J. Mar. Biol. Ass. U.K. (2007), **87**, 129–133
Printed in the United Kingdom

doi: 10.1017/S0025315407054677

Effects of pingers on the behaviour of bottlenose dolphins

Ruth H. Leeney*¶, Simon Berrow†, David McGrath‡, Joanne O'Brien‡,
Ronan Cosgrove∫ and Brendan J. Godley*

*Centre for Ecology & Conservation, University of Exeter, Cornwall Campus, Tremough, Penryn TR10 9EZ, UK. †Shannon Dolphin and Wildlife Foundation, Merchants Quay, Kilrush, Co. Clare, Ireland. ‡Galway–Mayo Institute of Technology, Dublin Road, Galway, Ireland. ∫Bord Iascaigh Mhara, Dock Road, Galway, Ireland. ¶Corresponding author, email: r.leeney@exeter.ac.uk

Trials were carried out in the Shannon estuary, Ireland, to test the effects of continuous (CPs) and responsive pingers (RPs) on bottlenose dolphin behaviour. In controlled trials, active and control pingers were deployed on fixed moorings, with T-PODs—acoustic monitoring devices to detect cetacean activity. In a separate trial, pingers were deployed from a moving boat which actively located dolphin groups in the estuary, and dolphin behaviour was recorded. In the static trials, overall detection rates of dolphin vocalizations on the T-POD were significantly lower in the presence of active CPs, but this was not the case for RPs. Mean inter-click interval values were longer for click trains produced in the presence of inactive RPs than for active RPs, active or inactive CPs. In boat-based trials, both active CPs and RPs appeared to affect bottlenose dolphin behaviour, whereby dolphins immediately left the area at speed and in a highly directional manner, involving frequent leaps.

INTRODUCTION

By-catch may affect the structure and function of marine systems at the population, community and ecosystem levels (International Whaling Commission, 2001). Several mitigation measures, including acoustic deterrent devices or 'pingers', have been used in attempts to reduce small cetacean by-catch (Barlow & Cameron, 2003). Evidence as to the effectiveness of pingers is equivocal, with results varying among species, fishing gear types and geographical area (Jefferson & Curry, 1996). The goal of acoustic deterrent devices is the production of sound to warn the animals of the gear, or to cause them to leave the area. However, the long-term effectiveness of such methods in solving marine mammal–fishery conflicts is still questionable and this has caused delay and confusion with regards to implementing legislation requiring the use of acoustic deterrent devices in fisheries (Jefferson & Curry, 1996).

Investigating the behavioural responses of bottlenose dolphins (*Tursiops truncatus* Montagu) to gillnets and acoustic alarms in North America, Cox et al. (2003) found that while dolphins approached the net closely, more frequently when alarms were inactive, the alarms had much less of an effect on bottlenose dolphins than has been observed for porpoises (*Phocoena phocoena* L.). The authors caution that the use of pingers would be unlikely to reduce by-catch of bottlenose dolphins in gillnet fisheries in their study area, because of the limited behavioural responses they observed.

The present study aimed to field-test the continuous pinger and the newly-developed responsive pinger on wild bottlenose dolphins, in order to assess the responses of this species to both pinger types.

MATERIALS AND METHODS

Study area

The study was carried out in the Shannon estuary, on the west coast of Ireland (Figure 1). The Shannon estuary is the most reliable location in which to encounter bottlenose dolphins in Irish waters, and provided an easily accessible population of animals, close to shore, many of which are individually identifiable. Under EU Habitats Directive (1992) legislation, the Shannon estuary is a candidate Special Area of Conservation (cSAC), thus permission was obtained from the National Parks and Wildlife Service prior to the field trials, as the emission of acoustic sound signals is a notifiable activity within a cSAC. A risk assessment strategy was also compiled to mitigate any potential disturbance effects of the tests on the bottlenose dolphins in the Shannon estuary. Fieldwork was carried out from 4–24 July 2005.

