

PINGERS, PORPOISES AND POWER: UNCERTAINTIES WITH USING PINGERS TO REDUCE BYCATCH OF SMALL CETACEANS

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Abstract

Incidental mortality in gillnets is probably the most serious global threat to dolphin and porpoise populations. In 1994, a well-designed study demonstrated a 92% reduction in bycatch of harbour porpoises in sink gillnets equipped with acoustic pingers. This result has not yet been fully replicated; in the New Hampshire area where the experiment was conducted or elsewhere. Statistical power analyses indicate that such studies are feasible only in areas of high entanglement rate. Currently unanswered research questions include whether the 1994 results can be replicated, whether habituation might decrease effectiveness over time, and what the mechanism of deterrence is. Practical constraints include the size, cost and battery life of current pingers, and whether their use could be monitored cost-effectively. From a management perspective, even if the effectiveness of pingers is confirmed, widespread incorporation of them into gillnets may not alone be sufficient to meet the requirements of the US Marine Mammal Protection Act. For this reason scientists, managers and fishers must continue to explore other options, including time/area closures and encouragement of more selective fishing methods. © 1998 Elsevier Science Ltd. All rights reserved.

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INTRODUCTION

Incidental mortality of dolphins (Delphinidae) and porpoises (Phocoenidae) occurs in almost every marine gillnet fishery, killing many tens of thousands of animals annually (IWC, 1994). In several cases this mortality threatens stocks and/or species with extinction (Reeves and Leatherwood, 1994).

One of the species most frequently killed in such interactions is harbour porpoise, *Phocoena phocoena*

(Jefferson and Curry, 1994; IWC, 1996). For example, recent estimates of incidental catches in US waters of the Gulf of Maine ranged from 2900 (1990; 95% CI=1500–5500) to 1200 (1992; 95% CI=800–1700; Bravington and Bisack, 1996). Estimates of the abundance of this stock range from 37,500 (1991; 95% CI=26,700–86,400) to 67,500 (1992; 95% CI=32,900–104,600). Some of these bycatch levels (Palka *et al.*, 1996) are unlikely to be sustainable (Woodley and Read, 1991) and may have caused changes in life history and distribution (Read and Gaskin, 1990).

The US Marine Mammal Protection Act (MMPA) mandates that incidental mortality of marine mammals in commercial fisheries must be (1) biologically sustainable as defined by the 'Potential Biological Removal' (PBR) formula, and (2) decrease to levels approaching zero by 30 April 2001. The 'Zero Mortality Rate Goal' is currently proposed to be 10% of the PBR (Barlow *et al.*, 1995). Applying this scheme in the Gulf of Maine yields an allowable annual removal level (PBR) of 403 porpoises, but after 30 April 2001 annual mortality should not exceed 40. Hence the MMPA imposes an inescapable requirement on fishers and scientists to solve the problem of harbour porpoise mortality in gillnets.

Proposed solutions to the problem of bycatches in gillnets have included several types of gear modifications, including the use of acoustic 'alarms' on nets to warn animals of their presence (e.g. Hatakeyama *et al.*, 1994). An acoustic alarm system might reduce bycatch if porpoises become entangled because they are unaware of the nets' presence. Such a system could work if (a) the sounds are intrinsically aversive, (b) they encourage echolocation, and therefore make detection of the net more likely, and/or (c) the porpoises learn to associate the sound with the danger of the net, and hence perceive it as indicating danger (Dawson, 1994). However, some 15 years of experiments with various acoustic methods have shown little promise of providing substantial or consistent reductions in entanglement rates (Dawson 1991, 1994; Todd and Nelson, 1994; Jefferson and Curry, 1996).

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A recent experiment with acoustic emitters or 'pingers' (Kraus *et al.*, 1997) differed from previous work in two ways: (1) it was carefully designed to give the best possible chance of detecting differences in catch rate between nets with and without pingers, and (2) unlike previous studies, nets with active pingers had a substantially lower entanglement rate.

