Agenda Item 4.3: **In-depth review of Read Report and advice to Parties on bycatch mitigation**

Mitigation of small cetaceans bycatch; evaluation of acoustic alarms (MISNET)

Submitted by: **Per Berggren**

ASCOBANS

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Mitigation of small cetacean bycatch; evaluation of acoustic alarms (MISNET)

Final Report 28 March 2002

Type of contract: Shared-cost research project.

Total cost: 180.869 EUR **EC contribution**: 172.889 EUR

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TABLE OF CONTENTS

APPENDICES

1.1 ABSTRACT (English)

The MISNET project (Mitigation of small cetacean bycatch; evaluation of acoustic alarms) addressed B.3:1 *Fisheries impact on marine mammals, seabirds elasmobranchs and reptiles* of the Common Fisheries Policy's (CFP) 2000 call for proposals. The objectives of the project were:

1) To investigate the extent of the habitat degradation caused by pingers by determining both the shift in position of closest surfacing and underwater echolocation activity *and* the maximum distance at which encounter rate and echolocation activity is affected by pingers.
2) To determine if porpoises attempt to swim through nets where malfunctioning pingers create an acoustic gap (the failure tolerance of pingers).

The field experiment was conducted in Bloody Bay, Isle of Mull, West Scotland, UK between 3 April and 13 June 2001. Acoustic and visual monitoring of harbour porpoises was conducted around a simulated gillnet set in water around 40m deep and equipped with acoustic alarms (pingers). The experimental set-up consisted of eight Dukane NetMark 1000™ pingers evenly distributed along a 700m lead line. The two central pingers were always quiet while the three pingers on each side were programmed to be simultaneously either on or off during two 4-hour observation periods every tidal cycle. Porpoise click detectors (PODs) were deployed on the lead line between the silent pingers and among the active pingers. Single PODs were also deployed perpendicular to the active pingers at distances of 250, 500 and 750m. The experiment area was surveyed from a land site with an 80m elevation using naked eye, binoculars and a theodolite to determine porpoise distribution and surface movements. Observers were not aware of whether the pingers were active or silent.

Porpoise clicks and click trains logged on the PODs were identified and counted for each observation period. When pingers were on, there was a significant reduction in the number of observation periods with porpoise clicks up to a distance of 500m from the simulated net. Further, the echolocation activity (number of clicks and click trains per unit time) was significantly reduced up to a distance of 500m.

The visual data supported the acoustic results with a lower encounter rate recorded within 375m of the active pingers. Theodolite tracks of porpoises showed a shift in mean closest surfacing point to the simulated net from 431m when pingers were off to 752m when they were on. Further, the average distance from the simulated net during tracks increased from 653m to 961m when pingers were on. Apart from one track, there was no indication that porpoises would choose to cross a net equipped with active pingers where malfunctioning pingers create an acoustic gap of 300m.

In conclusion the results showed that pingers significantly reduced the number of porpoises within 500m from the simulated net. The results further indicate that this deterrence method is not sensitive to a few malfunctioning devices, although this will depend on the distance between pingers. This supports the view that pingers as a mitigation measure are effective in preventing bycatch in certain fisheries by displacing porpoises from the vicinity of the net. However, the difficulty of achieving effective monitoring and enforcement of pinger use is well known and pingers should therefore not be seen as a satisfactory method of reducing porpoise bycatch in gill nets.

Finally, the area of reduced porpoise activity was larger than observed in previous studies, implying greater possible impact through exclusion of porpoises from critical habitat or effects on their movement patterns.

1.2 ABSTRACT (French)

Le projet MISNET («Mitigation of small cetacean bycatch; evaluation of acoustic alarms»: réduction de la captur des petits cétacés; évaluation des alarmes acoustiques) s'adressait à l'appel à proposition B.3:1 de l'année 2000 ayant pour thème l'impact des pêcheries sur les mammifères marins, les oiseaux de mer, les élasmobranches et les reptiles, appel de la Politique Commune de la Pêche. Les objectifs du projet étaient:

1) d'étudier l'importance de la dégradation de l'habitat accasionnée par les «pingers», en déterminant les changements au niveau de la position d'apparition à la surface et de l'activité sous-marine d'écholocation, ainsi que la distance maximale à laquelle le taux de rencontre et l'activité d'écholocation sont affectés par les «pingers».
2) de déterminer si les marsouins essaient de nager à travers les filets lorsuq eles «pingers» sont défectueux, créant alors un vide acoustique (la défaillance tolérée des «pingers»).

Les essais sur le terrain ont été menés dans la baie de Bloody, île de Mull, située à l'ouest de l'Ecosse, entre le 3 avril et le 13 juin 2001. L'observation acoustique et visuelle des marsouins fut réalisée autour d'un jeu de filets «fictifs» émergés à environ 40 m de profondeur et équipés d'alarmes acoustiques. L'installation expérimentale se composait de 8 «pingers» Dukane NetMark 1000^{TM} également répartis le long d'une ligne de sonde de 700 m. Les deux «pingers» centraux étaient toujours silencieux alors que les trois «pingers» présents de chaque côté étaient programmés pour être simultanément actifs ou silencieux au cours des deux périodes d'observation de quatre heures effectuées à chaque cycle de marée. Des détecteurs de clics de marsouin (PODs) étaient installés sur la ligne de sonde entre les «pingers» silencieux et au sein des «pingers» actifs. Des PODs isolés étaient également placés perpendiculairement aux «pingers» actifs à des distances de 250, 500 et 750 m. La zone expérimentale était surveillée à partir d'un site à terre situé à 80 m de hauteur. L'observation était réalisée soit à l'oeil nu, soit à l'aide de jumelles et d'un théodolite afin de déterminer la répartition des marsouins et leurs mouvements de surface. Les observateurs ignoraient si les «pingers» étaient actifs ou silencieux.

Les clics de marsouin et les séries de clics enregistrés par les PODs étaient identifiés et comptés pour chaque période d'observation. Lorsque les «pingers» étaient actifs, une diminution signficative du nombre de périodes d'observation avec des clics de marsouin jusqu'à une distance de 500 m du filet était relevée. De plus, l'activité d'écholocation (nombre de clics et de séries de clics par unité de temps) était significativement réduite jusqu'à une distance de 500 m.

Les données visuelles renforçaient les résultats issus de l'acoustique avec un taux de rencontre plus faible enregistré dans la zone des 375 m autour des «pingers» actifs. Les suivis de marsouins au théodolite indiquaient un changement au niveau de la position moyenne d'apparition à la surface la plus proche du filet « fictif », allant de 431 m lorsque les « pinger» étaient silencieux à 752 m lorsuq'ils étaient actifs. De plus, la distance moyenne par rapport au filet a augmenté au cours des suivis allant de 653 m à 961 m lorsque les «pingers» étaient actifs. Excepté pour un suivi, rien n'indiquait que les marsouins choisiraient de traverser un filet équipé de «pingers» actifs défectueux, créant un vide acoustique de 300 m.

En conclusion, les résultats ont montré que les «pingers» réduisaient significativement le nombre de marsouins dans la zone des 500 m autour du filet «fictif». De plus, les résultats indiquent que cette méthode de dissuasion n'est pas sensible aux appareils défectueux, bien que cela dépende de la distance entre les «pingers». Cela soutient le fait que les «pingers» en tant que mesure de réduction sont efficaces pour prévenir la capture dans certaines pêcheries en éloignant les marsouins des parages du filet. Cependant, la difficulté de parvenir à un suivi efficace et à la mise en place de l'utilisation du «pinger» est bien connu et les «pingers» pourraient par conséquent ne pas être considérés comme une méthode satisfaisante permettant de réduire la capture de marsouin dans les filets. Finalement, la zone d'activité du marsouin était plus large que celle observée au cours des études précédentes, pouvant impliquer un impact plus important tel que l'exclusion des marsouins d'habitat critique ou des effets sur leurs mouvements.

2. NON-SPECIALIST SUMMARY

Pingers prevent bycatch but deter porpoises from large areas

An experiment using acoustic and visual monitoring of harbour porpoises around a simulated gillnet equipped with acoustic alarms (pingers) was conducted in Bloody Bay, Mull, UK between 3 April and 13 June 2001. The project had two main objectives:

1) To investigate the extent of the habitat degradation caused by pingers by looking at the spatial distribution of porpoises in the presence of pingers.
2) To determine whether porpoises attempt to swim through nets where malfunctioning pingers create an acoustic gap.

