Effect of acoustic deterrents on the behaviour of common dolphins (*Delphinus delphis*)

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ABSTRACT

Not all delphinids are similarly affected by acoustic deterrent devices (pingers). At-sea trials were carried out to assess a range of acoustic signals and deterrents on the behaviour of common dolphins. In initial tests two acoustic deterrent devices, which previously produced an evasive response by bottlenose dolphins, failed to elicit any similar behaviour in common dolphins. A new signal output device, which permitted a range of signals to be tested at various source levels and characteristics was subsequently developed but again no significant effects on the behaviour of common dolphins were observed. Two commercially available acoustic deterrents, which had deterred common dolphins in previous studies, produced an occasional mild evasive response. Significant modification of the signal type or source level may be more effective, but our results suggest that pingers, at their current state of development, may not provide a consistently effective deterrent signal for common dolphins.

KEYWORDS: ACOUSTICS; INCIDENTAL CATCHES; CONSERVATION; MANAGEMENT PROCEDURE; FISHERIES; GILLNETS; COMMON DOLPHIN; BOTTLENOSE DOLPHIN; NORTHERN HEMISPHERE

INTRODUCTION

Large numbers of dolphins and porpoises die in fishing gear worldwide, posing serious threats to several populations and species (Northridge, 1991; Perrin *et al*., 1994). This bycatch may also affect the structure and function of marine systems at the population, community and ecosystem levels (IWC, 2001). There have been a number of studies testing the usefulness of acoustic devices or `pingers' to deter small cetaceans from fishing nets, with mixed results (Barlow and Cameron, 2003; Jefferson and Curry, 1996). A number of studies (Culik *et al*., 2001; Johnston, 2002; Kastelein *et al*., 2000; Laake *et al*., 1998; Olesiuk *et al*., 2002) have tested the efficacy of pingers on set gillnets, targeting harbour porpoises (*Phocoena phocoena*) in particular. Reductions in bycatch of this species have been observed in controlled experiments with pingers on commercial gillnets (Kraus *et al*., 1997; Trippel *et al*., 1999). Cox *et al*. (2003) found that while bottlenose dolphins (*Tursiops truncatus*) approached a gillnet fitted with acoustic alarms more frequently when alarms were inactive, the alarms had much less of an effect on dolphins than had been observed for porpoises, suggesting they would be unlikely to reduce bycatch. Recently, a study by Kastelein *et al*. (2006) has shown very different reactions of a captive harbour porpoise and striped dolphin (*Stenella coeruleoalba*) to an acoustic alarm. Clearly, the responses of small cetaceans to pingers will vary among species, and perhaps among individuals. It is, therefore, not appropriate to generalise from the results of previous field tests on other species (IWC, 2000).

A variety of pelagic trawl fisheries in international and European waters incidentally catch a wide range of cetacean species (Fertl and Leatherwood, 1997; Morizur *et al*., 1999). However, there have been few published studies on the use of acoustic deterrent devices to reduce cetacean bycatch in these fisheries. In order to attempt to reduce the number of dolphins caught in the pelagic trawl fishery for albacore tuna (*Thunnus alalunga*), Bord Iascaigh Mhara (BIM; the Irish Sea Fisheries Board) have developed pingers which, it is hoped, will displace dolphins from the net opening during towing and thus reduce the risk of entanglement (BIM, 2000). Leeney *et al*. (2007) showed that these pingers were effective, at least in the short term, in eliciting avoidance behaviour by bottlenose dolphins. However, these pingers are intended to target primarily the short-beaked common dolphin (*Delphinus delphis*), the species most frequently entrapped in pelagic trawls in the Irish albacore tuna fishery (BIM, 2000). In the present study, similar field trials were conducted to determine the effectiveness of these pingers and other acoustic deterrents on this species.