Equipment

Pingers

Two types of pinger were tested. Continuous pingers (CPs; prototype pelagic trawl deterrent, Loughborough University/Aquatech UK) produce a short duration (<1 s) continuous, high-intensity sound source emitted at intervals of between 5 and 20 s. The sound frequency modulated between 20 and 160 Hz with a source level of 165 dB re 1μPa @ 1 m. This equipment has been trialled for robustness on commercial tuna trawlers since 2003, and has been tested in a controlled environment where it had been shown to alter dolphin behaviour, but until these trials it had yet to be tested on wild dolphins in the field. The Aquatec Interactive

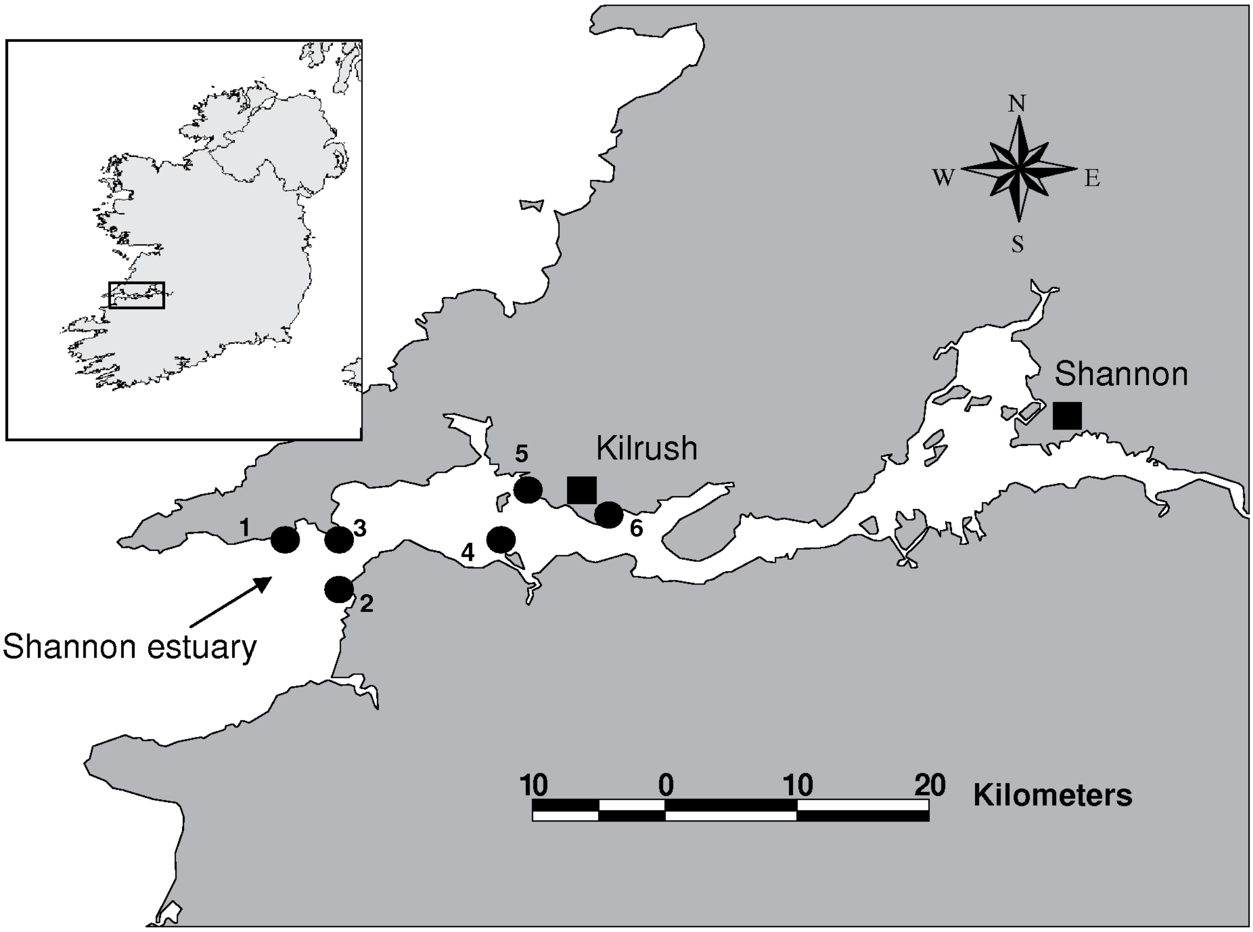

Figure 1. Map of Ireland showing the study area and the static deployment sites 1–6. 1: Rehy; 2: Leck; 3: Kilcredaun; 4: Carrig; 5: Aylevaroo; 6: Moneypoint.

pinger ('responsive pinger', RP; Aquamark interactive pinger, Aquatec UK) has been developed to minimize battery use and likelihood of habituation. The RP alarm is only activated when an internal hydrophone receives clicks from a dolphin between 10 and 150 m from the pinger. The sound output source level is also 165 dB re 1μPa @ 1 m, and sound frequency modulated between 35 and 160 kHz, with harmonics up to 160 kHz. The output of the RP can be adjusted to produce different types and lengths of signals. For these trials, a standard setting involving a 300 ms alarm was used.

The T-POD

The T-POD is a self-contained submersible computer and hydrophone, which recognizes and logs echolocation clicks from porpoises and dolphins (www.chelonia.co.uk). The T-POD can be either towed from a boat, or statically deployed by means of anchoring it to the sea-floor. After the T-POD has been recovered, data are subsequently processed on an external personal computer (PC) to detect click trains and to distinguish them from trains of clicks arising from boat sonar. The PC software (TPOD.exe) takes the click data and finds 'trains'—more or less regular