Potential Mitigation Measures for Reducing the By-catches of Small Cetaceans in ASCOBANS Waters

Report to ASCOBANS

December 27th 2000

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Introduction

By-catch, the unintended mortality of non-target species, is widely recognized as one of the most serious environmental impacts of modern commercial fisheries (Alverson et al. 1994; Dayton et al. 1995). By-catches may affect the structure and function of marine systems at the population, community and ecosystem levels (Crowder and Murawski 1998). Long-lived vertebrate species with low fecundities, such as sharks, sea turtles and marine mammals, are particularly vulnerable to depletion from by-catches. In some cases, by-catches may threaten populations, and even species, with extinction (*e.g.* D'Agrosa et al. 2000).

With growing recognition of the potentially adverse effects of by-catches, fisheries managers are working to document the occurrence, magnitude and impact of this phenomenon. In cases where by-catches are recognized as unsustainable or undesirable, the fishing, environmental and scientific communities are attempting to develop workable solutions to this pervasive problem (Murawski 1994; Hall 1996; Hall 1998). Progress has been made in reducing by-catches in some fisheries (*e.g.* Joseph 1994; Hall and Donovan 2000; Hall et al. 2000), but much work still remains in most areas of the world.

By-catches pose one of the most serious threats to dolphins and porpoises in the area covered by the Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas. In this report, I review the potential mitigation measures available to address this problem in the ASCOBANS area. In particular, I draw on recent experiences from the United States, where a management framework has been in place for several years to address by-catches of marine mammals in commercial fisheries. I will not review measures implemented to reduce the by-catch of pelagic dolphins in the tuna purse-seine fishery in the eastern tropical Pacific, because of the unique nature of this interaction and because these mitigation strategies have been discussed extensively elsewhere (see Joseph 1994; Hall 1996; Hall 1998). In addition, I will not review work that has been conducted in, or adjacent to, the ASCOBANS area, as I expect this material will already be familiar to readers.

I begin by reviewing briefly the regulatory and legal framework in place in the United States, because this framework underpins the U.S. approach to by-catch mitigation. I describe four case studies of dolphin and porpoise by-catches for which mitigation strategies have been developed. I review recent efforts to implement these measures and evaluate their strengths and weaknesses, before drawing general conclusions from these experiences.

Legal and Regulatory Framework in the United States

Below I review the legal and regulatory framework of the United States that pertains to the management of by-catch of small cetaceans in the United States. This review is brief and, by necessity, incomplete. I refer the reader to Baur et al. (1999) and references therein for a more complete review of this subject.

Legislative Framework

In federal waters of the United States, commercial fisheries are regulated under the Magnusen-Stevens Fishery Conservation and Management Act (MFCMA) of 1976. This jurisdiction extends from state waters (inside three nautical miles from shore) to the boundaries of the Exclusive Economic Zone. Each state is responsible for regulating fisheries prosecuted in state waters, within three nautical miles of shore. The MFCMA is implemented by eight regional fishery management councils, each comprised of individuals knowledgeable in the management, conservation or commercial harvest of fishery resources, together with representatives of state and federal agencies. The councils develop fishery management plans consistent with a set of national standards contained in the MFCMA and its amendments. Fishery management plans are reviewed and approved by the Secretary of Commerce, who has responsibility for implementation of regulations. Scientific and technical assistance is provided to the regional councils by the National Marine Fisheries Service, a branch of the Department of Commerce.

In the United States, the management of marine mammals is proscribed by the Marine Mammal Protection Act (MMPA) of 1972. The two fundamental goals of the MMPA are to ensure that marine mammal stocks: (1) do not fall below optimum sustainable population (OSP) levels and (2) are maintained as functioning elements of their ecosystems. In practice, management efforts are directed at the first of these two goals. To achieve this goal, the MMPA prohibits *takes* of marine mammals, except under specific circumstances, where a *take* is "*to harass, hunt, capture or kill or attempt to harass, hunt, capture or kill*" (Baur et al. 1999). OSP has been defined by the National Marine Fisheries Service as a population size exceeding the Maximum Net Productivity Level (MNPL). In turn, the MNPL is defined as the population size that yields the greatest net increment from additions to the population due to reproduction and growth, minus losses due to natural mortality. MNPL is generally assumed to occur between 50% and 70% of a stock's carrying capacity or historic population size (Taylor and DeMaster 1993). Stocks below this level are considered *depleted*. Effectively, therefore, the primary management goal of the MMPA is to maintain marine mammal stocks above MNPL (Baur et al. 1999). Implementation of the MMPA is the responsibility of either the Secretary of Commerce or the Secretary of the Interior, depending on which species of marine mammal is considered. Some populations of marine mammals in the United States are also listed as *threatened* or *endangered* under the Endangered Species Act (ESA) of 1973. Like the MMPA, the ESA prohibits the taking of listed marine mammals and also includes provisions for the protection of critical habitat for these populations.

Specific Regulatory Provisions Regulating By-Catches

In 1994, the MMPA was amended to deal specifically with the by-catch of marine mammals in commercial fisheries (see Baur et al. 1999 for a complete description of the history of this issue). Under these amendments, the Secretaries of Commerce and Interior are responsible for the preparation of assessment reports for each of more than 150 stocks of marine mammals in the United States. These reports must contain information on: stock structure, abundance, trends, sources and magnitude of anthropogenic mortality and an evaluation of whether or not this mortality exceeds threshold levels specified by the Act (see review by Read and Wade 2000). These reports undergo external peer review and are then published as a formal assessment of the status of each stock of marine mammals. The stock assessment reports are updated regularly and the most recent versions are available on the web (NMFS 2000a).