MATERIALS AND METHODS

Six different acoustic devices were tested. Two prototype devices from BIM (Continuous Pinger and Responsive Pinger) were tested on five occasions and a modified version of the RP (RP2) on five occasions. An RP was also modified into a multiple signal output device and was tested on 15 occasions using different signals. Finally the CETASAVER and the Dolphin Deterrent Device (DDD) were tested on five and ten occasions each, making a total of 45 trials carried out in this study.

Deterrent devices and acoustic signals

The Continuous Pinger (CP; prototype pelagic trawl deterrent, Loughborough University/*Aquatech* UK), produces a short duration (<1s) continuous, high intensity sound source emitted at varying intervals of between 5 and 20s. The sound frequency was modulated between 20 and 160kHz with a peak source level of 157dB re 1µPa@1m. The *Aquatec* Interactive or Responsive Pinger (RP;

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Aquamark interactive pinger, *Aquatec* UK) logs and stores dolphin echolocation clicks as well as logging when the pinger is activated and for what duration. The RP acoustic signal is only activated when an internal hydrophone receives clicks from a dolphin between 10-150m from the pinger. This is due to technical considerations. As a dolphin approaches a unit, the length of the decoded echolocation clicks in the pinger increases due to the electronics. Using the present settings, 10m is the computed minimum distance for the unit; any closer than this the unit will not decode the echolocation clicks and not activate the pinger. The peak sound output source level is also 157dB re 1μPa@1m, with sound frequency modulation between 35 and 160kHz, and harmonics up to 160kHz. The output of the RP can be adjusted to produce different types and lengths of signals. For most of Trial 1, a standard setting involving a 300ms alarm was used (termed RP1). However towards the end of Trial 1, the duration of the acoustic signal from the RP on activation was increased from <1s to 10s (termed RP2). Both the CP and RP were used in Trial 1.

A multiple signal output device was developed by BIM, which permitted acoustic characteristics to be altered in real time permitting a range of signals at various source levels, frequencies, lengths and output levels to be tested. The device was connected to a laptop via a RS232 communications cable enabling the remote operation and resetting of this device. This device was used during Trial 2; settings for each test are shown in Table 1.

The CETASAVER (03 version) is manufactured by IFREMER and it has two types of signal. The first is a frequency modulated signal between 30-150kHz of 1s duration (random time and frequency organised sweeps of base square wave). The peak intensity is 190dB re 1μPA@1m and a pulse at 178μPA@1m. The signal is repeated at a minimum of every 2s, maximum of 5.5s with an average of 4s. The second signal is a click train at 90kHz of 0.1s duration, with constant click time and repetition. The Dolphin Deterrent Device (model DDD02F) is manufactured by STM Products, Italy and has three signal types: a starting sequence; a frequency modulated signal; and click trains. The starting sequence is a complex of sound patterns of frequency-modulated signals and identification patterns including a low frequency contribution. The frequency modulated signal ranges from 5 to 250kHz with a duration between of 0.5 and 9s with random time and frequency organised sweeps of base square wave similar to the CETASAVER. Its peak intensity is 174 dB re 1μPa@1m and a pulse at 165-170μPa@1m. Both devices were tested during Trial 3.

A licence was obtained from the National Parks and Wildlife Service of the Department of Environment, Heritage and Local Government to emit sounds which could potentially disturb dolphins, following the submission of a risk assessment. An abundance of 11,141 (CV=0.61) common dolphins in the Celtic Sea was estimated in July 2005 (SCANS II 2008). During the winter, common dolphins range widely and are likely to be more abundant in the Celtic Sea than in the summer (Brereton *et al*., 2005). Thus only a very small proportion of the common dolphin population in the Celtic Sea was likely to be exposed to these sounds.

Experimental design

Three trials were carried out from an 11m catamaran (MV *Holly Jo*); Trial 1 between 31 January and 4 February 2006, Trial 2 on 29 January 2007 and Trial 3 on the 19 April 2007, all off the south coast of Ireland between Castletownshend and Youghal, County Cork (Fig. 1).