The results from the experiment showed that pingers repelled porpoises up to 500m from the simulated net and that only rarely will porpoises attempt to swim through an acoustic gap of 300m created by malfunctioning pingers.

Harbour porpoises (*Phocoena phocoena*) get entangled and suffocate in gillnets and other fishing gear throughout their distribution range in the northern hemisphere (Perrin et al. 1994). This bycatch has lead to increased concern over the status of this species in recent years. Several studies in European waters have shown that bycatch levels in gillnets fisheries may not be sustainable, e.g. in the Celtic Sea, the central North Sea, the Skagerrak, Kattegat and the Baltic Seas (Berggren et al. 2002, Tregenza et al. 1997, Vinther 1999). The issue is of particular concern in the Baltic Sea, where action is needed to reduce bycatch to save Europe's most threatened population of harbour porpoises. In this, and other, areas harbour porpoise abundance has declined drastically during the last 50 years.

There is an urgent need to develop mitigation measures to prevent the bycatch of small cetaceans in European fisheries. Experiments with pingers have shown that these can reduce the frequency of porpoise bycatch at least in the short-term (Kraus et al. 1997).

However, there are also indications that pingers may have the undesirable effect of excluding porpoises from areas around pingers that could potentially represent critical habitats. Further, previous studies using pingers have also noted possible problems with malfunctioning equipment creating a silent gap through which porpoises may attempt to swim.

The current project "Mitigation of small cetacean bycatch; evaluation of acoustic alarms (MISNET)" addressed two important aspects on the impact and efficiency of pingers. The first was to investigate the extent of habitat degradation caused by the devices. The shift in position of closest surfacing and underwater echolocation activity was investigated in addition to the maximum distance at which the frequency of sightings and the underwater echolocation activity was affected. The second was to investigate whether occasionally malfunctioning pingers on a net preclude pingers as an effective bycatch mitigation measure because porpoises attempt to swim through silent gaps.

The experimental set-up of the study consisted of eight Dukane NetMark 1000™ pingers evenly distributed along a 700m lead line set on the bottom at 41-43m depths and acting as a simulated net. The two central pingers were always quiet while the three pingers on each side were programmed to be simultaneously either on or off during two 4-hour observation periods every tidal cycle (see below about the tidal cycle). Porpoise click detectors (PODs) were deployed on the lead line between the silent pingers and among the active pingers. In addition, perpendicular to the active pingers, single PODs were deployed at distances of 250, 500 and 750m. The purpose of the PODs was to monitor the occurrence and distribution of porpoises around the simulated net by recording the click sounds porpoises produce while echolocating. The area was also surveyed by three observers stationed on an 80m cliff overlooking Bloody Bay. The observers used naked eye, binoculars and a theodolite to determine porpoise distribution and surface movements.

When the pingers were on there was a significant reduction in the number of observation periods with porpoise clicks logged at distances up to and including 500m from the simulated net. The rates of logging of clicks and click trains were also significantly reduced at distances up to and including 500m.

The visual data supported the acoustic results with a lower encounter rate recorded within 375m of the active pingers. Theodolite tracks of porpoises showed a shift in mean closest surfacing point to the simulated net from 431m when pingers were off to 752m when they were on. Further, the average distance from the simulated net during tracks increased from 653m to 961m when pingers were on. Apart from the track of one porpoise, there was no clear indication that porpoises would choose to cross a net equipped with active pingers through an acoustic gap of 300m. However, the track of the surfacings of this animal indicate that it crossed the simulated net near the midpoint where the silent pingers where located. This suggest that some porpoises may be bycaught in nets equipped with pingers. Others studies using pingers have documented bycatches in nets with active pingers indicating that this mitigation method will not reduce bycatch to zero. This is particularly important in an area like the Baltic Sea with a very small estimated population size (less than 1000 animals) where low bycatch rates can have a significant impact on the status of the population.

In conclusion the results showed that pingers significantly reduced the number of porpoises within 500m from the simulated net. The results further show that the effectiveness of pingers is not destroyed by occasional malfunctioning devices. This supports the view that pingers can prevent bycatch in certain fisheries.

The area of reduced porpoise activity is larger than observed in previous studies, implying greater possible impact through exclusion of porpoises from critical habitat or effects on their movement patterns.

The MISNET project (Mitigation of small cetacean bycatch; evaluation of acoustic alarms) addressed B.3:1 *Fisheries impact on marine mammals, seabirds elasmobranchs and reptiles* of the Common Fisheries Policy's (CFP) 2000 call for proposals. The objectives of the project were:

1) To investigate the extent of the habitat degradation caused by pingers by determining both the shift in position of closest surfacing and underwater echolocation activity *and* the maximum distance at which encounter rate and echolocation activity is affected by pingers.
2) To investigate the failure tolerance of pingers, i.e. whether this method to reduce the bycatch rate of harbour porpoises allows occasional malfunctioning devices or if sporadic failure may preclude pingers as a bycatch mitigation measure.

3. INTRODUCTION

Harbour porpoises (*Phocoena phocoena*) are subjected to bycatch in gillnets and other fishing gear in their entire distribution range in the northern hemisphere which has lead to increased concern over the status of this species in recent years (Perrin et al. 1994, HELCOM 1996, ICES 1997, ASCOBANS 2000, IWC 2000). Several studies in European waters have shown that bycatch levels in gillnets fisheries may not be sustainable, e.g. in the Celtic Sea (Tregenza et al. 1997), the central North Sea (Vinther 1999), the Skagerrak and Kattegat Seas (Berggren et al. 2002, Harwood et al. 1999) and the Baltic Sea (Berggren et al. 2002). The issue is of particular concern in the Baltic Sea where action is needed to reduce bycatch to save Europe's most threatened population of harbour porpoises (ASCOBANS 2000).

In Swedish waters of the Baltic, Kattegat and Skagerrak Seas harbour porpoise relative abundance has declined drastically between the 1960s and 1980s (Berggren and Arrhenius 1995a) with no subsequent recovery (Berggren and Arrhenius 1995b). Porpoises have also become less common during the last decades in other areas in the Baltic region, including Danish (Andersen 1982, Clausen and Andersen 1988), Polish (Skora et al. 1988), and Finnish (Määttänen 1990) waters. The population estimate in the Baltic Sea is very low, a survey in 1995 in ICES areas 24 and 25 yielded an abundance estimate of 599 animals (Berggren et al. unpubl.). Morphological, genetic and contaminant studies have shown that harbour porpoises in the Baltic Sea are distinct from animals in the Skagerrak-Kattegat Seas (Börjesson and Berggren 1997, Wang and Berggren 1997, Berggren et al. 1999).

Bycatch of harbour porpoises occur year round in the Baltic, Kattegat and Skagerrak Seas in various bottom and surface gillnet and trawl fisheries (Berggren 1994, Harwood et al. 1999). Observer programmes operating in the bottom set gillnet fishery for cod and pollack in 1995 and 1996 have showed that bycatches in the Swedish Skagerrak Sea is 2.4% per year of the calculated abundance and 1.2% in the Swedish Kattegat Sea (Carlström and Berggren 1996, Harwood et al. 1999). Bycatch of porpoises is also known to occur in ten additional Swedish fisheries (Berggren 1994) and in Danish fisheries (Vinther 1999) in the same areas although no estimates for these bycatches are available. No observer programmes have been conducted in the Baltic Sea to estimate the magnitude of bycatch in this area. However, calculations on potential limits to anthropogenic mortalities for harbour porpoises in the Baltic Sea show that reported bycatches in this area are non-sustainable (Berggren et al. 2002).

There is an urgent need to develop mitigation measures to prevent the bycatch of small cetaceans in European fisheries. Experiments with pingers have showed that these can reduce the frequency of porpoise bycatches at least in the short-term (e.g. Kraus et. al. 1997, Larsen 1997). In Swedish waters, a field experiment designed to evaluate the efficiency of pingers as a means to reduce the bycatch of harbour porpoises in the bottom set gillnet fishery for cod was conducted in the Skagerrak Sea in 1997. The results from this study indicate that pingers may reduce the bycatch rate, but that they may also have the undesirable effect of excluding porpoises from areas around pingers that could potentially represent critical habitats (Carlström et al. in press).

