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Acoustic alarms reduce bycatch of harbour porpoises in Danish North Sea gillnet fisheries

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ABSTRACT

A double-blind experiment in the Danish gillnet fishery for cod (*Gadus morhua*) demonstrated that pingers can substantially reduce bycatch of harbour porpoises (*Phocoena phocoena*). Fourteen vessels fished a total of 168 days in the North Sea in 1997. In the wreck fishery the total effort was 1052 nets with active pingers, 1056 nets with dummy pingers and 74 nets without pingers. Eight porpoises were caught, all in nets with dummy pingers. In the flat bottom/stony ground fishery the total effort was 5596 nets with active pingers, 5210 nets with dummy pingers and 2973 nets without pingers. Sixteen porpoises were caught, including 1 animal in a net with active pingers, 6 in nets with dummy pingers and 9 in nets without pingers. The difference in bycatch between nets with active pingers and nets with inactive or no pingers was highly significant ($p < 0.007$) for both the wreck fishery and the flat bottom/stony ground fishery. We conclude that the direct effects of the pinger signals on the porpoises caused the reduction in bycatch, which means that the results can be generalized to other situations where harbour porpoises are taken in gillnets. Generalized linear modelling demonstrated that cod cpue was not affected negatively by pingers. It was furthermore estimated that the stony ground fishery had significantly lower ($p < 0.001$) cpue values (a factor 0.47) compared to the wreck fishery. The results of this experiment led to the introduction of pingers in Danish gillnet fisheries in 2001 and were also part of the basis for EU Council Regulation 812/2004 introducing EU-wide use of pingers.

1. Introduction

An investigation of the bycatch of harbour porpoises in the Danish North Sea bottom set gillnet fishery in 1992 and 1993 concluded that the total annual bycatch was in the order of 7000 animals (Vinther, 1999). Later, a more refined analysis gave an average annual bycatch of 5591 over the years 1987–2001 (Vinther and Larsen, 2004). This level of bycatch was considered to be unacceptable and research into ways of mitigating this bycatch was initiated in 1996 by DIFRES[1] (now the National Institute of Aquatic Resources).

Research conducted in the USA, UK and the Netherlands had suggested that acoustic alarms (pingers) could be efficient in reducing the bycatch of porpoises (Goodson et al., 1997; Kastelein et al., 1997; Kraus et al., 1997). As a part of the EU funded BY-CARE project, DIFRES conducted a controlled experiment in 1997 with the main objective to test whether the use of pingers could reduce the bycatch of harbour porpoises in the Danish gillnet fishery for cod. Information was also collected on the total fish catches including discards, to evaluate whether the pingers had an effect on cod catchability. The experiment was conducted in cooperation with the fisheries organizations and interested fishermen to draw on their experience, and to identify as early as possible any potential problems in using pingers during routine fishing operations.

2. Methods

The principal criteria for selecting a fishery for the pinger experiment was that it should have as high a harbour porpoise bycatch rate as possible, to facilitate estimation of a specific reduction. Of the North Sea fisheries in which the bycatch rate was known, the bottom set gillnet fishery for cod in the area 55°30′–57°30′N and 2–6°E in the third quarter of the year had the highest bycatch rate (Vinther, 1995). This fishery is a highly selective single species fishery in which the target species usually constitutes more than 90% of the total catch weight, and bycatch species are of minor economic importance. Haddock (*Melanogrammus aeglefinus*), ling (*Molva molva*) and saithe (*Pollachius virens*) are the most frequent bycaught species but they rarely constitute more than 1–2% of the total catch weight. The bottom set gillnet fishery for cod has two components: one is the fishery on flat bottom or stony grounds and the other is the so-called wreck fishery. There were indications

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[1] Danish Institute for Fisheries Research.

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that the wreck fishery had a higher bycatch rate than the other cod gillnet fisheries, which was later confirmed by Vinther (1999). However, there were insufficient numbers of vessels pursuing the wreck fishery to base the trial on these vessels alone. Nets used in these fisheries were 1000 meshes long, typically 21.5–26.5 meshes high and stretched mesh size was 130–170 mm. The head rope was 8 or 10 mm and 70–80 m long given hanging ratios of around 0.5. Nets were tied together into strings of varying length. In the wreck fishery strings were 4–10 nets long and typically 2–4 strings were placed on each wreck. In the fishery on flat bottom/stony grounds, strings were typically 20–60 nets long, depending on whether they were set in parallel rows or as a single meandering string. Fishing depths were typically 20–80 m and soak times in September were 8–15 h, depending somewhat on water temperature.

The experiment was designed as a double-blind experiment with a control group of nets with inactive pingers (“dummies”). The double-blind aspect meant that neither the crew nor the observer knew which of the pingers on board were active and which were dummies. To avoid consistent differences between the participating vessels in fishing practices and preferred areas having an effect on the results of the experiment, all vessels alternated on a daily basis between fishing with active pingers and dummy pingers on the nets. Thus each vessel was given an active set of pingers as well as a dummy set. Each pinger was given an individual ID-number and each set was colour coded to facilitate identification. Between trips all active pingers were checked to ensure proper functioning and the vessels received different sets of both active pingers and dummies before heading out on the next trip.