Acoustic deterrent devices were attached singularly to a 7m long modified scaffold pole, which was attached to the vessel at mid-ships around 7m from the bow, with devices at a depth of 2-3m. The pole and pinger could easily be turned by hand through 90^0 to port and starboard if necessary to ensure the deterrent was emitting sound towards the dolphins in the vicinity of the vessel. The vessel travelled daily from shore to approximately 15km offshore in search of common dolphin groups. In Trial 1, once a group of common dolphins were located within 50m of the boat, the pole was lowered over the side with no acoustic deterrent device attached, and secured to the side of the vessel.

At least two, two-minute samples (controls of dolphin behaviour) were recorded (as per Leeney *et al*., 2007) before the pole was removed, an acoustic output device attached and then re-deployed. A further two behavioural samples were then recorded if possible. A HP30 hydrophone (MAGREC, UK) was used as an independent method of determining whether dolphins were echolocating and whether the RP had been activated. The HP30 hydrophone was attached to the pole with cable ties and the cable fed into an amplifier box.

Table 1

Signal type and characteristics for tests carried out with the frequency modified signal output device during Trial 2, Jan. 2007.

Signal no.	Signal type	Duration (mins)	Frequency (kHz)	Signal length (ms)	Signal interval (s)
1	Control	-	-	-	-
2	Frequency modulation	1	30-130	200-1,000, random (fixed)	Random 2-6
3	Random clicks	1	~ 60	1,500 (fixed)	Random 2-6
4	Tonal frequency	2	20	300	Random 2-6
5	Up sweep	2	20-80	300	Random 2-6
7	Up sweep	2	21-80	300	Random 2-6
8	Down sweep	2	80-20	300	Random 2-6
13	Frequency modulation	1	30-130	200-1,000, random (fixed)	1
14	Random clicks	1	~ 60	1,500 (fixed)	2
15	Tonal frequency	1	20-80	1,000	1
17	Up sweep	1	80-20	200-1,000, random (fixed)	1
18	Down sweep	1	80-20	1,000	1
23	Frequency modulated	1	31-130	200-1,000, random (fixed)	2
24	Frequency modulated	1	31-130	200-1,000, random (fixed)	2
25	Random clicks	1	~ 60	1,500 (fixed)	2