Under the 1994 amendments, a maximum allowable level of anthropogenic mortality is determined for each stock of marine mammals. This level, known as the Potential Biological Removal (PBR), is defined as:

$$PBR = N_{min}(0.5)(R_{max})\ F_R$$

where N_{min} is the minimum population estimate for the stock, R_{max} is the maximum theoretical or estimated net productivity of the stock at a small population size, and F_R is a recovery factor set between 0.1 and 1.0 (Wade 1998). The intent of this scheme is to provide a conservative removal level that will allow populations to recover to or remain above MNPL. Simulation models indicate that the approach is robust to biases associated with estimates of mortality, abundance, stock structure and other parameters (Wade 1998). As long as the magnitude of anthropogenic removals, such as by-catches, are below PBR, a stock of marine mammals should equilibrate above MNPL.

The 1994 amendments to the MMPA further require that mortality of marine mammals in commercial fisheries be reduced to negligible levels, referred to as the Zero Mortality Rate Goal (ZMRG), by April 2001 (Baur et al. 1999). The National Marine Fisheries has yet to finalize its operational definition of ZMRG (Dalton 2000), but it is likely that the eventual goal will be to reduce by-catches to less than 10% of PBR (NMFS 2000b). To date, most management has been directed at reducing by-catches to below PBR, but future take reduction efforts will also have to address ZMRG.

The MMPA further requires the Secretary of Commerce to categorize fisheries according to their likelihood of taking marine mammals during the course of their operations. Vessels in fisheries that are deemed to have frequent (Category I) or occasional (Category II) by-catches are required to obtain regulatory authority to make such by-catches by registering with the National Marine Fisheries Service. To assess the magnitude of by-catches, the National Marine Fisheries Service places observers aboard commercial fishing vessels to estimate the by-catch rate. This observed by-catch rate is then applied to a measure of total fishing effort to estimate the total by-catch for the fishery (*e.g.* Bravington & Bisack 1996; Bisack 1997). Vessels in Category I and II fisheries are required, by law, to carry an observer, if requested.

If the magnitude of by-catches, or other anthropogenic mortality, exceeds PBR for a stock of marine mammals, that stock is deemed to be *strategic*. In such cases, the MMPA requires that a *take reduction plan* be developed. These plans must include regulatory and/or voluntary measures that will reduce anthropogenic mortality and serious injury to below PBR within six months of their implementation. The take reduction plans are developed by teams of stakeholders, including representatives from federal agencies, academic and scientific organizations, environmental groups, commercial and recreational fishing groups and others. These stakeholders work through a process of negotiated rulemaking, in which they work with a federally appointed mediator to develop the plan. The objective of the process is to submit a *consensus* plan to the Secretary of Commerce that includes measures to reduce the by-catch of marine mammals in each Category I and II fishery for which by-catches of the strategic stock occurs. Plan development is rapid; the MMPA mandates that each plan be submitted to the Secretary of Commerce within six months of the formation of the team. The Secretary is then responsible for publishing and implementing the formal plan to reduce by-catches, based on the recommendations of the team. If the team is unable to achieve consensus on a plan, members submit statements outlining their position to the Secretary, who is then responsible for formulating a plan. I will not review the take reduction process here in detail, because several extensive reviews have been conducted by others (Cole 1997; Eisele 1997; Resolve 1999; Moore 2000; Young 2000). Take reduction teams will also be responsible for developing strategies to reduce by-catches to the ZMRG.

The take reduction process is the crucible in which by-catch mitigation strategies are developed in the United States. The intense pressure under which these teams work forces fishermen, scientists, managers and representatives of environmental groups to work *together* to find ways to reduce the by-catches of marine mammals in commercial fisheries. If the team cannot reach consensus on the Plan, the Secretary of Commerce is required by the MMPA to develop a plan to reduce takes below PBR. This default provision has acted as an incentive for stakeholders of diverse backgrounds and interests to work together to develop by-catch mitigation strategies. To date, five take reduction teams have been convened; three of these teams submitted consensus plans to the Secretary of Commerce. One of the two teams that failed to reach consensus dealt with the by-catch of large whales and thus is not relevant to ASCOBANS. The histories of the other four teams are reviewed briefly below.

Individual Case Studies

Gulf of Maine Harbour Porpoise Take Reduction Plan

By-catches of harbour porpoises in the Gulf of Maine multispecies sink gill net fishery have been among the largest of any marine mammal in U.S. commercial fisheries over the last decade (Waring et al. 1999). This fishery uses demersal gill nets to target a variety of groundfish species, including cod, pollock, flounder, monkfish and dogfish. The specific configurations of gear type (mesh size, twine diameter, string length, vertical profile, floatation) and fishing practices (soak duration and depth) vary considerably by region and target species. The PBR for this stock, which occurs in both U.S. and Canadian waters, is 483 porpoises per year. The by-catch of porpoises in the Gulf of Maine multispecies sink gill net fishery was estimated at 2,100 animals in 1994, when the MMPA amendments were passed (Waring et al. 1999), resulting in the determination that this was a strategic stock. The Gulf of Maine Harbour Porpoise Take Reduction Team was convened in February 1996 and met five times before submitting a consensus plan to the Secretary of Commerce in July 1996. This team was unusual in that many members had been working towards reducing by-catches as the Harbour Porpoise Working Group for several years prior to formation of this take reduction team. The Harbour Porpoise Working Group was an informal coalition of commercial gill net fishermen, scientists and representatives of environmental groups with interests in this issue, who met from 1990 to 1995. For example, members of this Group had organized a large-scale scientific experiment to determine the effectiveness of acoustic alarms, or pingers, in 1994 (Kraus et al. 1997), prior to the formation of the take reduction team.

The consensus take reduction plan included several measures designed to reduce the by-catch of harbour porpoises in this fishery, including: (1) time-area closures; (2) the use of pingers (acoustic alarms placed on nets) in specified times and areas; (3) research designed to improve our understanding of the mechanism and function of pingers; and (4) outreach and training programs. The team used data on variation in by-catch rates derived from the observer program to design a spatially and temporally explicit approach to reduce by-catches. The plan also assumed that by-catches of harbour porpoises from this stock in Canada and the Mid-Atlantic states would be addressed by separate plans (see below).