sequences of clicks that are characteristic of sonars—of either boat or cetacean origin. These click trains are then classified by the programme to distinguish cetacean trains from boat sonars and from trains which may sometimes arise by chance from sources of random clicks (for example, propellers, sand movement, snapping shrimps). T-PODs were set to record dolphins only. Four version 4 units were used for this study, and were field-calibrated prior to use. The field calibration involved deployment of all four T-PODs from a single mooring, for a 28 h period. T-POD housings were secured together using tape and cable ties. When T-POD data were filtered to remove all non-cetacean trains, and expressed as detection positive minutes per hour (DPM.h^{-1}), there was no significant difference between T-PODs (F=0.327, P=0.806).

Sampling design

Two main methods for testing the pingers were used: static moorings of pingers with T-PODs, and boat-based trials. The static mooring trials had the advantage of eliminating any effect boats may have on the behaviour of the dolphins; however, these fixed arrays had only limited access to dolphins. Boat-based trials offer the advantage of enabling dolphin groups to be actively located and record any immediate effect of pingers on dolphin behaviour.

Static mooring trials

Six sites were used for these trials (Figure 1). The mooring consisted of an anchor, attached to a line which ran to a large surface buoy. The T-POD was affixed from 5 to 12 m below

Table 1. A priori *behavioural categories used in behaviour recording during boat-based trials (modified from Bearzi et al. 1999).*

Behaviour	Categories
Group formation	Tight, loose, dispersed, widely dispersed
Surfacing mode	Quiet, peppy, occasional races, stationary; aerial behaviour
Directionality	Straight, zigzag, none, stationary
Direction	Compass points/none
Speed	Slow, normal, fast
Distance from boat	Estimate in metres
Overall behaviour	Travelling, foraging, aerial behaviour, socializing