In this paper we review current research and outline unresolved issues associated with pinger use to reduce bycatch, including uncertainties about their effectiveness. Our purpose is to stimulate discussion on this issue, and help chart the way forward for research and management.

RECENT FIELD STUDIES OF PINGER EFFECTS

Preliminary trials of pingers on sink gillnets in New Hampshire in 1992 and 1993 were promising but inconclusive because of their small scale and poor experimental design. The National Marine Fisheries Service convened a scientific review panel to consider these results and outline design features needed for a more definitive study. Following these recommendations, Kraus *et al.* (1997) conducted a full-scale experiment in New Hampshire coastal waters (on Jefferies Ledge) during autumn 1994. The pingers used in this experiment emitted a 300 ms pulse every 4 s, with a fundamental frequency of 10 kHz, but with harmonics that extended to beyond 80 kHz.

Kraus *et al.*'s study was exemplary in its design and execution. Importantly, the experiment took place in an area of high bycatch rates. Neither fishers nor independent observers knew which pingers were active. The experiment was designed following a statistical power analysis of the scale needed to detect a 50% difference, and the design was balanced (equal numbers of control and experimental sets). These basic aspects of good experimental design have been lacking in most previous studies (Dawson, 1994).

This trial produced the most spectacular reduction shown by any study of gillnet modifications to date. Nets with active pingers caught two porpoises in 421 strings while nets with inactive pingers caught 25 porpoises in 423 strings.

Results of pinger use since this experiment have been less clear. Observers monitored the commercial use of pingers in the Jefferies Ledge area during the fall 1995 fishery. No porpoises takes were observed in 225 hauls. Pre-pinger take rates suggest that 4–7 porpoises would have been taken had pingers not been used. In the spring fishery in this area, however, observers saw nine porpoises taken in 88 hauls—exactly the same average take rate as the previous five years. Similar trials in a spring fishery in Massachusetts Bay resulted in two takes observed in 171 hauls—also the same average take rate as the previous five years (IWC, in press). Data from the use of pingers south of Cape Cod in Spring

1996 (no observed takes in 53 sets) are not helpful because there are no historical data for comparison.

The results from the Kraus *et al.* (1997) experiment are supported by studies in two other areas. Gearin *et al.* (1996) placed 2.7 kHz pingers on bottom-set gillnets in the Makah fishery for salmon (*Onchorhynchus tshawytscha*), in the coastal waters of Washington State. In both the 1995 and 1996 trials, porpoise bycatches were significantly reduced in nets equipped with pingers. Design problems with the 1995 trials were rectified the following year. Theodolite observations during the latter trial showed that porpoises avoided the area around the nets with pingers (Laake *et al.*, 1997, unpub. ms.). Theodolite observations of a simulated net in Clayoquot Sound (British Columbia) showed that porpoises avoided 2.7 kHz pingers but did not avoid float-type passive reflectors (Koschinski and Culik, in press).

Since the 1994 New Hampshire experiment, pingers have been embraced as part of a mitigation strategy to reduce bycatches of harbour porpoises to levels below the PBR threshold in the Gulf of Maine. This strategy also includes the designation of times and areas in which no gillnet fishing is allowed, to eliminate the risk of bycatch (Anderson *et al.*, 1996).

OBSTACLES AND PREREQUISITES TO THE WIDESPREAD USE OF PINGERS

Several scientific and practical issues need to be resolved before pingers can be advocated as a useful management tool to reduce bycatch.

Key questions relating to the effectiveness of pingers

1. What generalisations are possible from the results of the Kraus *et al.* experiment?

The Kraus *et al.* (1997) trial was conducted in one area, in one season. It must be replicated in both time and area before results can be validly generalised for harbour porpoises in similar habitats. Likewise, we cannot expect the New Hampshire results to apply to other species. Currently, no data are available to indicate whether pingers might reduce the bycatch of delphinids, although from our experience with harbour porpoises and coastal delphinids, this seems unlikely. Harbour porpoises seem to be neophobic—they tend to react negatively to novel stimuli. On the other hand, dolphins often respond inquisitively to new stimuli.