For a variety of reasons (see Young 2000), the National Marine Fisheries Service did not publish the final take reduction plan until December 1998 (see Appendix 1), after it was sued by several environmental organizations for failing to meet its statutory obligations. During the intervening period, however, the New England Fishery Management Council implemented several of the measures included in the take reduction plan, as well as many other measures designed to reduce gill net fishing effort the Gulf of Maine. The Council was under intense pressure to reduce fishing mortality on the Gulf of Maine cod stock during this period, because the stock was overfished and declining. These additional measures included limits on the number of fishing days per year, trip limits of target species and number of gill nets. The take reduction plan came into effect in January 1999; monitoring efforts since that time afford the opportunity to evaluate the success of its mitigation measures. The by-catch of harbour porpoises in the Gulf of Maine sink gill net fishery during 1999, the first year of plan of the plan's implementation, was estimated to be 270 animals, a 77% reduction in the historical (1994-1998) average by-catch and well below the PBR of 483 (Rossman 2000). Due to the large number of conservation measures implemented recently in this fishery, however, it is difficult to ascertain which particular strategy or strategies have been responsible for this reduction (see below). Detailed descriptions of the work of this take reduction team can be found in Cole (1997) and Young (2000).

Mid-Atlantic Harbour Porpoise Take Reduction Plan

Harbour porpoises from the Gulf of Maine stock move to the coastal waters of the Mid-Atlantic states (New Jersey to North Carolina) during the winter, where they are vulnerable to by-catch in a variety gill net fisheries for groundfish and small pelagic fishes. Because fisheries in the Mid-Atlantic were believed to be largely distinct from those in the Gulf of Maine, the National Marine Fisheries Service convened a separate take reduction team to address these by-catches in February 1997. The work of this team was complicated by several factors, including the existence of the Gulf of Maine harbour porpoise take reduction plan (which had 'allocated' 100 porpoise by-catches to the Mid-Atlantic region) and the fact that many fishermen from the Gulf of Maine were, in fact, moving seasonally to the Mid-Atlantic states to fish for groundfish.

This take reduction team submitted its report to the National Marine Fisheries Service in August 1997. The team was able to reach consensus on most, but not all, aspects of the take reduction plan. The plan included a suite of measures that differed fundamentally from those adopted by the Gulf of Maine team. Specifically, the Mid-Atlantic team recommended the following mitigation strategies: (1) a single time-area closure for the monkfish fishery in an area of historically high porpoise by-catch; and (2) restrictions on fishing gear in the dogfish and monkfish fisheries, including: net length, mesh size, twine diameter, and limits on the total number of nets used by individual fishermen. The gear restrictions were based on an analysis of data from the observer program that indicated certain types of nets had disproportionately high rates of porpoise by-catches (Palka 2000). The consensus portion of the plan also included recommendations for research and outreach. The team was unable to agree whether or not to conduct a scientific experiment to determine the efficacy of pingers in Mid-Atlantic gill net fisheries.

As was the case in the Gulf of Maine, the National Marine Fisheries Service failed to meet its statutory deadline in publishing and implementing the Mid-Atlantic Harbour Porpoise Take Reduction Plan. After successful litigation from environmental groups, the Service finally published regulations implementing this plan, together with the Gulf of Maine Harbour Porpoise Take Reduction Plan, in December 1998 (Appendix 1). The measures designed to reduce by-catches of harbour porpoises in this take reduction plan have been in place since January 1999. In 1999, the estimated by-catch of harbour porpoises in the Mid-Atlantic region was 49 animals, down from an average of 358 between 1995 and 1998 (NMFS 2000b). As with the Gulf of Maine Take Reduction Plan, however, it is not clear which, if any, of the mitigation strategies have caused this reduction or whether other factors, such as changes to fisheries management plans, are responsible (see Palka 2000).

Atlantic Offshore Cetaceans Take Reduction Plan

The Atlantic Offshore Cetaceans Take Reduction Team was convened in May 1996 to address the by-catch of various species of cetaceans in three fisheries: the pelagic drift net fishery for swordfish; the pelagic long line fishery for swordfish and tunas; and the pelagic pair trawl fishery for swordfish and tunas. The cetacean species taken as by-catch in these fisheries included: common dolphins, offshore bottlenose dolphins, several species of beaked whales, short and long-finned pilot whales, right whales, humpback whales and sperm whales (Waring et al. 1999). Right, humpback and sperm whales are listed as *endangered* under the U.S. Endangered Species. Mitigation measures for the pelagic drift net and pair trawl fisheries are pertinent to by-catches of small cetaceans in fisheries within the ASCOBANS area and will be described below, but I will not address strategies adopted for the pelagic long line fishery.