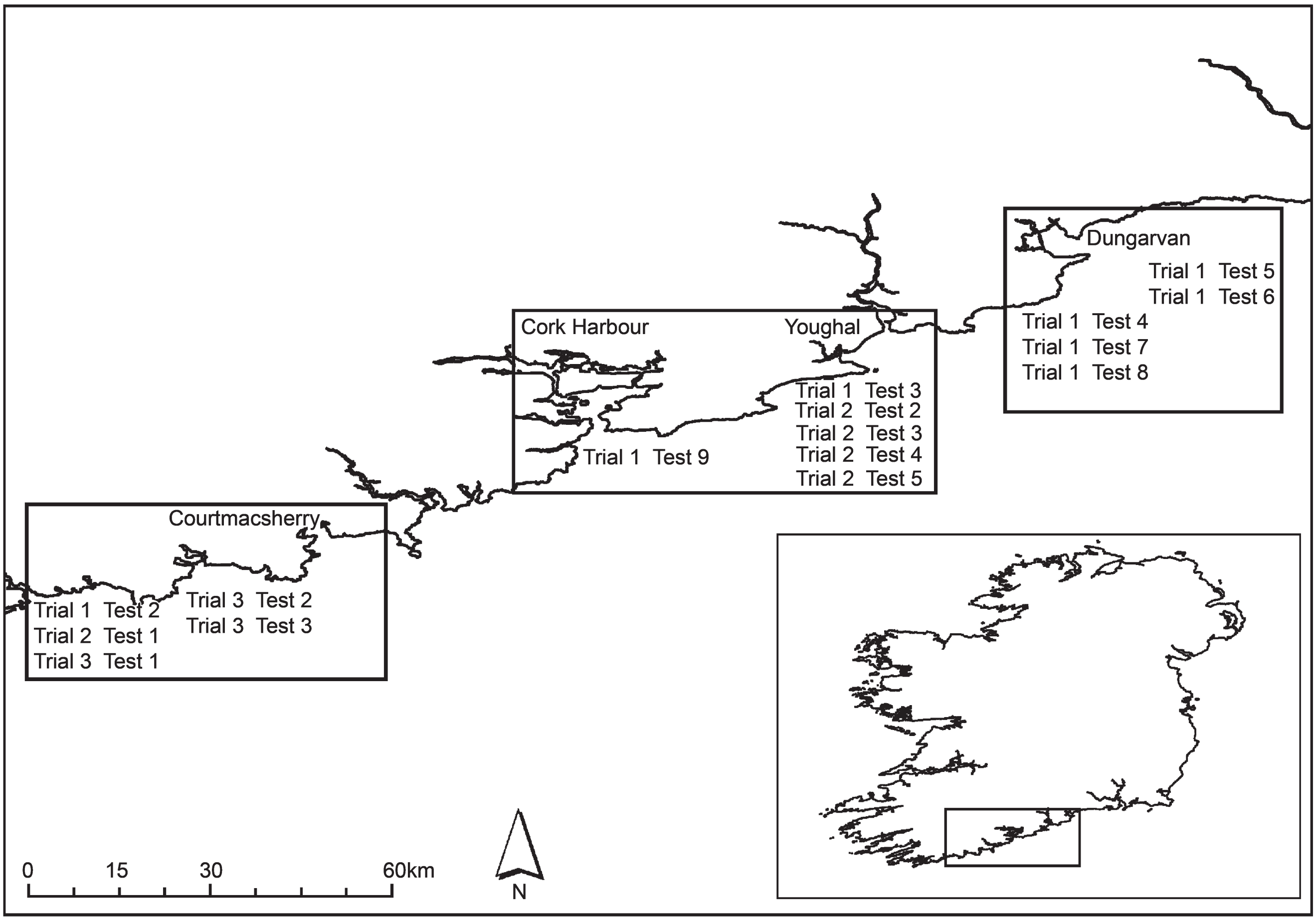

Fig. 1. Map showing location of common dolphin trials along the south coast of Ireland.

During Trial 2, the multiple signal output device remained fixed on the scaffold pole throughout. Initial behavioural sampling occurred in the absence of a signal; a test signal was then produced and further behavioural samples were taken.

The tests in each trial were observer 'blind', in that the person recording the behaviour had no knowledge of the type or status of the pinger being deployed, or signal output. The behaviour recorder was stationed at the bow of the boat, whilst another team member prepared and deployed each signal output device, noting the time of deployment, the type of device and its status (on or off). Device type and status were allocated to each encounter in no particular order. A bat box III (*Stag Electronics*) was tuned to the relevant frequency to test whether the acoustic deterrent devices were emitting a signal, prior to deployment.