2. What is the mechanism of deterrence?

Currently, it is not clear why nets with active pingers caught fewer porpoises in the Kraus *et al.* (1997) trial. The pingers may have influenced porpoise behaviour indirectly. The bycatch of Atlantic herring (*Clupea harengus*) was 6.5 times lower in strings with active alarms than in those

without, and many of the porpoises caught had been feeding on herring. Herring and other clupeoid fishes can hear the frequencies emitted by current pingers (Nestler *et al.*, 1992) and may have reacted to the alarms by moving away from the vicinity of the nets. If so, pingers might be ineffective in places where porpoises do not eat herring. Harbour porpoises in Washington State, the other area in which pingers have apparently reduced porpoise bycatch, also feed on herring (Gearin *et al.*, 1994). Without understanding how pingers work, it is impossible to predict whether they will work in a new area.

3. Will pingers lose effectiveness over time?

This question is currently unanswerable because of the limited duration (2 months) of the New Hampshire experiment, and the fishery trials which followed it. Porpoises in New Hampshire are considered to be migratory, rather than resident (IWC, 1996). Koschinski and Culik (in press) found that while porpoises avoided a simulated net with pingers, this effect appeared to decrease during the six days of intensive monitoring during continuous pinger use. They suggested habituation as a possible explanation. One would expect a much higher chance of habituation in areas where porpoises are resident, and thus exposed to pinger sounds more continuously.

4. Do they work in a real-life fishery?

Following the 1994 trial, gillnet fishers in New Hampshire have continued to use pingers. As indicated above, results suggest pingers are sometimes effective, sometimes not. This raises serious doubts that pingers will be effective long-term, and emphasizes the need for a cautious approach in the wake of the New Hampshire experiment.

Practical issues

(a) Cost

Current cost of the latest generation of the pingers used by Kraus *et al.* (1997) is 40–US\$55 each (Kraus, pers. comm.). Kraus and his co-workers used one pinger per 92 m of net. Pinger cost is substantial if one contemplates equipping an entire gillnet fishery at this ratio, and changing batteries regularly. Capital and running costs are likely to limit pinger use to valuable fisheries in developed countries.

(b) Practicality in real fishing operations

The pingers currently used in New Hampshire are small (11.5 cm length × 4.8 cm diameter), and are the first generation of sound emitters that are practical for routine use in gillnets (c.f. Hatakeyama, 1994). Battery life is currently 30 days. Ideally, pingers should be sufficiently robust and ergonomic to be an integral part of the gear, and left in place for a season's duration.

(c) Pinniped damage to gillnet catches

Seal damage to net-caught fish is a problem in some gillnet fisheries (Reeves *et al.*, 1996). Given the learning ability of pinnipeds (e.g. Schusterman, 1981) it seems likely that these predators will learn to associate the pinger sounds with the presence of nets, and therefore food, increasing damage to catches (see also Jefferson and Curry, 1996).

Monitoring and policing

Should pinger use become mandatory, management agencies will need to ensure compliance. If pingers activate automatically, have long battery life, are date-stamped, and are incorporated as an integral part of gillnetting gear, monitoring could be done at the dockside. Otherwise at-sea observation will be needed. Battery life may be the key issue for compliance.

RECOMMENDATIONS FOR RESEARCH AND MANAGEMENT

Scientific recommendations

1. Replication of results in time and space

Pinger experiments that are replicated in time and space are the most immediate need. These studies should include a range of different habitats. It will be particularly important to choose some areas where herring is not a major item of the diet of harbour porpoises.

Before further trials can be robustly designed it is crucial to know the entanglement rate expected in control nets. Additionally, three decisions must be made on (a) the target for bycatch reduction (an obvious one is that imposed by the requirements of the MMPA), (b) the level of statistical 'significance' required (chance of falsely detecting a difference; e.g. $p = 0.10$), and (c) the level of statistical power required (ability to detect a difference of the magnitude specified; e.g. 0.80; see Fairweather, 1991 for further explanation). Then, straightforward statistical approaches to analysing frequencies (e.g. Fisher's exact test) can be used to calculate the sample size required to demonstrate the target difference.