After arduous negotiations (see Eisele 1997), this team reached consensus on a take reduction plan for all three fisheries in November 1996. Negotiations of this team were complicated by the fact that the National Marine Fisheries Service denied the petition of fishermen to use pelagic pair trawl gear to take swordfish and tunas in September 1996, while the team was still meeting. Prior to this decision, pelagic pair trawls were classified as an experimental fishery and required annual authorization from the National Marine Fisheries Service. This regulatory decision essentially terminated this fishery in Atlantic waters of the U.S. Exclusive Economic Zone. The team continued to consider potential mitigation strategies for this fishery, however, and included these recommendations in its final consensus plan. The recommendations for this fishery included: (1) certification of vessel operators and fishing gear; (2) development of industry performance standards; and (3) research on the behaviour of cetaceans in the vicinity of pair trawls. For the pelagic drift net fishery, the team included the following recommendations: (1) 100% observer coverage; (2) limited entry into the fishery; (3) a large seasonal area closure in a region of high by-catches; (4) a set allocation system to individual vessels to reduce the derby nature of the fishery; (5) an experiment to determine whether pingers would be effective in reducing cetacean by-catches; (6) research on potential gear modifications; (7) outreach and monitoring programs; and (8) a buy-out program to reduce effort, by allowing fishermen to sell some or all of their set allocations to other fishermen or other interested parties (*e.g.* environmental groups). These measures were the most innovative and far-reaching of any take reduction plan developed to date. Nevertheless, in 1998 the National Marine Fisheries Service published regulations prohibiting the use of drift net fishing gear for taking North Atlantic swordfish, terminating this fishery. Several analyses have questioned whether this action was due to the high by-catch rates of cetaceans in this fishery, as maintained by the National Marine Fishery Service, or due to competition for allocation of the swordfish quota between the drift net and long line fisheries (Eisele 1997; Young 2000). To date, regulations addressing the by-catch of cetaceans in the pelagic long line fishery for swordfish, have not been published or implemented by the National Marine Fisheries Service. It is not possible to evaluate the mitigation strategies recommended by the team for the pelagic pair trawl and drift net fisheries, because both fisheries were closed prior to the implementation of these measures.

Pacific Offshore Cetacean Take Reduction Plan

The drift net fishery for thresher sharks and swordfish is similar to the Atlantic pelagic drift net fishery for swordfish and tunas; in fact, a few vessels have participated in both fisheries. The Pacific drift net fishery has a by-catch of: common dolphins, various beaked whales, short-finned pilot whales, pygmy sperm whales, sperm whales and humpback whales (Cameron and Forney 2000). The Pacific Offshore Cetacean Take Reduction Team was convened in February 1996 and met five times before submitting a consensus plan to the Secretary of Commerce in August 1996. The team was extremely effective in negotiating a set of mitigation measures to reduce the by-catch of small cetaceans in this fishery. These measures include the following: (1) regulating the depth at which nets are set; (2) conducting an experiment on the efficacy of pingers and, if the experiment was successful, requiring the use of these acoustic devices on all nets in the fishery; (3) mandatory skipper workshops; and (4) reduction in the number of drift net permits. The National Marine Fisheries Service published and began to implement final regulations, based on the team's recommendations, in October 1997 (Appendix 2). Since that time, further modifications have been made to the plan, including another experiment to determine the effect of pinger placement on the nets. After adoption of mitigation measures in this fishery in 1997, cetacean mortality decreased in 1998, and then rebounded in 1999 to levels similar to those observed prior to formulation of the plan. Estimated total mortality of cetaceans in this fishery was 418 in 1996, 209 in 1997, 54 in 1998 and 222 in 1999 (Cameron and Forney 2000).

Potential Mitigation Strategies

Acoustic Alarms

Pingers, or acoustic deterrent devices, are intended to reduce the by-catch of small cetaceans by producing a sound that: (1) is aversive to small cetaceans; (2) alerts small cetaceans to the presence of nets; or (3) is aversive to the prey of small cetaceans. As noted by the Scientific Committee of the International Whaling Commission (IWC 2000), on the basis of current evidence, the most plausible hypothesis is that pingers reduce by-catch rates by producing a sound that dolphins and porpoises find aversive. Pingers were first developed to reduce the number of entanglements of humpback whales in Newfoundland cod traps (Lien et al. 1992). Gill net fishermen in the Gulf of Maine learned of the use of these devices in Newfoundland experimented with pingers in the early 1990s. In the autumn of 1994, a large-scale experiment in the Gulf of Maine demonstrated their effectiveness in reducing the by-catch of harbour porpoises (Kraus et al. 1997).

Several pingers, producing various types of sound, are now commercially available in Europe and North America. Scientific experiments have demonstrated that acoustic alarms are effective in reducing the by-catch of small cetaceans in several areas of North America, including the Gulf of Maine (Kraus et al. 1997; Kraus and Brault 1998); California (Barlow and Cameron 1999); Washington State (Gearin et al. 2000); and the Bay of Fundy (Trippel et al. 1999). Similar experiments have been conducted within the ASCOBANS area itself (see review in IWC 2000). To date, in almost every case in which carefully controlled scientific experiments have been conducted, pingers have reduced the by-catch of small cetaceans in gill net fisheries. Based on this evidence, acoustic alarms have promise as a potential mitigation measure (IWC 2000).

Pingers have been implemented in two take reduction strategies: the Gulf of Maine Take Reduction Plan and the Pacific Cetacean Take Reduction Plan (details in Appendices 1 and 2). In both cases, implementation was preceded by scientific experiments in which a significant reduction in cetacean by-catches was demonstrated under controlled circumstances. In fact, in the Gulf of Maine, two scientific experiments were conducted in the same location at different times of the year (Kraus et al. 1997; Kraus and Brault 1998). In California, a large-scale experiment was conducted during 1996 and 1997 (Barlow and Cameron 1999). Based on the results of these experiments, both fisheries now require pingers, although in the Gulf of Maine the requirement is only for specific times and areas where the risk of porpoise by-catches is high (Appendix 1). In both take reduction plans, pingers are an integral component of the overall take reduction strategy.

Acoustic alarms reduce the by-catch of small cetaceans, when used under controlled conditions. Observed reductions in by-catch rate were 12-fold for common dolphins in the California experiment (Barlow and Cameron 1999) and 10-fold for harbour porpoises in the first Gulf of Maine experiment (Kraus et al. 1997). This level of by-catch reduction would be sufficient to meet most management objectives, even in the absence of other measures. The results of these experiments led the Scientific Committee of the International Whaling Commission (IWC 2000) to conclude that "the results of these experiments can be generalised to other situations where harbour porpoises are taken in bottom-set gill net fisheries." Thus, no further scientific trials are required prior to the implementation of acoustic alarms in bottom-set gill net fisheries within the ASCOBANS area. In addition, because several scientific experiments have already been conducted in the ASCOBANS area, many fishermen are already familiar with pingers as a potential mitigation tool. Several models of pingers are now available, with a variety of acoustic properties. And, as with any technology, experience in the field has resulted in improvements in performance.