the surface, depending on the site, with the pinger directly below it. Pingers were negatively buoyant and thus helped to keep the T-POD vertical in the water column. One pinger of each type was set to be active, and one inactive. These four treatments (CP on, CP off, RP on, RP off) and the four T-PODs were independently and randomly allocated to different sites for a 24-h period, and this was carried out on six replicate days between 10 and 17 July 2005. As this study was limited by time and funding, we were unable to carry out all possible pinger–T-POD-site combinations during the static mooring trials. We thus ensured that active pingers were not allocated to any site for two consecutive days, that no T-POD unit was consistently deployed with the same pinger or pinger type, and that T-PODs were moved around all sites. This minimized the possibility that data were confounded by any variations in T-POD sensitivities, or by repeated acoustic disturbance of any one site which may have allowed for some habituation to the pingers by specific individuals associated with an area. The gear was deployed in the morning before midday, and retrieved the next day, allowing for a 24-h deployment period. The data from the static moorings were analysed in two ways. Firstly, T-POD data from the entire deployment were analysed, to assess the overall level of dolphin activity detected by the T-POD. This was expressed as DPM h^{-1}. In order to investigate differences in echolocation behaviour in relation to the gear, details of each click train were also exported and the mean inter-click interval (ICI) was calculated. Mean ICI was calculated as: Mean ICI=D/(NClx–1), where D is the duration of the train in s and NClx is the number of clicks in the train.

Boat-based trials

Dolphin groups were actively located within the estuary from a 5.4 m Lencraft rigid inflatable boat with an 80 hp Yamaha engine. Dolphin groups were approached carefully, maintaining at least a 50 m distance from the group (unless they approached closer themselves), to minimize disturbance. Dolphin behaviour was recorded for two sequential samples, each of two minutes' duration. Maintaining the 50 m distance to the group, an active or inactive pinger was then deployed from the back of the boat and dolphin behaviour recorded for a further 2 samples, when possible. The treatment in each trial was observer blind, in that the person recording the behaviour had no knowledge of the type or status of the pinger being tested. This was achieved by having the observer face the front of the boat whilst another team member prepared a pinger and deployed it, noting the time of deployment, the pinger type and status.

Due to the time restrictions mentioned above, we prioritized the testing of active pingers of both types, which resulted in fewer replicate samples being collected for inactive pingers. Pinger type and status were allocated to each encounter in no particular order. Behaviour was recorded in seven behavioural categories (Table 1; categories modified from Bearzi et al. 1999), via scan sampling (Altmann 1974). We sampled focal schools, rather than individuals, since dolphins in the Shannon estuary are usually found in groups. The data were then analysed to look for a combination of changes in behavioural categories, which might constitute some disturbance effect. Such changes might include a tightening in group formation, with increased directionality, speed of travel and breathing synchrony (Kastelein et al. 2001; Heimlich-Boran et al. 1994).

Photographs were taken of the dorsal fins of as many group members as possible, to compare to later encounters and therefore ensure that the same individuals were not constantly being exposed to the pingers.

RESULTS

In the static trials, there were medians of 0 DPM.h^{-1} and 0.36 DPM.h^{-1} for active and inactive CPs respectively, whilst for active and inactive RPs, median detection rates were 0 DPM.h^{-1} and 0.625 DMP.h^{-1}. Testing separately for each pinger type, there was a significant difference between on and off CPs (Mann–Whitney test, $Z=-2.432$, $P<0.05$; Figure 2A), but no difference in detection rates between active and inactive RPs ($Z=-0.764$, NS; Figure 2A). Conversely, the median of mean ICI values was significantly higher for inactive RPs (0.080 s) than active ones (0.019 s) (Mann–Whitney test, $Z=-5.278$, $P < 0.001$; Figure 2B), but no such difference was apparent between active and inactive CPs (0.015 and 0.018 s, respectively; $Z=-1.297$, NS; Figure 2B). This implies a greater occurrence of slow click trains, with longer time between consecutive clicks, in the presence of inactive RPs than around active RPs or CPs of any type.