The main objective of the experiment was to determine whether the use of pingers could result in a significant reduction in harbour porpoise bycatch, here understood as a statistically significant reduction of at least 50% determined with a probability of 0.95. Analyses of bycatch rates from previous years suggested that a total effort of around 1000 km of nets fished, equally distributed on the treatment group (nets with active pingers) and the control group (nets with dummies) was necessary. To limit the effect of a seasonal trend in the bycatch rate, the experiment was limited in duration to approximately 5 weeks. Based on information on the typical effort of a vessel engaged in the selected fishery, it was estimated that 12 vessels were required to obtain a total effort of 1000 km in 5 weeks of fishing. The main criteria for selecting the 12 vessels needed were similarity with respect to fishing practice, preferred fishing area and fishing gear. All participating vessels had an independent observer on board for the duration of the experiment. The principal tasks of the observer were the attachment and replacement of pingers following specific guidelines and collection of information on gear type, fishing effort, pinger use and bycatch of cetaceans. In addition the observer collected data on species and size composition of all other catches including discards. The collection of data was centred on a haul, defined here as a number of nets with the same mesh size, set at roughly the same position and depth and with similar seabed conditions. In the wreck fishery, a haul was defined as all the nets with the same mesh size set on a wreck.

The pinger used was a prototype, LU-1 developed by Loughborough University, England, with the technical specifications listed in Table 1. LU-1 was equipped with a capacitor switch, which activated the signal emission when the pinger was submerged in water. Before the experiment and after each fishing trip, all active pingers were tested to ensure proper functioning. Pingers were attached to the nets with a carabiner hook on a short line and a 50 mm-wide Velcro strap glued to the mid part of the pinger and strapped around the head rope. The pingers were attached to the tail-ends, *i.e.* the bridles used to tie the nets together into strings. The general rule for inter-pinger distance was that no part of a net should be more than one net length (~70 m) from a pinger. In general this would mean placing pingers between every other net. However, when strings were set in parallel rows close to each other, only every other row or sometimes only every third row would have pingers attached. On wrecks it would normally be sufficient to have one pinger on each side of the wreck.

Table 1
Technical specifications of the LU-1 pinger used in the experiment.

Property	Specifications
Frequency	8 Different signals between 40 and 120 kHz
Source level	145 dB (re. 1 microPa @ 1 m)
Signal length	300 ms
Signal interval	Random between 5 and 30 s
Length	145 mm
Diameter	44 mm
Volume	0.22 l
Weight (in air)	c. 400 g

In the wreck fishery, where only a few short strings are set on each wreck, it was possible to attach the pingers during shooting of the nets. However, in the flat bottom/stony ground fishery strings are normally shot at a higher speed (up to 6 knots), and it is not possible to attach the pingers during shooting. Here the pingers were attached and replaced during hauling when the nets passed the table where the catch was removed, before going through the net cleaner and into the net pounder. Since all pingers were brought ashore for checking between trips, this attachment procedure meant that in the flat bottom/stony ground fishery pingers could not be placed on the nets in the first set on a new trip. These sets without pingers constituted a third group in the experiment.

The bycatch of harbour porpoises was considered as a Bernoulli process, where each sampling unit (here the individual nets) was given the value 1 if there was a bycatch in the net, or 0 if there was no bycatch in the net. For each of the three groups in the experiment this resulted in two figures, that together described the probability of porpoise bycatch in that group. Using Fisher’s Exact Test it was tested whether the three groups had significantly different probabilities of bycatch. The data were analyzed separately for the wreck fishery and the flat bottom/stony ground fishery, because bycatch rates were expected to differ between these two fisheries (Vinther, 1999).

Pinger effects on catches of the main target species, cod, were analyzed using generalized linear modelling (GLM, McCullagh and Nelder, 1989). Catch per unit effort (cpue) values were calculated as total cod catch weight per net (kg net^{-1}). The variation in cpue values (*CPUE*) by haul was modelled in response to five factors: pingertype (*PT*), fishery (*F*), ICES-rectangle (*IR*), mesh-size (*MS*) and Vessel (*V*). A traditional GLM approach was considered appropriate; zero cpues are few (0.15% of the observations) and the assumption of log-normally distributed cpue values cannot be rejected based on plots of standardized model residuals against the quantiles of standard normal distribution (QQ-plots, Fig. 1). All variables and possible first-order interactions were tested using the log likelihood value of the full parameterized model as a baseline. Model reductions (the mesh size factor and all first-order interactions) were made at a 0.1% significance level (log likelihood ratio test) resulting in the following end model:

$$\mathrm{Log}(CPUE_{ijk}) = \beta_0 + PT_i + F_j + IR_k + V_l + \varepsilon_{ijkl} \quad (1)$$

Model 1 was parameterized on the basis of catch records of cod from 494 haul of the experimental fishery (99 hauls had incomplete information on target species catch and could not be included). The cod cpue values ranged from 0.08 to 538 kg net^{-1}. β_0 is the common fixed intercept and i denotes the three pinger categories (pinger, dummy-pinger and no-pinger), j denotes the two fishery categories (wreck and flat bottom/stony ground), k denotes the 22 different ICES rectangles, l denotes the 14 different vessels in the experimental fishery, and ε is a random noise parameter, assumed