It is obvious that large reductions in bycatch are easier to detect than small ones and hence require experiments on a smaller and less expensive scale (Fig. 1). Less obvious is that such simple 'prior power analysis' (*sensu* Fairweather, 1991) can provide guidance on what species tests should be conducted on, in what areas, and during which times. For example, it is clear that very large-scale trials are required if the probability of entanglement in unmodified (control) nets is low (below about 2%; Fig. 2). If the bycatch rate in unmodi-

fied sets is 1%, almost 2700 sets each of unmodified gear and modified gear would be needed to show a 50% bycatch reduction with 80% power (at $p=0.10$). This means that such studies cannot be carried out cost-effectively in areas of low entanglement rate. This is an important constraint since the low reproductive rate of dolphins and

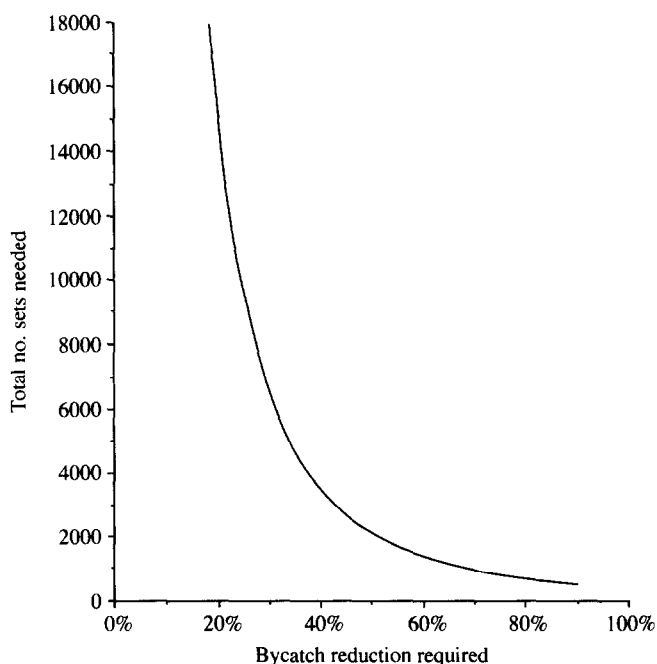


Fig. 1. The approximate total number of sets of net strings (1:1 ratio of modified:unmodified) needed to demonstrate with 0.80 power ($p < 0.10$, 1-tailed) a bycatch reduction of given magnitude, assuming a probability of entanglement per control set of 0.025. Computations are via the normal approximation to Fisher's exact test.

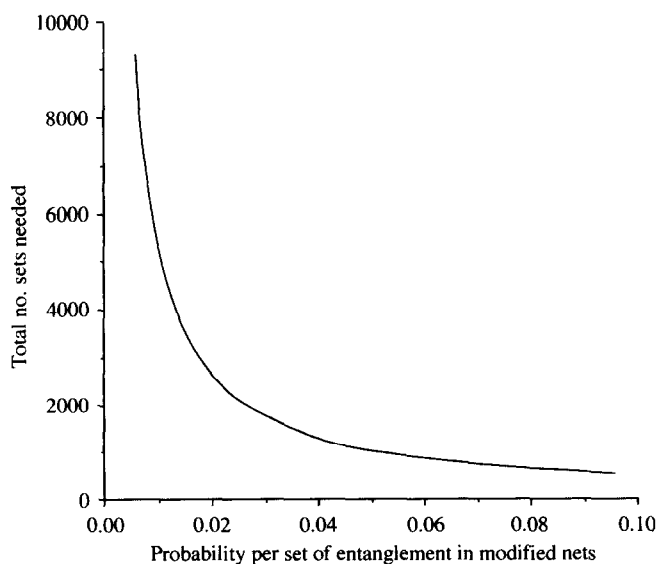


Fig. 2. The approximate total number of sets of net strings (1:1 ratio of modified:unmodified) needed to demonstrate with 0.80 power ($p < 0.10$, 1-tailed) a 50% bycatch reduction given various probabilities of entanglement in unmodified strings.

porpoises makes small populations vulnerable even at low rates of entanglement.