In total, 13 trials were carried out from the boat: four each with an active RP and an active CP; four with an inactive CP and one with an inactive RP. Despite small sample size, boat trials produced evidence of the potential efficacy of active pingers (Figure 2C). In three out of four trials with active RPs, and three out of four with active CPs, dolphins were observed to undergo a dramatic change in behaviour, following the deployment of the pinger. Pre-deployment behaviours varied, but in all of these six cases, post-deployment behaviour was the same. This 'evasive behaviour'

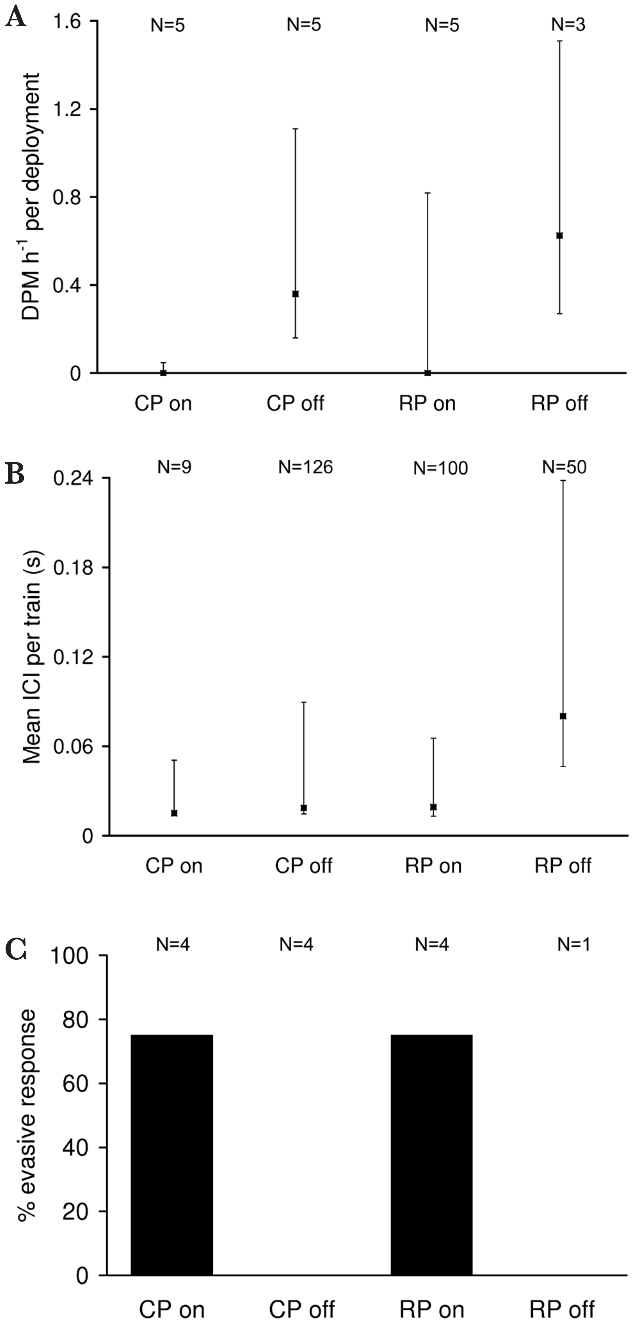

Figure 2. Effects of pingers on bottlenose dolphin behaviour (continuous pinger: CP; responsive pinger: RP). (A) detection positive minutes (DPM) per hour (median ± IQ range) from T-POD data from static deployments. (B) mean ICIs per train (median ± IQ range) from T-POD data from static deployments. (C) proportions of 'evasive response' reaction to pingers deployed from boat.

was characterized by dolphins showing an increase in speed of travel, directionality becoming (or remaining) straight but with dolphins suddenly moving away from the boat in a straight line formation, and surfacing fast with frequent leaps. In these cases the encounter ended within 2 min of the pinger deployment, as the dolphins had left the area. In the other two cases, no 'evasive response' was observed and dolphins did not leave the vicinity of the boat. Of the four trials with an inactive CP, on three occasions there were no observable changes in behavioural state of the dolphins, with the deployment of the gear. On the fourth occasion, dolphins appeared to move faster after the gear was deployed, but not in the dramatic manner observed in the trials with active pingers. In the single trial with an inactive RP, no change was observed in any of the behavioural categories.