For Trial 3, a 6m XS Rigid Inflatable Boat (RIB) with 115hp outboard engine was used in order to test two acoustic commercially developed deterrents, the CETASAVER and the Dolphin Deterrent Device (DDD). A group of around 20 common dolphins was located and approached by the *Holly Jo*. As the dolphins started to bowride, their behaviour was recorded from the *Holly Jo*. The RIB was stationery at a distance of several hundred metres from the bow of the *Holly Jo* at the start of each test. As the *Holly Jo* travelled towards the RIB at a velocity of 7.5km hr^{-1} the distance between the vessels was recorded every 5-10s from the RIB using a Leica LRF 1200 Rangemaster, which is accurate to ±1m up to a 400m range. An acoustic deterrent was deployed from the RIB to a depth of 2m but observers on the *Holly Jo* were unaware of the time of deployment, the type of device used or the status of the device (on/off). No controls were deployed and the behaviour prior to deployment was used to compare behaviour pre- and post- deployment of an acoustic deterrent. The DDD had two components to it, a short transmission of around 30s duration at the start of its deployment, followed by a regular transmission. Other trials (Anon., 2007) have suggested that the opening sequence may have a greater deterrent effect than the main deterrent signal. The first two tests carried out omitted the initial sequence by starting the device in the boat prior to deployment. Three subsequent tests were carried out using the full signal including the opening sequence from an initial distance of more than 100m but as no changes in behaviour were recorded, these were carried out with the full signal when dolphins were close (<30m) to the deterrent. The final test with the CETASAVER (Test 5) involved deploying the device when the dolphin group was less than 50m from the RIB. Dolphin behaviour during these close approach tests was also recorded from the adjacent *Holly Jo*, which was within 200m of the RIB with recorders observing the dolphins through 8×40 binoculars. At the end of each test the deterrents were tested aurally to ensure they were working.

Behavioural sampling

Behavioural sampling followed the methods detailed in Leeney *et al*. (2007). Behaviour was recorded in seven behavioural categories modified from Bearzi *et al*. (1999) via scan sampling (Altmann, 1974). Focal groups/schools were sampled (see Mann, 1999), rather than individuals, since common dolphins are usually found in groups and the gross changes in behaviour that might be associated with a deterrent reaction were of interest in the study. The group-follow protocol may under-record those behaviours that are less obvious or associated with a few individuals, but here behaviours were used that could be reliably and consistently recorded following the recommendations of Mann (1999). The data were then analysed to look for a combination of broad changes in behavioural categories, which might constitute some disturbance effect. The behavioural response observed was categorised into three levels of reaction intensity, based on observations of the effects of disturbance on behaviour in small cetaceans (Lusseau, 2003; Nowacek *et al*., 2001):

Level 0 = no detectable change of the behaviour.

Level 1 = avoidance (change of direction by 90°) or change of activity rhythms (increase of surfacing interval, tightening of group formation or increase of swimming speed).

Level 2 = significant change of behaviour: combination of rapid change of swimming direction (opposite direction from the source), increase of swimming speed and co-ordinated surfacing behaviour.

A wide area was covered in order to maximise the possibility of encountering multiple groups of common dolphins. Photographs were taken of the dorsal fins of as many individuals of each group as possible to facilitate recognition and avoidance of groups, which had already been exposed to tests. Adults with calves were avoided, although calves were present in some of the larger groups that tests were carried out on (see Tables 2 and 4).

RESULTS

A total of 10 encounters with apparently different groups of common dolphins occurred during Trial 1. Sixteen tests were carried out on group sizes ranging from 4 to 24 dolphins. After the first two deployments of active pingers, which solicited no reaction, two tests were carried out per group. An ongoing assessment of the reactions of dolphins to various changes in pinger settings was made. If no visible change in behaviour was recorded after the first test, another test was carried out using different settings, providing the dolphins remained in the vicinity of the vessel. This maximised the number of trials that could be carried out within a short time frame. All dolphins were bow-riding the survey vessel during each trial.

Five groups of common dolphins were located on 29 January 2007 during Trial 2. The structure of these groups was dynamic and numerous individuals may therefore have been involved in more than one test. If no reaction to a pinger frequency was detected in the initial test, a second signal was immediately tested.

A total of five tests were carried out with the CETASAVER and nine with the DDD during Trial 3, all on the same group of dolphins. Both deterrents were confirmed to be working at the end of each test. The first tests were with CETASAVER, followed by eight with the DDD. The first two of the DDD excluded the opening sequence. Two further tests with CETASAVER were followed by one with the DDD.