To date, few studies have addressed questions on the ecological impact of pingers on harbour porpoises. The size of the exclusion zone around pingers has been studied by visual observations of surfacings (Laake et al. 1998, Cox et al. 1999, Culik et al. 2000, Gearin et al. 2000). The echolocation activity has been recorded by the deployment of a porpoise click detector (POD) at the position of the pinger (Cox et al. 1999, Culik et al. 2000). Larsen and Hansen (2000) have made a preliminary estimate of the size of the minimum habitat loss due to the use of pingers, but no evaluation has been carried out of total habitat degradation using detailed spatial information. Several pinger studies have noted problems with malfunctioning equipment, the most severe by Northridge et al. (1999). Despite the lack of knowledge in many areas, pingers are to be implemented in the Danish wreck fishery in the North Sea August 1st – August 31st 2000 (Anon. 2000).

The MISNET project addressed two important aspects on the efficiency and impact of pingers. The first was to investigate the extent of habitat degradation caused by the devices. The shift in position of closest surfacing and underwater echolocation activity was investigated in addition to the maximum distance at which the frequency of sightings and echolocation activity was affected. The second was to investigate the failure tolerance of pingers as a means of reducing the bycatch rate of harbour porpoises, i.e. whether sporadic failure would preclude pingers as a bycatch mitigation measure.

4. METHODS

4.1 Outline

The experiment was carried in Bloody Bay, Isle of Mull, West Scotland, UK between 3 April and 15 June 2001 (Figure 1).

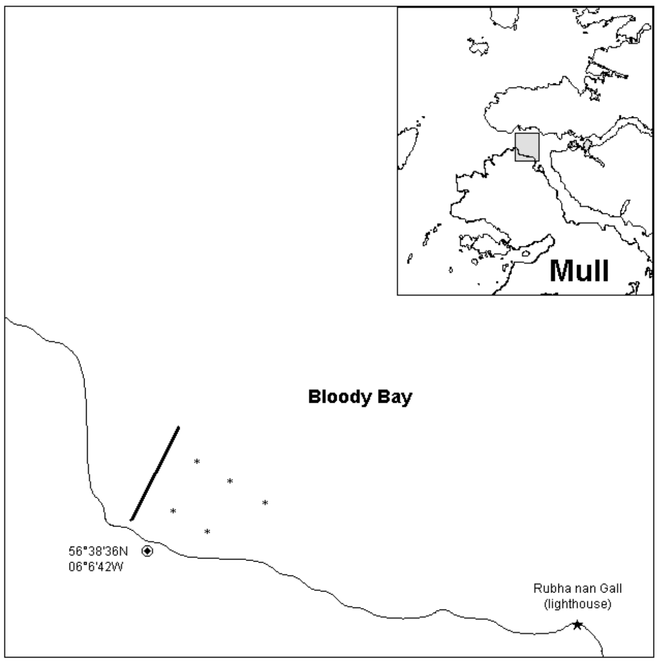

Figure 1. Map of Bloody Bay, Mull, UK where the experiment was conducted. The dark thick line indicates the location of the simulated net, the * indicate the positions of the PODs and the ⊙ by the latitude/longitude position indicates the location of the shore based observation team.

The field period was a total of ten weeks; the first three weeks were dedicated to equipment set-up and experimental trials followed by seven weeks of data collection.

The location was chosen on the basis of a known high harbour porpoise density, relatively low tidal currents, suitable depth, limited risk of damage by trawlers and proximity to an elevated coastline suitable for shore observations. In the experiment, echolocation activity, movements and distribution of sightings of harbour porpoises around a simulated bottom set net with pingers were recorded.

The experimental set-up consisted of a four person observation team scanning over an area containing a simulated net consisting of a lead line carrying eight pingers and three harbour porpoise click detectors (PODs) set on the bottom in a SW to NE direction at a depth between 41-43m. The lead line was 700m long with the pingers spaced out every 100m and the PODs separated by 250m (Figure 2). The two central pingers were always quiet (achieved by reversing the battery packs in the pingers) while the three pingers on each side were programmed to be simultaneously either on or off according to a pre-programmed schedule (Figure 3). The three PODs on the simulated net were placed next to active pingers (POD 3 and 5) and in between the two central pingers that always were silent (POD 4). Five single PODs were also deployed perpendicular to the active pingers, at distances of 250, 500 and 750m at depths between 35-43m (Figure 2).

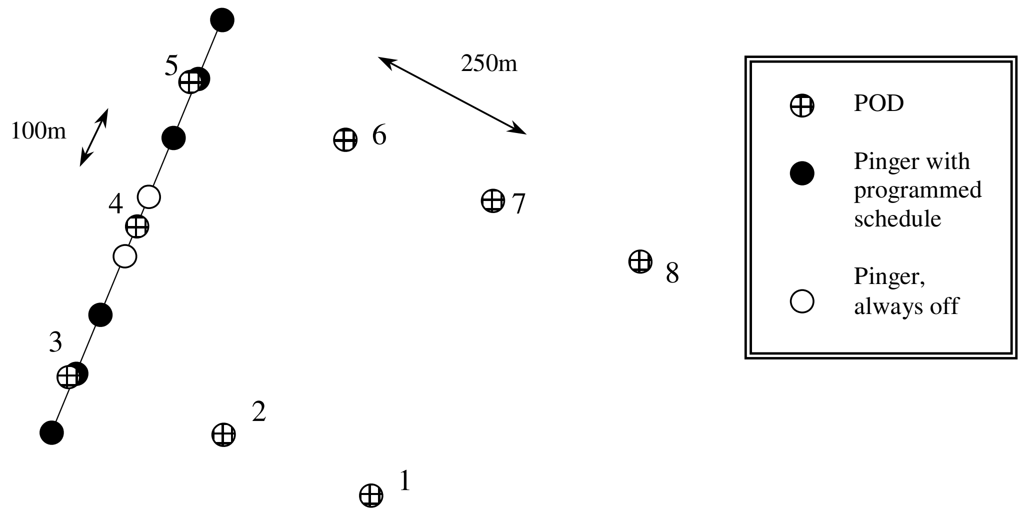

Figure 2. Three PODs (3-5) were placed on the simulated net and five single PODs (inshore southern row 1-2 and offshore northern row 6-8) were deployed at distances of 250, 500 and 750m and perpendicular to simulated net. The pingers were positioned 4m above the bottom and the PODs 2m.

The ends of the line were anchored and marked with buoys at the surface. The five individual PODs were also anchored near the bottom with a line and a buoy at the surface. By placing pingers close to the bottom the configuration of a bottom set net equipped with pingers was simulated, but the risk of porpoise entanglement avoided. The PODs collected data at the same depth, i.e. at the positions where potential entanglements would occur. Both pingers and PODs were slightly buoyant.

A mooring for the simulated was set and retrieved using a fishing boat. The rig was designed so that the lead line with anchors, pingers and PODs could be hauled to the surface while leaving the main mooring on the seabed. The haul of the simulated net and the individual PODs was done every two weeks, using a small motorboat, to replace batteries and to download data. When setting and re-setting the equipment the positions were determined using a GPS. The positions were also checked from land using a theodolite (Topcon total station GTS 212).

The area was surveyed using naked eye, binoculars and a theodolite from an observation site located 80m above sea level to determine porpoise distribution and surface movements. The onshore location of the observers was determined using the mean value of multiple GPS readings. The height of the location was calculated from the known location and the declination angle to a nearby lighthouse, Rubha nan Gall, for which both location and altitude was available from a nautical chart.

The location of a porpoise sighting in the study area was calculated from the declination and horizontal angles to the sighting taken from the known position and altitude of the observers.

The location of the simulated net was determined by using the average of the GPS positions taken when the net was set and hauled. The distance between the sighting positions and the simulated net was calculated in the GIS software ArcView (ESRI ArcView 3.1).

All calculated porpoise sighting positions were corrected for tidal height using custom developed software (info@pihldata.se).

The output of the pingers was measured and sound source levels were recorded using a portable hydrophone system.