DISCUSSION

Pingers are being adopted as a potential management option for by-catch mitigation, prior to detailed testing, and despite equivocal evidence regarding their effectiveness (Jefferson & Curry 1996). Here we have presented preliminary data that suggest that the sounds generated by the pingers have the potential to induce a response in bottlenose dolphins in Irish coastal waters. Furthermore, significantly lower levels of vocalization (and thus, we may infer, of dolphin presence) were detected in the region surrounding active CPs. Culik et al. (2001) observed similar avoidance of areas ensonified by acoustic alarms by porpoises in Canada. This effect was not observed for RPs. However, active RPs are essentially no different from inactive RPs (i.e. both are silent) until a dolphin is within the RP detection distance, whereupon the RP may be activated; thus overall levels of dolphin activity in the area would be expected to differ less dramatically between active and control RPs than between the active and control CPs. Behavioural data from the boat trials support the supposition that, although activity levels around active RPs were not reduced, the alarm produced by these pingers has the potential to displace dolphins, but with the added benefit that they are not constantly adding noise to the marine environment, making habituation less likely.

The median of mean ICI values was significantly lower for active RPs than for inactive ones, but this pattern was not evident for CPs. The incidence of higher ICI values for trains in the presence of inactive pingers could be interpreted as a vocalization response. M. Amundin (unpublished data) described distress calls by harbour porpoises, characterized by short duration and high click repetition rates. We suggest that bottlenose dolphins in the vicinity of such active pingers may have produced a high pulse-repetition frequency (PRF) vocal response to the acoustic alarm. Alternatively, lower ICI values could indicate that dolphins approached and investigated the active RP once it was activated, particularly if high PRF 'buzz' trains were emitted as an investigative response. This would suggest that dolphins actually approached the pinger rather than being displaced by it. If this was the case, we might then also expect this response to active CPs; however, no such pattern was observed. This may be due to the small sample size for inactive CPs. There were very low encounter rates for active CPs, which led to there being relatively few click trains from which to extract ICI values, although that in itself may be indicative of avoidance by dolphins of a more constant, invasive sound source. This result may be due to experimental artefact. The collection of more data would certainly help to elucidate whether there are in fact differences in dolphin vocalization behaviour in these different situations.

In studying the behaviour of cetaceans from a survey vessel, it can be difficult to separate the effects of disturbance caused by the vessel itself, from other behaviours being observed in the field. However, in the present study the boat trials were designed to record any immediate effect of the pinger and any boat effect is likely to have been minimal and be similar across all treatments. Within the caveats of small sample size, in the present study, we observed a change in dolphin behaviour, in 75% of trials with active pingers, suggesting that both CP and RP could act as a deterrent for bottlenose dolphins and make them increase their distance from the sound source. Harbour porpoises exposed to acoustic alarms by Kastelein et al. (2001) reacted by swimming away from the sound source and increasing their respiration rate. Both continuous pingers and responsive pingers had a similar effect on the behaviour of bottlenose dolphins once activated, suggesting that the source level and frequency are sufficient to deter bottlenose dolphins. It is likely that the RP would have a more dramatic effect than the CP as the bottlenose dolphin has to be within 10 to 150 m of the RP to activate it. The lack of an evasive response, on two occasions, to active pingers is difficult to explain. It may be that the pingers failed to activate, or to elicit a response on these occasions. The use of a hydrophone in future trials would allow verification that pingers have indeed gone off and that the time of the alarm corresponds to the observed reactions of the dolphins.

Not all odontocete species react to underwater sounds in the same way. Field studies with the Dukane NetMark 1000 alarm, which has a marked deterring effect on harbour porpoises (Kastelein et al., 2001), suggest that some other odontocete species such as Indo-Pacific humpback dolphins (*Sousa chinensis*) and bottlenose dolphins (*Tursiops truncatus*) showed little or no response to the alarm (Cox et al., 2003). Likewise, Kastelein et al. (2006) showed a similar discrepancy in the responses of a harbour porpoise and a striped dolphin (*Stenella coeruleoalba*) to a Dukane NetMark XP-10 alarm.