Behavioural responses

Trial 1

The behaviour of common dolphins recorded during deployment of the pole (BEFORE) and after the deployment of the pole and a pinger (AFTER) during Trial 1 is shown in Table 2. Dolphins were always fast swimming on the bow. After deployment of the pinger, fast swimming on the bow was still the most frequently recorded behaviour. No behaviour that could be described as evasive was recorded for any trial. No change in surfacing mode or group formation, indicative of evasive behaviour, was observed. When recorded, the distance from vessel after deployment increased on seven occasions (54%, mean increase of 18m), stayed the same on four occasions (31%) and decreased on two occasions (15%, mean decrease of 5m). On two occasions, both whilst testing an active CP, dolphins were observed making an obvious movement away from the bow of the vessel immediately after the pinger was deployed, but

Table 2

Description of dolphin behaviour before and after deployment of a pinger during Trial 1. Only changes in behaviour are shown.

				Before					After					
Test no.	Pinger type	Pinger status	Group size[1]	Group form[2]	Surf mode[3]	Speed[4]	Dist <than	Behav.[5]	Group form[2]	Surf mode[3]	Speed[4]	Dist <than	Behav.[5]	Evasive behaviour
1	CP	On	8A	T-Lo	Li	F	10m	BR		Li/OR		+30m		NO
2	RP	On	1A 1J	T-Lo	Li/OR	F	25m	BR				+10m		NO
3	RP	On	10A 2C	T-Lo	Li	F	15m	BR	Lo-D					NO
4	CP	On	10A 2C	Lo-D	Li	F	15m	BR				+5m		NO
5	RP	On	4A	T-Lo	Li	F	25m	BR		Li/OR				NO
6	CP	On	6A 1 J	T-Lo	Li/OR	F	25m	BR	Lo			-5m		NO
7	RP	Off	6A	T-Lo	Li/OR	F	25m	BR		P		-5m		NO
8	RP	On	7A	Lo	Li	F	10m	BR	Lo-D			+15m		NO
9	RP2[6]	On	5A 24-6A	Lo	Li	F	20m	BR		Li/OR		+50m	BR/BRE	NO
10	CP	On	6A	Lo	Li/OR	F	10m	BR/BRE		Li	N	+10m	BR	NO
11	RP2[6]	On	7A	Lo	Li	F	15m	BR						NO
12	RP	Off	7A 1C	Lo	Li	F	15m	BR		Li/OR		+5m	BR/CO	NO
13	RP2[6]	On	4-12	Lo	Li	F	15m	BR						NO
14	CP	Off	4A	Lo	Li	F	15m	BR				-5m		NO
15	RP2[6]	On												NO
16	RP2[6]	On												NO

[1]Dolphin age categories: A=adult, J=juvenile, C=calf. [2]Group formation: T=tight, Lo=loose, D=dispersed. [3]Surfacing mode: Li=lively, OR=occasional races. [4]Speed: F=fast, N=normal, S=slow. [5]Behaviour: NS=normal surfacing, BR=bow-riding, OR=occasional races, BRE=breaching, CO=courtship. [6]RP2 refers to the new setting with pinger duration increased to 10 seconds.

this reaction was short-lived and could not be described as evasive. Overall, observations suggested little change in the behaviour of dolphin groups after the deployment of pingers (both CP or RP and either active or inactive).

The results from the click train detection function of the RP during trials in 2006 are shown in Table 3. Although the RP showed that dolphin clicks were detected and logged, the dolphin must be at least 10m from the RP to activate the pinger. According to the RP log, the pinger was activated on at least six occasions, three occasions when the original settings were used (RP1) and three occasions when the signal duration was increased to 10 seconds (RP2). A hydrophone was used as an independent measure of click detection. Dolphin click activity was detected on the hydrophone on all of the CP deployments and all RP2 deployments (Table 3). On two occasions (Tests 9 and 11), the pinger was activated according to the hydrophone but was not logged by the RP. This suggests that the RP did not always log its own activation. During three tests, there were no recordings on the hydrophone despite pinger activation being logged by the RP. This may be due to the emission of high frequency signals, beyond the detection range of the hydrophone. Nonetheless, these data show that the dolphins were echolocating and did activate the RP on a number of occasions, but did not show any evasive behaviour.