The acoustic and visual data were analysed in order to evaluate at what distances echolocation activity and frequency of sightings were affected by the sound of the active pingers and if the echolocation activity and frequency of tracked porpoises increased at the position of the silent pingers.

4.2 Equipment and sampling methodology

The pingers used in the study was the Dukane NetMark 1000™ pingers (www.dukane.com/seacom/Products/ComMarine.htm). These are the most commonly used pingers in both controlled experiments and commercial fishing operations worldwide. Furthermore, the sound source level and accordingly the spacing of these pingers result in a rig of a size that is suitable for shore-based observations.

The pingers were on for a 4 hour period in two successive tidal cycles and then off for the next two tidal cycles. This was controlled by a custom made clock built into the battery pack of the pingers which triggered all pingers to be simultaneously on or off according to the pre-programmed schedule (in minutes): on 240, off 505, on 240 and off 1995 (Figure 3). This protocol allowed for the data collection periods to occur during the same tidal phase. The protocol was also set-up to minimize possible habituation by porpoises to pingers while still allowing collection of data on a regular basis within the time frame available for the fieldwork. The experiment was "blind" in the sense that the observers did not know whether pingers were on or off ("pinging" or silent) during observation periods.

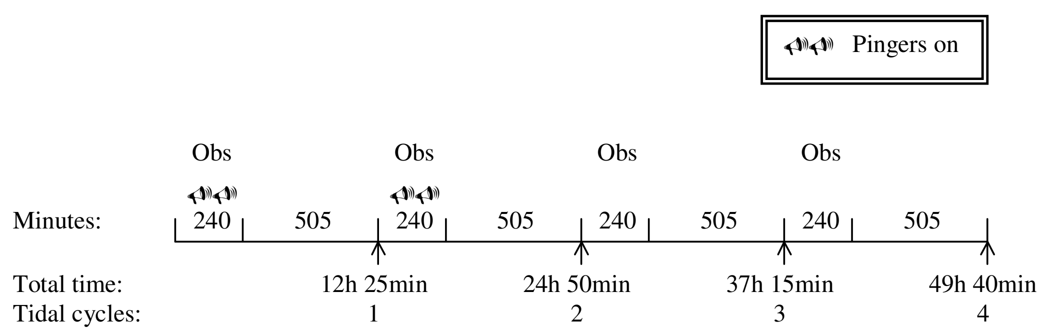

Figure 3. The pingers were either on or off during two 4-hour (240 min.) observation periods every tidal cycle. The programmed schedule allowed the observation periods to occur during the same phase in the tidal cycle.

The POD is a self-contained submersible computer and hydrophone that recognizes and logs sonar clicks from porpoises. The POD runs on six 1.5V alkaline D-cell batteries and can log clicks for up to 14 days at depths of up to 150m. The filter frequencies can be set at 10kHz centres from 20 to 170kHz (for more information and technical specification of the PODs, please see http://www.chelonia.demon.co.uk). All PODs except one were programmed to make six 10-seconds scans for porpoise clicks at 130 & 90 kHz every minute 24 hours a day. The remaining POD (number 5) made five 10-seconds scans for porpoises at 130 & 90 kHz and one 10-second scan for vessels at 60 & 20 kHz every minute 24 hours a day. High frequency clicks from porpoises are ideally suited to the POD because they are both very high pitched - at the quietest frequency band in the spectrum of marine noise - and they are very narrow band. The POD's ability to distinguish them from biological and other sources of clicks has proved to be excellent.

The observation team consisted of two observers scanning the area (an inshore and an offshore observer) and one observer tracking detected groups of harbour porpoises. The inshore scanning observer used naked eye scanning from left to right and focussed on a semi-circle search area within the first 600m from the position on land. The offshore scanning observer used binoculars (Fujinon 7*50) scanning from right to left and searched an area defined by semi-circles between 600m and 1900m from the position on land (Figure 4).

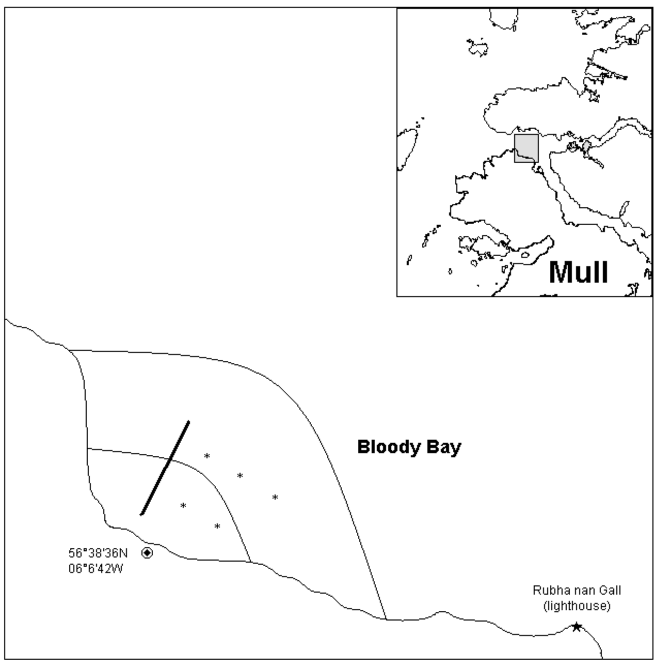

Figure 4. The inshore naked eye observer scanned a semi-circle within the first 600m from the position on land and the offshore used binoculars to scan an area defined by semi-circles between 600m and 1900m.

The naked eye observer used a hand-held declinometer (Clino Master, Sisteco, Finland) and a custom made angle board mounted on a tripod to record declination and horizontal angles, respectively. The offshore observer used binoculars equipped with a declinometer and mounted on a tripod with a custom made horizontal angle board. The declinometer attached to the binoculars was calibrated using a theodolite. Time, declination and horizontal angles, group size, behaviour and aspect (i.e. the group's orientation in relation to the observer) of the animals were recorded on tape recorders following a data protocol (see Appendix 1). After a sighting had been recorded both inshore observers resumed their scanning from where they had first picked up the sighting.

The tracking observer used a theodolite to track movements of porpoise groups detected by the scanning observers. Date, time, sighting number, horizontal and vertical angles were logged on the theodolite. A data recorder who assisted the tracker logged time, sighting number, temporal information on the movements, group size, behaviour and aspect on a tape recorder (see Appendix 2). The animals were tracked until a closer group of animals was sighted or until the sighting was lost. Further confirmation of group sizes was generated using a video camera mounted on a tripod.

The theodolite was also used to determine the positions of the buoys marking the ends of the two arms at the beginning and end of each trial. Environmental data on visibility, glare, sea state and wave direction was noted every 30 minutes or when conditions changed (see Appendix 3). Only data collected during clear, partly cloudy or continuous cloudy days with sea state 0-3 was used in the analyses.

The sound source level of four pingers was recorded using a hydrophone (Brüel & Kjær 8103) with a sensitivity of -211dB re 1V/uPa connected to a custom built amplifier (Marenius model FMVHY2B) with a gain of 50dB ± 0.3dB, and an analogue to digital converter (Picoscope ADC-212) and a portable computer.

Measurements were made at sea at 1m distance from the pinger with an acoustic shield to prevent surface reflections. Pingers were rotated to assess directionality. The sound pressure level at the peak spectral frequency was used.

4.3 Sampling protocol, data management and statistical analysis

4.3.1 Visual data

Visual data was collected between 26 April and 13 June 2001. Of these 47 days, the first day was dedicated to training and three days during the period were used for hauling pingers and PODs out of the water to change batteries and download data. During 15 days the weather conditions were beyond the acceptable limits (see above). This left 28 days when data could be collected by the visual observers.

The visual data was collected during the 4-hour periods when the pingers were either on or off and occurring during daylight hours. The scanner observers rotated positions every half hour and had half an hour break after one hour of observation. This gave a maximum of three hours of effective visual data collection during each daylight observation period. All data were transferred into Excel spread sheets for analysis. To compare densities of porpoise groups when pingers were on or off the visual data was pooled from inshore and offshore observers into concentric zones around the simulated net (125-375m, 375-625m, 625-875m). In addition we also compared densities of porpoise groups in the inner area (0-125m) and an outer area (>875m). The radii of the concentric zones were chosen so that they would encompass the single PODs placed at 250m intervals from the simulated net. Only initial observations were included in this analysis.