Nevertheless, there are significant drawbacks to the use of pingers as a mitigation strategy. The devices are expensive, require periodic maintenance, are prone to failure, may interfere with the setting and hauling of the net, can reduce fishing performance and, in general, are unpopular with fishermen. Gill net fishermen on the Gulf of Maine Take Reduction Team have indicated that their colleagues are reticent to use pingers because of their cost and interference with setting and hauling procedures. Fishermen have also voiced concerns regarding the effects of the devices on fishing efficiency; most pingers are negatively buoyant and may lower the height of the head rope while the nets are fishing. In addition, pingers not equipped with salt water switches function continuously, even when stowed on board, and their continuous function is an annoyance to fishermen. In the California drift net fishery, fishermen have expressed concern over their safety when attaching pingers to nets when setting in rough seas (Cameron and Forney 2000). In tests in Virginia, gill net fishermen experienced reduced catches of Atlantic shad, perhaps because the fish are able to hear the alarms, although this appears to be an isolated experience. Finally, there are concerns regarding the long-term effectiveness of these devices, due to the potential for habituation by dolphins and porpoises over long periods of exposure (Cox et al. 2000).

In both Gulf of Maine and California, there have been serious problems of compliance with regulations requiring pingers. In the Gulf of Maine, compliance with required pinger use has ranged from 38% to 91% in areas in which the devices were required (NMFS 2000b). Thus, in some areas, more than 60% of gill net strings are not equipped with pingers, although their use is required by law. These data are taken from observed hauls of gill nets – trips in which federal observers accompanied fishermen on their trips. It is likely that, when non-observed trips are also considered, the actual level of compliance is actually considerably lower. In addition, these observations do not include strings of gill nets with incomplete pinger coverage or with non-functional pingers, because observers do not check to ensure that pingers are functioning when nets are brought on board.

In the Gulf of Maine, the by-catch rate of porpoises in strings of gill nets equipped with pingers has increased from 0.0 porpoises per haul in 1997 (n = 403 hauls) to 0.3 porpoises per haul in 1999 (n = 236 hauls) (NMFS 2000b). As noted above, because observers do not check to see whether or not the alarms are functional when the nets are hauled, it is not possible to determine whether this is a result of habituation or poor maintenance of the devices. Partial pinger coverage or function on a string of nets could produce 'black holes' which may actually increase the risk of entanglement (IWC 2000).

In the Bay of Fundy, Canada, where pingers are *not* required, not a single fishermen uses the devices, although they have been demonstrated to reduce the by-catch of harbour porpoises in scientific experiments (Trippel et al. 1999). The Bay of Fundy example, supported by observations from the Gulf of Maine, indicates that most fishermen will not use pingers on a voluntary basis. If pingers are to be used as a mitigation strategy, therefore, their use must be enforced by periodic checks or other monitoring of compliance.

In the United States, enforcement of required pinger use has proven to be a difficult proposition. The agency responsible for monitoring at-sea compliance, the U.S. Coast Guard, has declined to haul gill nets at sea to determine whether or not they are equipped with functioning acoustic alarms. This is because Coast Guard vessels are not equipped to haul sink gill net gear and because of the potential liability of the agency should the gear or catch be damaged during the process. Instead, the Coast Guard has resorted to periodic boarding of vessels in the process of hauling gill nets to determine whether or not the nets are equipped with functioning pingers. To date, two cases of non-compliance with pinger regulations have been brought to the courts from the Gulf of Maine fishery, one resulting in a fine of $1,050 US (Anonymous 2000) and the other case still pending.

Efforts to improve compliance with required pinger use by conducting dockside monitoring are also problematic. It is seldom practical for an enforcement agent to check the placement and function of pingers on stowed gill net gear. In addition, some fishermen may choose to place acoustic alarms on their nets as they are being set, rather than having them placed permanently on their gear.

The relatively high cost of pingers (between $40 and $80 U.S. each) and the lack of an effective enforcement system in the United States makes it unlikely that compliance with the required use of these devices will increase in the near future. In the most recent meeting of the Gulf of Maine Take Reduction Team in December 2000, members deliberated for more than a day over the most effective ways to increase compliance of required pinger usage. This prolonged discussion considered the merits of at-sea inspection, dockside enforcement and certification programs, without reaching consensus on a recommended action. Compliance and enforcement are also issues in the Pacific pelagic drift net fishery, where by-catches of cetaceans have occurred in strings of nets only partially equipped with functioning pingers (IWC 2000; Young 2000).

Time-Area Restrictions

Time –area restrictions are used by fisheries managers to address the by-catch of non-target species in situations where there is significant variation in the degree of co-occurrence between the catch of target and non-target species (Murawski 1994; Goodyear 1998). Fishing activities are regulated or prohibited in areas where by-catch rates are high and unrestricted in other regions (Murawski et al. 2000). Thus, this measure is effective when high by-catch rates are known to occur predictably in time and space. In essence, by-catch 'hot-spots' must exist *and* be identified before this management tool can be used.

Time-area fisheries restrictions have been implemented in the Gulf of Maine and Mid-Atlantic Harbour Porpoise Take Reduction Plans and were recommended for the now defunct drift net fishery in the Atlantic Offshore Cetaceans Take Reduction Plan. More permanent restrictions have been used in New Zealand to address the by-catch of Hectors dolphins in gill net fisheries (Dawson and Slooten 1993). In the Gulf of Maine, Mid-Atlantic and Atlantic Offshore Cetacean Plans, data on spatial and temporal variation, derived from observer programs, were available for analysis by the teams during their deliberations. In the Gulf of Maine and Mid-Atlantic, by-catches appeared to be clumped in time and space, although significant inter-annual variation existed in these patterns. In the drift net fishery, team members chose to eliminate a seasonal component of fishing effort which experienced very high by-catches of small cetaceans. Thus, it was possible for all three teams to predict what level of by-catch reduction would be achieved by closing certain areas, assuming that no displacement of fishing effort and by-catch resulted from those closures.