Trial 2

The behaviour of common dolphins exposed to signals from the multiple signal output device is shown in Table 4. Common dolphins were generally observed to be foraging prior to these trials, with bowriding only recorded on four occasions during controls. This contrasts with Trial 1, in which dolphins were mainly bow-riding prior to the deployment of pingers. There were no consistent changes in group formation, surfacing mode, speed of travel or mean distance from the vessel after deployment of the signal output device.

Trial 3

In tests with the CETASAVER, the distance between the dolphins and the *Holly Jo* increased during Test 1 from less than 10m to around 20m when the vessel was around 250m

Table 3

Results from the acoustic logs on the Responsive Pinger (RP) in Trial 1.

Test no.	Pinger type[1]	Pinger status	Time activated	Dolphin clicks detected	Pinger activation detected	Detected on hydrophone
2	RP	On	13:48:34	Y	Y	
3	RP	On	11:05:43	Y	Y	-
5	RP	On	14:58:23	Y	Y	-
5	RP	On	15:04:35	Y	N	-
5	RP	On	15:07:30	Y	N	-
8	RP	On	10:05:02	Y	N	-
9	RP2	On	10:53:30	Y	N	Y
11	RP2	On	11:07:54	Y	N	Y
13	RP2	On	10:36:14	Y	Y	Y
15	RP2	On	11:45:43	Y	Y	Y
15	RP2	On	15:24:42	Y	Y	Y
16	RP2	On	15:25:06	Y	Y	Y

[1]RP2 refers to the new setting with pinger duration increased to 10 seconds.

Table 4

Dolphin group size and behaviour before and after deployment of pinger during Trial 2. Only changes in behaviour are shown.

		Before					After					
Group composition[1]	Signal type	Group form[2]	Surf mode[3]	Speed[4]	Dist <than	Behav.[5]	Group form[2]	Surf mode[3]	Speed[4]	Dist <than	Behav.[5]	Evasive behaviour
10-15A, 2C	1	T	Li-OR	N-F	10m	BR		Q-OR		+20m	NS	NO
20-25A, 2C	2	T	Li-OR	N-F	10m	NS	Lo	Q	N		BR	NO
20A, 1C	3	T	Q-OR	N-F	30m	NS	T-Lo		N	-10m		NO
20A, 1C	4	T	Q-OR	N-F	30m	-	Lo		N	-10m	NS	NO
25A, 2J, 3C	5	T	N	N	50m	NS	Lo	Q-Li	N-F	-20m	BRE	NO
15-20A	7	T	N-OR	N	30m	NS	Lo	Q-OR	N-F	-10m	BR	NO
15-20A	8	T	N	N	30m	NS	T-Lo	N-OR	N-F	+20m	NS-BR	NO
10-12A	13	T	Li	F	10m	BR		N	N	+5m	NS-BR	NO
10-12A	14	T	N	N	30m	NS	Lo	Q		-15m	NS-OR	NO
10-12A	15	T	N-OR	N	10m	NS-OR		Q-OR	N-F			NO
7A, 2J	17	T-Lo	N	N-F	30	NS-BR		N-Li	N-F	+20m	OR	NO
25A, 4C	18	T-Lo	N	S	10m	BR-BRE	Lo	Li	F		BR	NO
15+	23	T	N-Li	N-F	10m	NS/OR	T-Lo	N	N	+20m	NS	NO
4A, 1J	23	T	N	N	10m	NS	-	-	-	-	-	-
4A, 1J	24	T	N	S	10m	BR					NS	NO
4A	25	T	Q	N	10m	NS		N-OR	N-F	+15m		NO

[1]Dolphin age categories: A=adult, J=juvenile, C=calf. [2]Group formation: T=tight, Lo=loose, D=dispersed. [3]Surfacing mode: Q=quiet, Li=lively, OR=occasional races, N=normal. [4]Speed: F=fast, N=normal, S=slow. [5]Behaviour: NS=normal surfacing, BR=bow-riding, OR=occasional races, BRE=breaching.