Porpoise sightings were recorded on 17 days (11 when pingers were off and 6 when pingers were on). The effective observation time during these days varied between two to three hours. There were an additional 11 observation days when no porpoises were sighted (7 when pingers were off and 4 when they were on). However, only days with porpoises sighted within the experimental area were used in the statistical analyses. The number of porpoises recorded per hour was used in the analysis to correct for differences in effective length of the observation periods. In the statistical analysis each of the concentric zones was used for comparisons between on and off periods. Given the non-normal distribution of the data due to many zero values within the distance zones a non-parametric analysis of variance (Mann-Whitney U-test) was used to test for difference. Since the hypothesis tested the extent of the habitat degradation caused by pingers by determining the shift in position of closest surfacing, one-tailed tests were used i.e. the alternative hypothesis was an increased distance for closest surfacing.

The tracker observation data was downloaded from the theodolite and imported into the GIS-programme ArcView 3.1 (ESRI) where tracks were plotted from the calculated positions. In total 59 porpoise groups were tracked within the study area. However, 13 of these tracks were of groups showing a clear behaviour of following passing fishing vessels and these were excluded from the statistical analyses. Of the remaining groups 35 were tracked when the pingers were off and 11 when they were on. Minimum and average distance to the simulated net was calculated for all tracks. A one-tailed Student's t-test was used to investigate whether there was an increase in the minimum distance and average distance to the simulated net when pingers were on.

In order to investigate whether tracks from porpoises crossed the simulated net, tracks were plotted in the GIS programme so that tracks crossing the lead line could be identified.

The statistical analyses were conducted in Statistica (Statsoft 1999) using a significance level of alpha = 0.05.

4.3.2 Acoustic data

Acoustic data were collected during 47 days between 26 April and 13 June 2001. The PODs were scanning for porpoise clicks 24 hours a day, but to address the objectives of the experiment the two 4-hour periods when the pingers were programmed to be either on or off during the same tidal phase were extracted for analyses. This resulted in a dataset with a maximum of 49 four-hour periods per POD when pingers were either on or off. The echolocation activity recorded by the PODs was analysed to compare these periods. The comparisons were made both for occurrence of clicks and for echolocation rate (number of porpoise clicks or click trains per unit time). To identify which of the recorded clicks and click trains that had been produced by porpoises a click train detection algorithm was developed. The porpoise click train detection algorithm scans the data files and identifies clicks in trains using a probability based pattern recognition algorithm and delivers the number of detected clicks and click trains per user defined time interval. The results can then be exported to Microsoft Excel for further data management.

All eight PODs (three on the array and five single) were analysed separately. The two situations - when pingers were on and when they were off – were compared in three different ways:

1) The number of observations periods with and without clicks.
2) The number of clicks recorded per observation period.
3) The number of click trains recorded per observation period.

The first two comparisons were stated in the original project proposal. The third was added to investigate whether the echolocation behaviour of porpoises is altered by pingers.

The data were tested for normality and homogeneity of variances. The data from all PODs was highly skewed due to many zeroes in the four hour observation periods. Therefore non-parametric tests were used in all analyses of the acoustic data. A Fisher's exact test was used to compare the number of periods with and without clicks. To test for differences in the number of clicks and click trains an analysis of variance (Mann Whitney U-test) was used. Since the hypothesis tested the extent of the habitat degradation caused by pingers by determining the shift in position of underwater echolocation activity, one-tailed tests were used i.e. the alternative hypothesis was a reduction in underwater echolocation activity. The significance level used was alpha = 0.05.

5. RESULTS

5.1 Pinger output

The recordings of the sound source level of four pingers showed that the peak frequency of the pinger sounds varied between 10.2 and 11.3kHz. A typical spectrum is shown in Figure 5. The peaks around 0kHz and above 70kHz are electronic artefacts and not sound produced by the pinger.

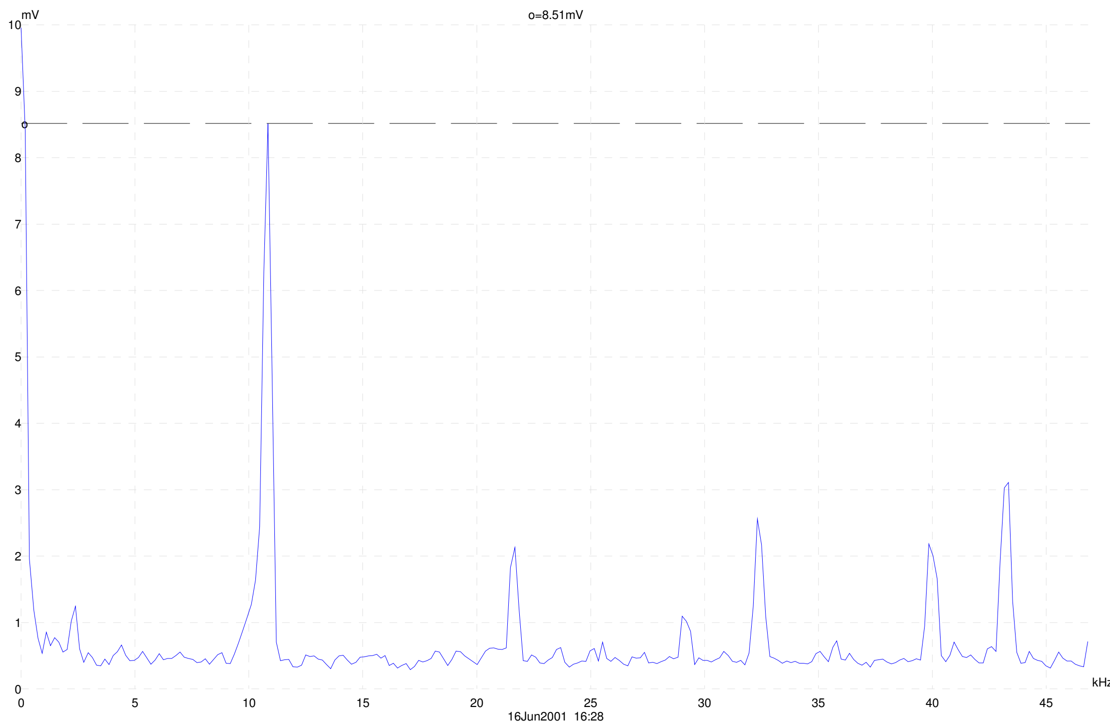

Figure 5. A typical spectrum of the sound of a pinger.

5.2 Visual data

The total number of porpoise groups observed by the inshore and offshore scanner observers was 149. The distribution of the sightings in the different distance intervals is shown in Figure 6.

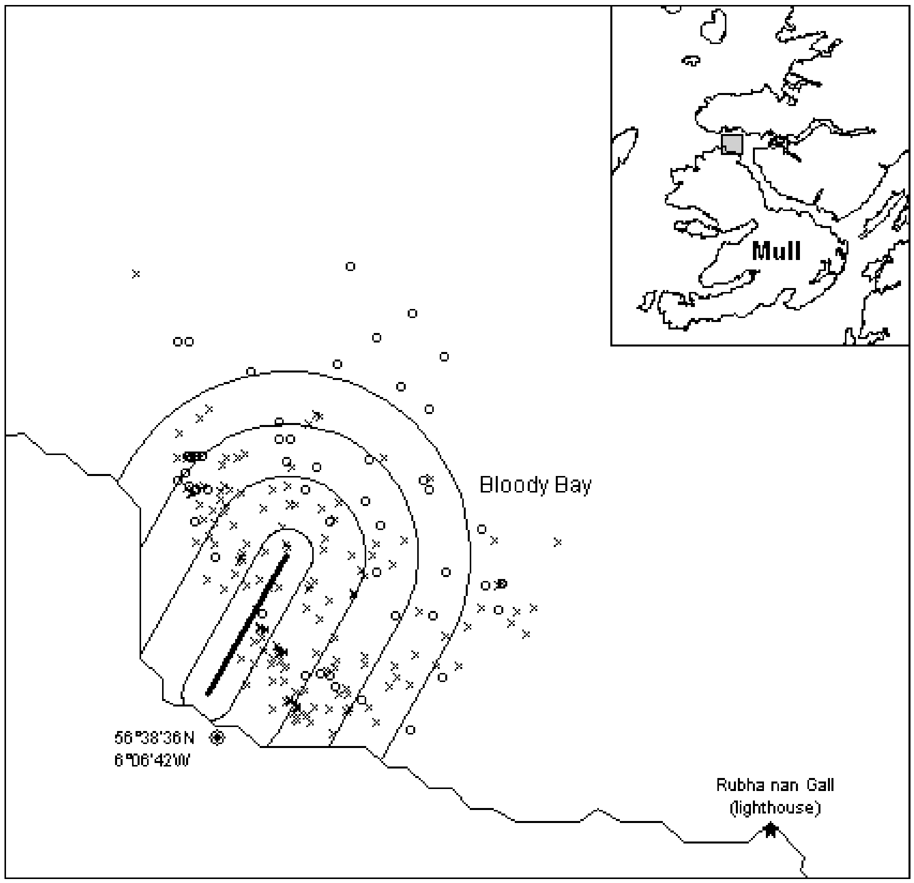

Figure 6. The location of porpoise groups detected by the scanner observers in the concentric distance zones from the simulated net. Porpoise groups sighted when pingers were off are marked by × and by ○ when pingers were on.

