, *Phocoena sinus*
Weakfish, *Cynoscion regalis*

Appendix 3.

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Appendix 5.

WORKSHOP TO ASSESS THE EFFECTIVENESS AND EFFECTS OF ACOUSTIC DEVICES FOR PREVENTING OR REDUCING THE ADVERSE EFFECTS OF MARINE MAMMAL-FISHERY INTERACTIONS

Battelle Conference Center
4000 N.E. 41st Street
Seattle, Washington

20 - 22 March 1996

AGENDA

20 March 1996

0900 Welcome and introductions; review of meeting objectives and arrangements (Convener)

0930 General overview of marine mammals and fisheries in the U.S. and elsewhere affected adversely by interactions (presented paper -- Michael Payne)

1000 General overview of hypotheses concerning the causes of, and possible means for preventing or reducing, problems caused by marine mammal-fishery interactions (presented paper -- Thomas Jefferson)

1030 Coffee Break

1045 General overview of what is known about the hearing capabilities of marine mammals, how and for what purposes marine mammals produce and use sound, how marine mammals respond to and are affected by different sounds, and why marine mammals fail in some situations to detect and respond to potentially hazardous fishing gear -- presented papers (15 min. each)

-- Large cetaceans (William Watkins)

-- Small cetaceans (Whitlow Au and Paul Nachtigall)

-- Pinnipeds (Ronald Schusterman)

1130 Panel discussion/commentary regarding marine mammal hearing and production of, and response to, sound
(Panel: John Ford, Darlene Ketten, and Jeanette Thomas)

1200	General discussion	
1215	Lunch	
1330 to 1730	Identification and evaluation of research done to date -- Presented papers (30 min.); invited commentary (10 min.); general discussion (5 min.)	
	(1330)	Using sound reflectors and generators to prevent or reduce entanglement of large cetaceans in fishing gear (presented paper -- Jon Lien/commenter -- David Goodson)
	(1415)	Use of sound reflectors and generators to prevent or reduce entanglement of small cetaceans in fishing gear (presented paper -- Stephen Dawson/commenter -- Andrew Read)
1500	Coffee Break	
	(1515)	Using sound to prevent or reduce pinniped depredation of caught fish, fish returning to hatcheries or spawning grounds, and mariculture operations (presented paper -- Peter Shaughnessy/commenter -- Bruce Mate)
	(1600)	Using sound to prevent or reduce depredation of caught fish by killer whales and other cetaceans (presented paper -- Craig Matkin/commenter -- Ann Bowles)
	(1645)	Possible effects of acoustic deterrents on marine mammals and other biota (Paper prepared by -- Bernd Würsig/presented by -- William Watkins)
1730	Panel discussion/commentary regarding possible effects of acoustic deterrents on marine mammals and other biota (Panel -- Roger Gentry, Ronald Kastelein, Scott Kraus, William Watkins)	
1800	General discussion	
1815	Adjourn	

21 March 1996

0900 Facilitated discussion to try to reach agreement on --

- critical uncertainties and variables
- priority species and fisheries
- research needs and priorities
- when acoustic deterrence might usefully be incorporated into fishery management regimes

(Douglas DeMaster -- facilitator)

1230 Lunch

1345 Constitute small drafting groups to prepare descriptions of key research tasks and to estimate the time, funding, special equipment, and logistic support that would be required to complete the described tasks

1415 Small drafting group meetings

1700 Progress reports by chairpersons of drafting groups

1730 Break for dinner

Evening free for continuation of small group discussions and drafting of research task descriptions

22 March 1996

0800 Distribution of draft task descriptions

0900 Review and, as possible, agree upon descriptions of key research/monitoring/management tasks
(Douglas DeMaster -- facilitator)

1200 Outline, and agree upon a procedure for completing and reviewing, the meeting report

1230 Adjourn

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