In conclusion, both models of pinger tested in this preliminary study appear to have the potential to exert a displacement effect on bottlenose dolphins, but habituation may occur. Longer-term studies are required to investigate this issue. Our results may prove useful for those considering pingers as a means of reducing the by-catch of bottlenose dolphins elsewhere in the world. However, a great deal of care must be taken in any attempt to extrapolate the results from studies on one species of cetacean to other species, even if these species have similar hearing abilities and live in broadly similar environments (Kastelein et al., 2006). Pingers have been shown to be effective in reducing common dolphin by-catch, for example in drift gill-net fisheries (Barlow & Cameron, 2003). Nonetheless, it may not be appropriate to generalize from the results of previous field tests on other species or in different fisheries. It will therefore be necessary for further tests to be carried out on other species of dolphins, particularly common dolphins which are the main species for which by-catch needs to be reduced in Irish waters, to assess whether this species will react in a similar fashion to pingers. Only then can these pingers be considered as a suitable by-catch mitigation tool for use in neritic gill-net and pelagic trawl fisheries.

Many thanks to C. Blunnie, D. Lyons, H. Tan, E. Ceurstemont, J. Blount and N. Tregenza. This manuscript has been improved considerably by comments from two anonymous referees. The study was funded by Bord Iascaigh Mhara (the Irish Sea Fisheries Board) and the European Social Fund. Special thanks to the other members of our field team: N. Griffin, S. Hansen, R. Hickey, E. McGrath, A. Young and P. Zielinski.

REFERENCES

Altmann, J., 1974. Observational study of behaviour: sampling methods. *Behavior*, **49**, 227–267.

Barlow, J. & Cameron, G.A., 2003. Field experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gill net fishery. *Marine Mammal Science*, **19**, 265–283.

Bearzi, G., Politi, E. & Notarbartolo di Sciara, G., 1999. Diurnal behaviour of free-ranging bottlenose dolphins in the Kvarnerić (Northern Adriatic Sea). *Marine Mammal Science*, **15**, 1065–1097.

Cox, T.M., Read, A.J., Swanner, D., Urian, K. & Waples, D., 2003. Behavioural responses of bottlenose dolphins, *Tursiops truncatus*, to gillnets and acoustic alarms. *Biological Conservation*, **115**, 203–212.

Culik, B.M., Koschinski, S., Tregenza, N. & Ellis, G.M., 2001. Reactions of harbour porpoises *Phocoena phocoena* and herring *Clupea harengus* to acoustic alarms. *Marine Ecology Progress Series*, **211**, 255–260.

Heimlich-Boran, J.R., Heimlich-Boran S.L., Montero, R. & Martin, V., 1994. An overview of whale-watching in the Canary Islands. *European Research on Cetaceans*, **8**, 37–39.

International Whaling Commission (IWC), 2001. Report of the scientific committee. *Journal of Cetacean Research and Management*, **3**, Suppl., 1–76.

Jefferson, T.A. & Curry, B.E., 1996. Acoustic methods of reducing or eliminating marine mammal–fishery interactions: do they work? *Ocean and Coastal Management*, **31**, 41–70.

Kastelein, R.A., de Haan, D., Vaughan, N., Staal, C. & Schooneman, N.M., 2001. The influence of three acoustic alarms on the behaviour of harbour porpoises (*Phocoena phocoena*) in a floating pen. *Marine Environmental Research*, **52**, 351–371.

Kastelein, R.A., Jennings, N., Verboom, W.C., de Haan, D. & Schooneman, N.M., 2006. Differences in the response of a striped dolphin (*Stenella coeruleoalba*) and a harbour porpoise (*Phocoena phocoena*) to an acoustic alarm. *Marine Environmental Research*, **61**, 363–378.

Submitted 9 June 2006. Accepted 14 September 2006.