The analysis showed a significant reduction (p=0.003) in the number of porpoise groups detected per hour within the concentric zone reaching 375m from the simulated net, with fewer porpoises detected during the periods when the pingers were on (Table 1). The other distance intervals showed no significant reduction when pingers were on and off (Table 1, Figure 7).

Table 1. Statistical data of the comparisons of the number of porpoise groups detected per hour by scanner observers in the five distance intervals when pingers were off and on, respectively. The comparisons were made with Mann-Whitney U-test and p-values less than 0.05 are marked with *.

Distance	Rank sum		U-value	N		p-value
interval	off	on		off	on	
0-125m	110.5	42.5	21.5	11	6	0.088
125-375m	126.5	26.5	5.5	11	6	0.003*
375-625	97.5	55.5	31.5	11	6	0.440
625-875m	100	53	32	11	6	0.459
>875m	89	64	23	11	6	0.138

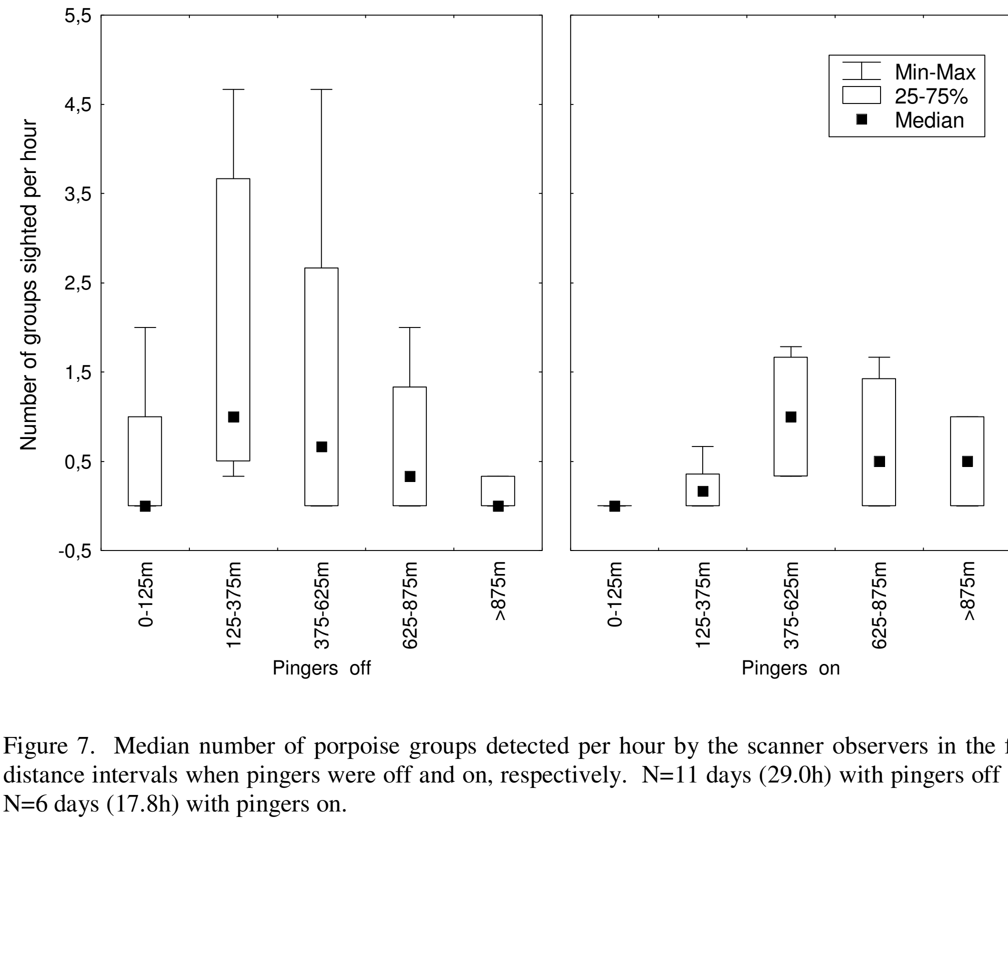

Figure 7. Median number of porpoise groups detected per hour by the scanner observers in the five distance intervals when pingers were off and on, respectively. N=11 days (29.0h) with pingers off and N=6 days (17.8h) with pingers on.

In total 46 porpoise groups were tracked during acceptable conditions and without presence of fishing vessels (35 when pingers were off and 11 when pingers were on) (Figure 8).

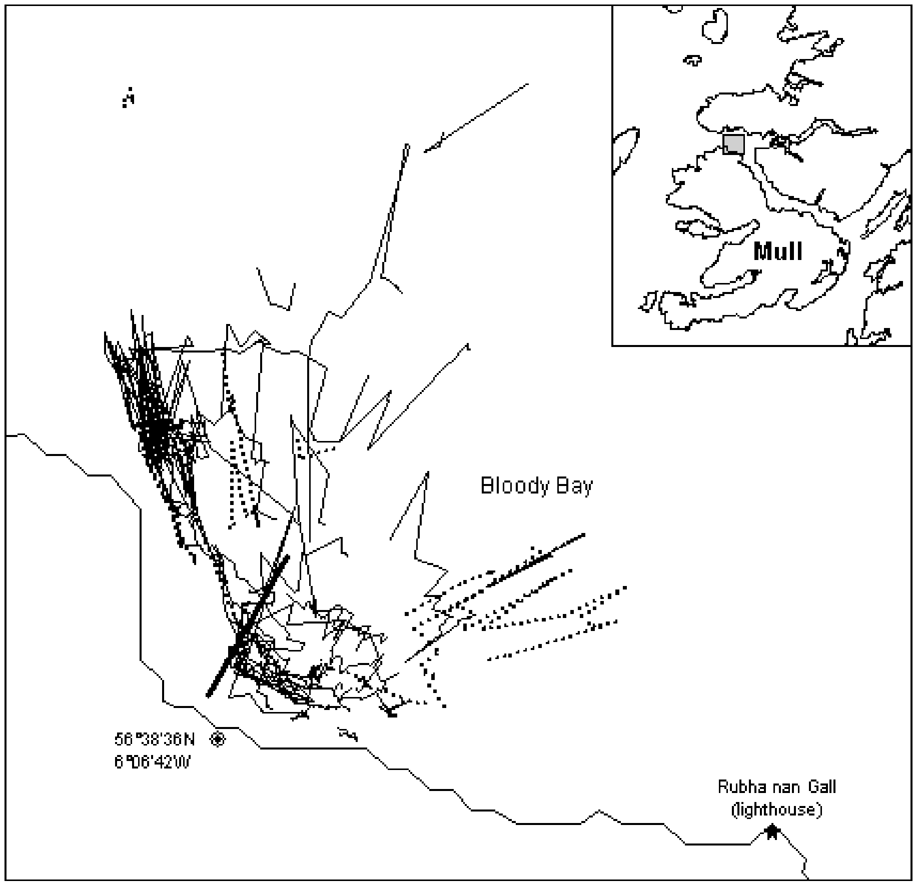

Figure 8. All tracked 46 porpoises displayed in relation to the simulated net. Tracks when pingers were off are marked with solid lines and when pingers were on with dotted lines.