In the Gulf of Maine Plan, certain areas are completely closed to gill net fishing during proscribed periods, while other areas require the use of pingers on a seasonal basis (Appendices 1 and 3). In addition, one permanent closure and a complex series of 'rolling closures' have been implemented in this fishery by the New England Fishery Management Council to reduce fishing mortality on stocks of groundfish. The resulting series of spatial and temporal restrictions on gill net fishing activity in the Gulf of Maine is complex, to say the least (see Figure 1 in Appendix 1). In the Mid-Atlantic Plan, a single area is completely closed to the gill net fishery for a one-month period (Appendices 1 and 3).

Murray et al. (2000) reviewed the efficacy of a time-area closure implemented by the New England Fishery Management Council in 1994, prior to the formation of the take reduction team. This closure, in the Mid-Coast area, was one of three instituted by the Council to reduce the by-catch of porpoises in the Gulf of Maine. Murray et al. (2000) concluded that the closure was not large enough, nor in place long enough, to be effective in reducing the by-catch of harbour porpoises. The failure of the closure was attributed to inter-annual variation in the spatial and temporal distribution of by-catches and to the displacement of fishing effort and by-catch mortality outside the closed area. The same conclusions may be drawn from the other two closures instituted in 1994, as the total by-catch of harbour porpoises actually rose following their implementation, from 1,400 in 1993 to 2,100 in 1994 (Bisack 1997). To have been effective, the closure system would have to encompassed more area and been in place for significantly longer periods. Such measures were eventually adopted in 1998, after prolonged and bitter debate, by the New England Fishery Management Council to conserve depleted stocks of groundfish in the Gulf of Maine under the New England Multispecies Fisheries Management Plan (Appendix 1).

Murray et al. (2000) concluded that there are specific conditions under which time-area restrictions may be effective in reducing the by-catch of small cetaceans: (1) the area where by-catch occurs is a small subset of the area where fishing effort occurs; (2) patterns of by-catch are predictable in time and space; (3) there is no displacement of fishing effort that results in by-catch rates as high or higher than in the closure area; (4) fishermen support and co-operate with the regulations; and (5) an adequate information base exists on which to design closures.

Time-area restrictions are unlikely to be effective in situations where there is little significant spatial or temporal variation in the by-catch rate, or in which there is considerable inter-annual variation in these patterns. In addition, these measures may be unpopular with fishermen, some of whom may be prevented from setting their nets in preferred fishing grounds. Compliance and enforcement are also issues with this approach; in the Gulf of Maine, for example, fishermen have set their nets in closed areas, even when federal observers were aboard their vessels (NMFS 2000b). A similar problem has arisen in the Gulf of California, Mexico, where fishermen routinely set their nets within the core zone of a Biosphere Reserve designed, in large part, to protect the critically endangered vaquita from by-catches (IWC 2000). Thus, any time-area closure system must be enforced to ensure compliance.

Modifications to Fishing Gear and Practices

Not all types of fishing gear, or the ways in which the gear are used, have equal probabilities of entangling a dolphin or porpoise. If by-catch rates vary significantly with fishing practices, regulations can be promulgated to require only the most benign practices. In situations where observer programs are in place, such data are collected routinely, but seldom analysed. Such measures have considerable promise to reduce the by-catch of small cetaceans, because they build on existing fishing practices, rather than generating new measures that may be unfamiliar to, and unpopular with, fishery participants.

Modifications to fishing gear and practices are components of the Mid-Atlantic Harbour Porpoise and Pacific Cetacean Take Reduction. In fact, such measures are the most important aspects of the Mid-Atlantic Plan (Appendix 1). In the Mid-Atlantic, measures include seasonal and spatial restrictions on the following: (1) the total length of each gill net string; (2) the diameter of monofilament twine; (3) mesh size; (4) the use of 'tie-downs' to reduce the vertical height on nets as they fish on the sea floor; and (5) a cap on the total number of nets fished by individuals. These measures were agreed to by the team after they examined analyses of data collected by observers working with this fishery indicated that the by-catch rate of harbour porpoises was significantly affected by the configuration of gill net gear (Palka 2000). Using these findings, the team negotiated a set of restrictions that were likely to meet the required reduction in by-catch. Similarly, the Pacific Cetaceans Take Reduction Team used an analysis of data collected by on-board observers to determine that the probability of entangling a cetacean was reduced by 25% when drift nets were set at depths greater than 6 fathoms, or 10.9 m (Appendix 2).

Other measures were considered by the Mid-Atlantic Team, but not included in their Plan. These measures included restrictions on the soak time of gill nets and the requirement that fishermen tend their nets while fishing. Such measures are likely to reduce the by-catch of small cetaceans by reducing total fishing effort, but were eventually rejected as either impractical or unenforceable. Nevertheless, these mitigation strategies are promising and may have merit in other fisheries. In a similar fashion, the Pacific Cetaceans Take Reduction Team recommended further evaluation of the potential for regulation of twine diameter and mesh size to reduce by-catches in the California drift net fishery (Appendix 2). In their plan, the Atlantic Offshore Cetaceans Take Reduction Team also recommended research on potential gear and fishing modifications.

Evaluation of the efficacy of measures in the Mid-Atlantic Plan have been complicated by significant inter-annual variation in by-catch rates and by changes in patterns of fishing effort caused by fisheries management measures (NMFS 2000b; Palka 2000). In a similar fashion, although by-catch rates have increased recently in the California drift net fishery (Cameron and Forney 2000), it is not possible to determine which factors are responsible for this change.