2. Research on habituation

There is a substantial risk that small cetaceans will habituate to pingers. Well-designed longer-term studies of entanglement rates in nets with and without pingers will help answer this question. The methods of Koschinski and Culik (in press) are potentially very useful, and much cheaper. In this study, cliff-top observers used a theodolite to quantify changes in porpoise distribution when pingers were in use on a simulated gillnet. They found that porpoises avoided the area when the pingers were 'on'. Such studies, however, are not a test of the effectiveness of alarms at keeping porpoises out of real nets, so they are not an alternative to full-scale gillnet trials.

Observations of captive animals interacting with fishing gear (e.g. Hatakeyama and Soeda, 1990; Kastelein *et al.*, 1995a) can provide detail not observable in the field. This is especially true for questions of how animals become entangled. However, studies of captive animals are open to criticisms about the artificial nature of experimental conditions and whether observed behaviour accurately reflects that seen in the wild. Echolocation rates, for example, might be lower in a reverberant tank than in the open ocean. This problem also applies to tests of response to pingers in captivity. For example, Kastelein *et al.* (1995b) showed that pinger sounds altered the behaviour of captive porpoises. They noted, however, that such a reaction might not occur in the wild because porpoises would not suddenly be exposed to loud sound; instead the sound would appear to gradually increase in volume as porpoises approached. Also, in the wild, porpoises would be able to avoid the source of the sound.

3. Research on causation

Experiments are needed to test whether the success of the 1994 experiment was mediated via the behaviour of the prey of harbour porpoises. Anecdotal reports suggest that pingers reduce the catch of target species in fisheries for alosids and clupeids (IWC, in press). Detailed experimental observations are required to confirm or refute these reports and provide information on the mechanism(s) by which porpoise bycatch was reduced in the 1994 experiment.

4. General issues

A recent international workshop on acoustic deterrents to reduce bycatch (Reeves *et al.*, 1996) endorsed the view that we should avoid putting sounds into the oceans unless we need to do so. Pingers could cause unexpected effects. For example, widespread use of pingers in the Gulf of Maine could alter the distribution of herring, a commercially important fish. Pingers may have

other effects that have not yet been detected. Wider-ranging studies of the effects of pinger noise are warranted.

If the benefits of pingers in reducing porpoise catch are confirmed by replicated studies, and if the issues of habituation and practicality can be overcome, an obvious next step is to see if pingers are effective in reducing the bycatch of other species. In our view it would be premature to extend pinger work to other species while these questions remain open.

Management recommendations

The Kraus *et al.* (1997) study cost approximately US\$500,000. While costs could certainly be reduced, scientists and managers must realise that robust tests of pinger effectiveness will be expensive. Compromising ability to detect changes in entanglement rates to save money on pinger experiments is likely to produce equivocal results in the short term. Such studies may need to be continued over many seasons to produce a reliable result. In our opinion this approach is unlikely to be cost-effective. Some fisheries may not be sufficiently valuable to warrant the trials needed to see whether pingers are effective.

In our view, pingers should not be used without data-gathering systems in place to see if they actually reduce entanglement rates. At the time of writing (March 1997) the Dukane Corporation had supplied pingers to 16 fisheries, only one of which has a monitoring programme (Kraus, pers. comm.). We are particularly concerned that such haphazard use might lead managers to conclude prematurely that the entanglement problem is being addressed, when in fact the pingers may be ineffective. To document the effectiveness of these devices over time it is imperative to continue to monitor bycatch of porpoises and other non-target species.

Even if pingers are effective in reducing incidental mortality by 90%, as suggested by the results of the New Hampshire experiment, their widespread use is unlikely to be sufficient to meet the Zero Mortality Rate goal mandated by the US MMPA. Managers, scientists and fishers should continue to explore other ways of reducing bycatch, including area closures and alternative fishing methods. Although we are cautiously enthusiastic about their promise, there is currently no justification for adopting pingers as a panacea for the problem of incidental mortality of small cetaceans in gillnets.

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