The tracker data showed a significant difference in the minimum distance from the simulated net when pingers were off compared to on (p=0.030). The average minimum distance when pingers were off was 431m (SD=441) compared to 752m (SD=599) when the pingers were on. Further, the average distance from the simulated net when pingers were off was 653m (SD=432) compared to 961m (SD=516) when the pingers were on. The difference was significant (p=0.027). Further, six of the tracks crossed the simulated net when the pingers were off and one crossed when the pingers were on. This last track crossed in the centre of the simulated net between the two silent pingers.

5.3 Acoustic data

There was a significant reduction in the number of 4-hour observation periods with porpoise clicks up to a distance of 500m from the simulated net when the pingers were on (Table 2).

Table 2. The table shows the percentage of four hour observation periods with clicks detected by the three PODs in the simulated net (POD 3-5) and the five PODs outside the net (POD 1-2 and 6-8) when pingers were off and on, respectively. The number of periods with and without clicks was compared with Fisher's exact test and p-values less than 0.05 are marked with *.

POD	Pingers off		Pingers on		p-value
	w. clicks	N	w. clicks	N	
1. S 500m	75%	40	43%	37	0.004 *
2. S 250m	65%	49	44%	45	0.034 *
3. Net S	43%	49	29%	45	0.116
4. Net mid	49%	49	38%	45	0.187
5. Net N	78%	49	47%	45	0.002 *
6. N 250m	88%	48	51%	43	0.000 *
7. N 500m	80%	49	58%	45	0.019 *
8. N 750m	65%	26	60%	25	0.457

The echolocation rate, measured as the number of clicks and click trains per time unit, respectively, was significantly reduced up to a distance of 500m.

The average number of clicks per hour detected by each POD is shown in Figure 9, and the results of the statistical comparisons are shown in Table 3.

Table 3. Statistical data of the comparisons of the number of porpoise clicks per observation period detected by the three PODs on the simulated net (POD 3-5) and the five PODs outside the net (POD 1-2 and 6-8) when pingers were off and on, respectively. The comparisons were made with Mann-Whitney U-test and p-values less than 0.05 are marked with *.

POD	Rank sum		U-value	N		p-value
	off	on		off	on	
1. S 500m	2508	1956	921	49	45	0.076
2. S 250m	1838	1164	461	40	37	0.002 *
3. Net S	2517	1948	913	49	45	0.048 *
4. Net mid	2573	1892	857	49	45	0.020 *
5. Net N	2881	1583	548	49	45	0.000 *
6. N 250m	2646	1539	593	48	43	0.000 *
7. N 500m	2557	1907	872	49	45	0.039 *
8. N 750m	705	621	296	26	25	0.287

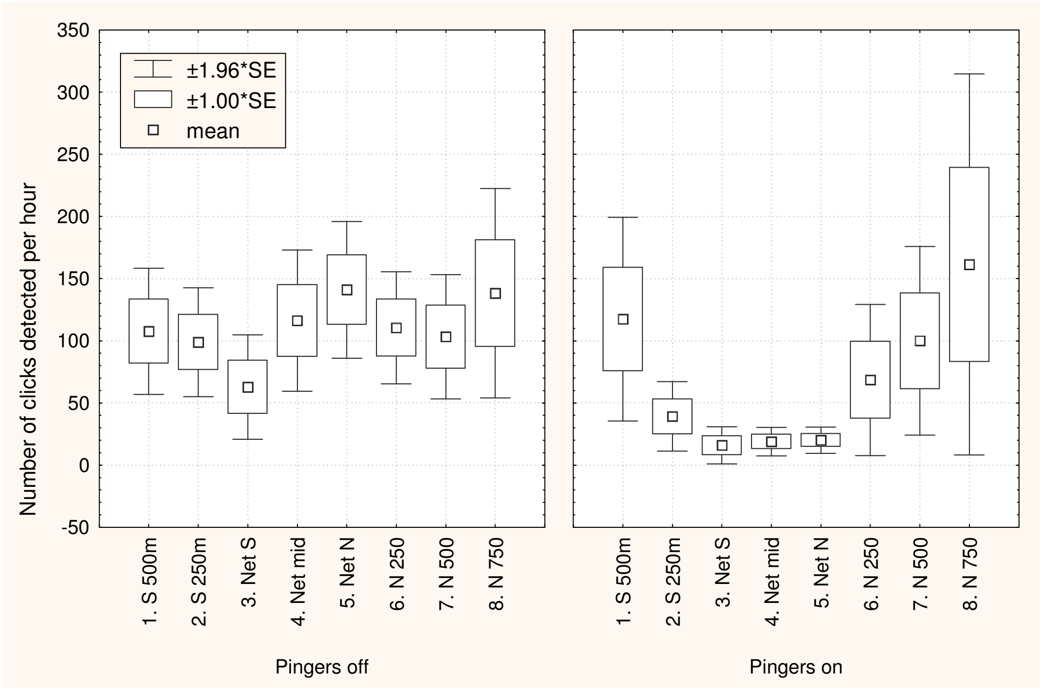

Figure 9. Average number of porpoise clicks detected per hour by the three PODs on the simulated net (POD 3-5) and the five PODs outside the net (POD 1-2 and 6-8) when pingers were off and on, respectively.

The result for click trains per unit time was similar to the results for clicks per unit time. Again, a significant reduction was found in the data recorded by PODs placed up to 500m from the simulated net (Table 4). The average number of click trains per hour when pingers were off and on, respectively, is showed in Figure 10.

Table 4. Statistical data of the comparisons of the number of porpoise click trains per observation period detected by the three PODs on the simulated net (POD 3-5) and the five PODs outside the net (POD 1-2 and 6-8) when pingers were off and on, respectively. The comparisons were made with Mann-Whitney U-test and p-values less than 0.05 are marked with *.

POD	Rank sum		U-value	N		p-level
	off	on		off	on	
1. S 500m	2465	1999	964	49	45	0.137
2. S 250m	1854	1149	446	40	37	0.001 *
3. Net S	2555	1910	875	49	45	0.022 *
4. Net mid	2561	1904	869	49	45	0.026 *
5. Net N	2872	1592	557	49	45	0.000 *
6. N 250m	2672	1514	568	48	43	0.000 *
7. N 500m	2570	1895	860	49	45	0.031 *
8. N 750m	689	636	311	26	25	0.396

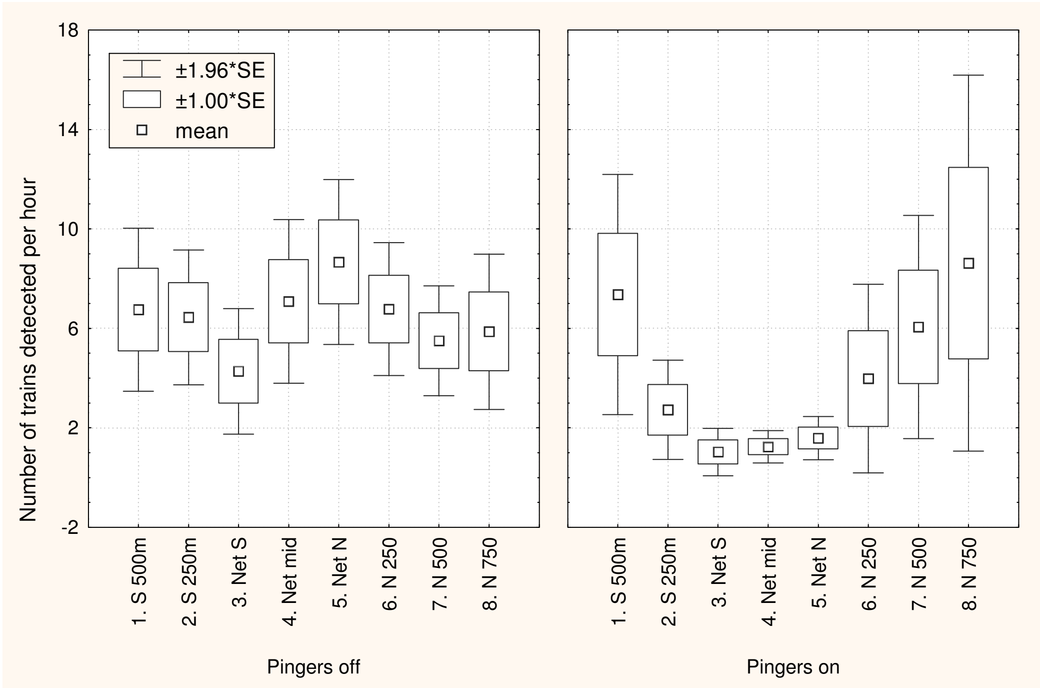

Figure 10. Average number of porpoise click trains detected per hour by the three PODs on the simulated net (POD 3-5) and the five PODs outside the net (POD 1-2 and 6-8) when pingers were off and on, respectively.