The use of restrictions on fishing gear and practices to reduce the by-catch of small cetaceans requires the following: (1) an observer program to collect information on fishing gear and practices; (2) variation in fishing gear and practices that results in concomitant variation in by-catch rates; and (3) agreement of the fishing industry to conform to such regulations. The latter factor is important, as it appears that significant non-compliance has occurred with provisions of the Mid-Atlantic Take Reduction Plan (Palka 2000). If such measures are unpopular with fishermen, enforcement must ensure compliance with the regulations.

Reducing Fishing Effort

The most straightforward means of reducing the by-catch of small cetaceans in commercial fisheries is to reduce the amount of fishing effort. Clearly, unless there is significant variation in the by-catch rate of fishery participants, a reduction in the amount of fishing effort should result in a proportional reduction in the number of dolphins and porpoises killed. In some cases, a threshold of by-catch mortality can be used to trigger a closure of a fishery (Hall 1998), which is essentially a termination of effort. In a similar fashion, the elimination of certain fisheries with high by-catch rates is essentially a complete (and effective) effort reduction measure.

The Pacific Cetaceans Take Reduction Plan incorporated a measure to reduce fishing effort as part of its strategy to reduce by-catches in the California drift net fishery. The team recommended a reduction in the number of permits issued in this fishery as a means of reducing by-catch (Appendix 2). This measure included a moratorium on new permits and a buy-back program to encourage part-time participants to leave the fishery. The Atlantic Offshore Cetaceans Take Reduction Plan, although never implemented due to the closure of the drift net fishery, included a buy-back program to reduce fishing effort. In this innovative program, individual vessels were to be allocated a quota of sets for each fishing season and could sell some or all of those sets to anyone with an interest in the fishery – other fishermen, or environmental groups that wished to retire a portion of the total fishing effort. This measure would have required observer coverage on all vessels in this small fishery.

Reductions of fishing effort are often an unpopular solution to by-catches (Hall et al. 2000). Nevertheless, in situations where the target species of a fishery is over-harvested, restrictions of fishing effort can have beneficial consequences for the fisheries resource, the species taken as by-catch and, eventually, participants in the fishery. In the Gulf of Maine, for example, fishing effort in the groundfish sink gill net fishery is currently restricted by several measures, including a days-at-sea provision, a cap on the number of nets, and trip limits on the amount of target species landed, in addition to measures designed to protect harbour porpoises. The most parsimonious explanation for the reduction in porpoise by-catches following the implementation of the Take Reduction Plan is *not* the effects of pingers and time-area closures, but the conservation measures that have reduced fishing effort on overfished stocks of groundfish. As noted by Rossman (2000) "The reduction in harbor porpoise by-catch during 1999 can mostly be attributed to a lack of commercial fishing effort..." Time will tell whether the measures put into place to conserve harbour porpoises will be effective when groundfish stocks recover and fishing effort intensifies.

Acoustically Reflective Gill Nets

Acoustically reflective gill nets are designed to improve the ability of echolocating odontocetes to detect nets. The acoustical characteristics of the nets are enhanced by adding dense material (such as $BaSO_4$) to the nylon used to manufacture monofilament. Nylon has a density similar to that of water, providing a poor target to echolocating odontocetes (*e.g*. Kastelein et al. 2000). The added material is considerably denser than water, resulting in nets with increased acoustical target strengths. This measure is predicated on the assumption that dolphins and porpoises echolocate in the vicinity of gill nets and that entanglement occurs because individual odontocetes do not detect nets in time to avoid them.

Acoustically reflective gill nets have not been implemented in any take reduction plan, but preliminary tests have been conducted in the Bay of Fundy. In the Bay of Fundy, experimental trials indicated that acoustically reflective nets are effective in reducing the by-catch of harbour porpoises in a statistically significant fashion (Trippel 2000). In 1998 and 2000, seven of 242 control strings had at least one porpoise by-catch, whereas no porpoises were taken in 124 strings of acoustically reflective gill nets (Trippel 2000). In the Bay of Fundy tests, no significant difference was observed in the catch rate of target species between control and acoustically reflective nets (Trippel 2000). The Scientific Committee of the International Whaling Commission endorsed further experimentation with this potential mitigation strategy, while acknowledging that previous attempts to use acoustically reflective nets (by incorporating material *lighter* than nylon) had been ineffective (IWC 2000). The Gulf of Maine Take Reduction Team, at its most recent meeting in December 2000, recommended that a large-scale experiment be conducted to determine whether or not acoustically reflective gill nets would reduce the by-catch rates of harbour porpoises in the groundfish sink gill net fishery.

If they prove to be effective in reducing the by-catch of small cetaceans in gill net fisheries, *and* do not reduce the catch of target fish species, acoustically reflective gill nets hold great promise as a mitigation strategy. The nets are relatively inexpensive (only 20% more than conventional gill nets) and, unlike pingers, do not require additional maintenance. As is the case with acoustic alarms, the mechanism by which these nets reduce by-catch (if, indeed, they do reduce by-catch) is not understood. For acoustically reflective nets to be effective, odontocetes must be echolocating in their vicinity; currently we do not understand how frequently and in what context dolphins and porpoise produce echolocation signals. Incorporation of acoustically reflective material into the nylon used to manufacture monofilament stiffens the resulting nets and it is possible that this stiffness, rather than any acoustic property, is responsible for the observed reduction of by-catch in preliminary trials. It is important to note, however, that the mechanism of function is not necessarily important, and that if some change to the physical properties of monofilament gill nets results in a lower by-catch rate of dolphins and porpoises, this modification has potential as a mitigation measure. Clearly, further experimentation is warranted with acoustically reflective gill nets.

Conclusions

The following conclusions reflect my analysis of mitigation measures implemented in the United States, as well as my personal experience as a member of three take reduction teams.