The clicks logged by a POD can have reached the POD from any direction. This means that a reduction in the recorded echolocation activity can have occurred anywhere within the detection range of the POD. The POD software allows the time and duration of logged clicks to be viewed from three PODs synchronously on the computer screen. The data has been searched for any instance of a POD detecting the same train as an adjacent POD without finding any example. Thereby the detection range of the PODs is concluded to be less than their spacing in this experiment, and that in view of the extent of the trend of detection rates with distance when the pingers are active an effect to 500m is supported.

6. DISCUSSION

The results from experiment showed that pingers deterred porpoises up to 500m from the simulated net. Both the acoustic detections of the PODs and the visual scanner and tracker observations support this conclusion although the detailed results varied to some extent. The use of several PODs deployed at distances between 0-750m from the simulated net showed that there was a significant reduction in the number of observation periods with and without clicks when pingers were on compared to off for PODs placed up to 500m from the simulated net. The acoustic data also showed significant decrease in the number of clicks and click trains detected per observation period by the PODs at 500m from the simulated net when the pingers were on. Further the visual data showed a significant decline in the number of porpoise groups detected per hour at 375m distance from the simulated net when the pingers were on.

A generally low porpoise density in part of the study area showed in both visual detections and echolocation activity on two PODs on the net, and although the rates showed the same pattern in relation to pinger activity the data volume was too small for a statistically significant result. The same sample size factor may have limited the range at which the effect of the pingers is significantly demonstrated in this study. Furthermore, due to the much smaller surface area of the inner area (0-125m), covered by the scanner observers, the chance of detecting porpoises and hence to test for differences when pingers were on and off in this concentric zone was lower compared to the other zones.

The deterrent distance was greater in this study compared to that shown in other studies (Laake et al., 1998, Cox et al., 1999, Culik et al., 2000, Trippel 2001). However, these other studies were based on visual data and it is possible that our experimental design using multiple PODs is a more effective method of determining the porpoises' response to the sound of pingers. The size of the area affected by pingers can greatly exceed the range at which they are heard by porpoises, e.g. if they impede the movement of porpoises into an area.

Apart from the track of one porpoise, there was no indication that porpoises would choose to cross a net equipped with active pingers where malfunctioning pingers could create an acoustic gap of up to 300m. However, the track of the surfacings of this animal indicate that it crossed the simulated net near the midpoint where the silent pingers where located. This suggests that some porpoises may be bycaught in nets equipped with pingers. Others studies using pingers have documented bycatches in nets with active pingers indicating that this mitigation method will not reduce bycatch to zero.

The results confirm the findings and conclusions from other studies (e.g. Kraus et al. 1997) that pingers can reduce the bycatch of porpoises in fishing nets equipped with pingers. A potential problem with displacement is that the ensonified areas may represent habitats critical to the survival of porpoises and the effect is likely to be more prominent in coastal waters where access to some areas is geographically restricted. The results also confirm some previous indications that porpoises may be excluded by pingers from larger areas (Carlström et al. in press). The present study show that the extent of the exclusion zone is up to 500m from the sound source. In many areas with intensive fishing this will likely lead to exclusion zones from nets with pingers overlapping to create exclusion zones that may cover entire fishing areas. Further, if non-alarmed nets are set in the habitats that porpoises are redistributed to the overall bycatch may not be reduced.

The results of the project is highly relevant to the CFP and directly addresses one of the priority areas in the call for proposals B.3:1 Impact of gillnets on small cetaceans. The project was conducted in a direct response to the current review of the CFP and the ongoing attempt to improve the integration of environmental considerations within the CFP. It addressed some of the problems currently known to exist in European fisheries with respect to small cetacean bycatch through (i) the investigation of the effectiveness of pingers as a bycatch mitigation measure and (ii) the evaluation of the extent of harbour porpoise habitat degradation caused by pingers. The strength of the project include improved cooperation between Member States, gathering the expertise needed from different fields in order to conduct efficient experiments with recently developed techniques at appropriate locations. The results will be of great importance for all the member states in the EU as incidental catches of small cetaceans are known to occur in all European waters. Dissemination of the results will be facilitated by preparing manuscripts for publication in the primary scientific literature. The final report will also be distributed to relevant international and national bodies, fisheries agencies, governmental institutions and fishermen's organisations in participating countries to ensure that all parties concerned will benefit from the results.

7. CONCLUSIONS

The results showed that pingers significantly reduced the number of porpoises within 500m from the simulated net. The results further indicate that this deterrence method is not sensitive to a few malfunctioning devices, although this will depend on the distance between pingers. This supports the view that pingers as a mitigation measure are effective in preventing bycatch in certain fisheries by displacing porpoises from the vicinity of the net. However, the difficulty of achieving effective monitoring and enforcement of pinger use is well known and pingers should therefore not be seen as a satisfactory method of reducing porpoise bycatch in gill nets. Furthermore, the area of reduced porpoise activity was larger than observed in previous studies, implying greater possible impact through exclusion of porpoises from critical habitat or effects on their movement patterns.

Based on the results of this study we can not recommend pingers as a long-term mitigation measure to solve the problem of bycatch at European level. Instead we propose that alternative and new fishing gear are developed and tested in efficient experiments to find long-term solutions to the bycatch problem in gillnet fisheries. One such alternative that has shown promising results in Norwegian coastal waters is fish pots (traps) (Furevik 1997).

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Appendix 1. MISNET SIGHTINGS FORM

Location ________________________________

Behaviour
SW normal swimming
MI milling = non-directional SW
ME meandering = group milling
LO logging
PO porpoising
OT other

Aspect
SL side left
SR side right
SU side unknown
HO head-on
TO tail-on
HT head or tail-on

Date			Form #	Forms in Day
Day	Month	Year		

Sight. #	Res. #	Obs	Time			Distance		Angle	Spe-cies	Spec. #	School size			No. of	Beh.	Asp.	Comment
			Hr	Min	Sec	Meters	Reticle	Degrees			Low	Best	High	Calves			

Appendix 2. MISNET THEODOLITE TRACKING FORM

Date		
Day	Month	Year

Form #

Forms in Day

Behaviour
SW normal swimming
MI milling = non-directional SW
ME meandering = group milling
LO logging
PO porpoising
OT other

Aspect
SL side left
SR side right
SU side unknown
HO head-on
TO tail-on
HT head or tail-on

Location

____

Track #	Pos. #	Obs.	Rec.	Time			Spe-cies	Spec. #	School size			No. of Calves	Beh.	Asp.	Comment
				Hr	Min	Sec			Low	Best	High				

Appendix 3. MISNET EFFORT FORM

Event
1 Begin effort
2 End effort
3 Observer rotation
4 Weather change
5 Other

Glare Strength
0 None
1 Slight
2 Moderate
3 Severe

Weather Code
0 Clear
1 Partly cloudy
2 Continuous clouds
3 Fog or thick haze
4 Drizzle
5 Rain
6 Showers
7 Snow or sleet

Sea State
0 Glassy, oily, i.e. no ripples anywhere
1 Mixture of glassy fields and fields with ripples
2 Ripples everywhere, but not a single white crest
3 Ripples everywhere, white crests here and there
4 White crests all over, but no breaking waves
5 Waves with foam visible after breaking
6 Lines of foam in the wind direction
7 Time to go to the pub!

Location ______________________________

Date		
Day	Month	Year

Form #

Forms in Day

Time		Event	Observers			Data	Wave	Glare			Weath.	Sea	Comment
Hr	Min		Theod.	Out/L	In/R	Rec.	Direct.	Streng.	Width	Angle	Code	State	