Clear Statement of Objectives

One of the advantages of the PBR approach is its simplicity – fishermen, environmentalists and fishery managers all have a clear goal to work towards. In addition, the goal is a simple and transparent product of three parameters readily understood by all stakeholders, not the outcome of a complex model. In negotiations conducted during the take reduction team process, all participants had a clear, quantitative goal to work towards. The participants may not have agreed with the objective of reducing by-catch mortality to below PBR, but, once involved in the process, they were able to work towards this goal.

ASCOBANS has already made significant progress to defining its conservation objectives. It is clear that, whatever by-catch mitigation strategies are eventually employed within the ASCOBANS area, the success of these efforts will depend on a clear, quantitative statement of conservation objectives and a timetable to reach these goals.

Involvement of Stakeholders

The take reduction process of the MMPA mandates the direct involvement of stakeholders in the formulation of strategies designed to reduce by-catches of marine mammals in commercial fisheries. It is both equitable and logical to involve fisheries participants in such decision-making; fishermen, after all, are the most familiar with their own practices and the consequences of these activities. Solutions to by-catch problems may already exist within the universe of current fishing practices – bringing fishermen to the table allows these ideas to surface, be evaluated, refined and then tested under controlled circumstances. In a similar vein, it is both fair and practical that representatives of environmental and animal welfare organizations be included in the development of by-catch mitigation strategies. It is the role of these individuals to ensure that conservation objectives are met; in the United States, environmental groups have played an integral role in the formulation and implementation of take reduction strategies.

In 1998, the National Marine Fisheries Service commissioned a survey of take reduction team members to evaluate their opinions of the negotiation phase of this process (teams continue to meet after the plans have been implemented, to monitor their effectiveness and suggest changes to the plans, if necessary). A majority of respondents indicated that the take reduction process was effective (86%) and fair (78%), although many participants (60%) were ultimately dissatisfied with the outcome of the negotiations (Resolve 1999). This indicates that, although team members may not have approved of the outcome of their negotiations, they agreed to these measures to achieve their goal of reducing by-catches below PBR (but see comments on enforcement and compliance below). Participants believed that they were more likely to achieve a successful outcome by participating in the process than by opting out and allowing the federal government to design a take reduction plan. This is clearly a critical component of the success or failure of such a negotiated rulemaking exercise. If participants believe they are more likely to achieve their goals outside the negotiation process, they will opt out. For the process to be successful, participants must be convinced that they can gain more by negotiating in good faith. The consensus framework and presence of a neutral mediator are both important components of the success of this approach.

In any search for solutions to the problem of by-catches, the direct involvement of stakeholders, including both fishermen and environmentalists, is necessary for the formulation of effective mitigation strategies.

Observer Programs

Without unbiased data on the pattern and variation of by-catches, it is simply not possible to develop or evaluate conservation alternatives. Voluntary data collection schemes do not provide useful information on the magnitude or distribution of by-catches. Data collected by independent observers were used intensively by every take reduction team reviewed in this report. These data underpin *all* efforts to reduce by-catches in the United States; in fact, despite the cost and inconvenience of such programs, it is difficult to conceive of any practical system of by-catch mitigation that did not rely on a data collection system employing independent observers. Such programs are necessary to provide the data required to formulate effective by-catch mitigation strategies and, after their implementation, to determine the success or failure of such approaches.

Case-specific approaches

Each operational interaction between small cetaceans and commercial fishing gear requires a solution specific to that combination of animals and gear. The behaviour of dolphins and porpoises varies from species to species, as do the methods employed by fishermen from area to area. It is seldom possible to generalize from one by-catch problem to another; most of these interactions will require a solution that reflects a unique combination of animal and human behaviour.

In addition, it is noteworthy that *none* of the take reduction strategies developed in the United States relied on a single mitigation measure. In all cases, stakeholders decided to employ multiple strategies to address these problems, likely due to the uncertainty associated with any particular individual measure. Implicit in this approach (but explicit in the take reduction paradigm) is the ability to monitor the effectiveness of each strategy after implementation and to use data from observer programs as a feed-back loop to modify take reduction strategies to meet management goals.

Compliance & Enforcement

The by-catch of a dolphin or porpoise in a trawl or gill net typically causes little or no reduction in catch or damage to gear. The carcass can be disposed of readily, usually with little delay in the time required to haul or set nets. Thus, the by-catch of a small cetacean seldom causes any economic cost to a fishermen. To persuade a fishermen to change his practices to avoid such occurrences, therefore, requires the imposition of an external cost, potential or realized, through regulation. Unfortunately, this cost can be achieved only through enforcement of penalties associated with non-compliance with regulations. One of the clear lessons from the U.S. experience is that enforcement is required to ensure compliance with take reduction measures. Most mitigation measures employed in U.S. fisheries to date have been plagued by non-compliance; managers must be ready to adopt enforcement measures and penalties that are sufficiently costly to ensure that fishermen comply with regulations designed to reduce by-catches.

Conflicts between Management Objectives

One of the fundamental obstacles to the development of effective strategies to reduce the by-catch of small cetaceans in commercial fisheries in the United States is the conflict between objectives of the MFCMA and MMPA. Fisheries management and marine mammal conservation are, in many cases, fundamentally in opposition. The primary objective of fisheries management, the optimization of yield from resource harvest, may be incompatible with the maintenance of marine mammal populations at their optimum sustainable populations (Gerber et al. 1999). Harmonization of these objectives, and expansion of traditional fisheries management goals to include the conservation of multiple species and ecosystems, is one of the most pressing challenges to U.S. fisheries managers in the coming century. It is likely that similar conflicts exist between the conservation objectives of ASCOBANS and national and the Common Fisheries Policy of Europe. The first step on this journey is an explicit recognition of the potential conflict between management objectives; until we recognize that such a problem exists, it is not possible to address it.

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