from the deterrent, which was deployed from the stationery RIB. In the next two tests, no changes in behaviour were observed. In Test 4 the dolphins began to move away from the *Holly Jo* when they got to within 30m of the deterrent. Their behaviour changed from 'bow-riding' to 'travelling'. In the final test (Test 5), when the deterrent was placed in the water within 50m of dolphins, there was no change in the behaviour of dolphins over a 20s period. However, all these reactions were considered a Level 0 reaction.

In the first test with the DDD, dolphin behaviour changed as they approached the deterrent. Their distance from the *Holly Jo* increased from 10 to 30m over the first 50s of the trial and from 30 to more than 50m when within 300m of the deterrent. Swimming direction also changed and 'occasional leaps and races' were recorded together with 'travel'. Thus, a mild change in behaviour (Level 1) occurred. However, when the trial was repeated there was no change in any of the behavioural categories recorded. After a short period without tests, allowing the dolphins to resume their foraging behaviour, further trials were carried out with the DDD. The DDD starting sequence, which has a 30s duration, was tested seven times, from distances 5-100m to the dolphins. It solicited a Level 1 evasive reaction on three occasions (43%). In Test 4 this occurred from a distance of around 180m, Test 8 from less than 5m and Test 9 from within 30m. However in a test when the DDD was deployed within 20m of the dolphins, no change in behaviour was recorded.

CONCLUSIONS

A total of 45 tests were carried out to determine the effects of various potential acoustic deterrent signals on the behaviour of common dolphins. No responses that could be described as evasive, such as escape behaviour, a rapid change of swimming direction or increase in swimming speed, were consistently observed. Although the same group of dolphins were sometimes subjected to a number of consecutive tests, up to 14 different dolphin groups, ranging in size and in composition, including adults, juveniles and calves were exposed to pingers or acoustic deterrent signals over the course of the study. It is likely, therefore, that the reactions to acoustic deterrent signals described here are typical of common dolphins off the south coast of Ireland. Although a dolphin's motivation and thus its response threshold to a deterrent signal, may be elevated during bow-riding (Anon., 2007), dolphins tested in this study were engaged in a number of different behaviours prior to pingers being deployed. Thus the reaction to acoustic deterrent signals described here is likely not associated with any specific behaviour.

From an experimental point of view, the constraint for the RP that dolphins must be greater than 10m away was not ideal for bowriding experiments as dolphins spent most of their time less than 10m from the device. However one would have expected some echolocation clicks between 10 and 150m as dolphins approached the vessel and therefore some reaction if the signal was effective. The CP did not have the same constraints. Comparing dolphin responses between the two devices should demonstrate if the <10m effective distance was an issue. As there were no evasive responses to either device it was not possible to carry out a meaningful comparison of responses and controlling for the 10-150m range in the RP was not required.

Common dolphins were shown to be echolocating during these trials and did activate the RP. On two occasions, dolphins were observed making a slight movement away from the bow of the vessel immediately after the pinger was deployed. Whilst this reaction could not be described as evasive, it does suggest that the sound was detected by the dolphins.

The range of frequencies, signal lengths and signal intervals tested using the multiple signal output device did not elicit any strong reactions. Similarly, no major changes in dolphin behaviour were observed in response to any of the five CETASAVER deployments. The experimental design and the person deploying the equipment was the same as in previous trials eliminating the possibility that this may have contributed to the different results obtained. Mild changes in behaviour (Level 1) were observed during four out of nine (44%) deployments with the DDD device. None of these responses could be categorised as evasive behaviour (Level 2). No change in behaviour was observed during five deployments, including three cases when the full DDD signal was deployed at less than 100m from approaching animals.

Although the controlled exposure experiments presented here are in stark contrast to the noisy, complex environment around an active fishing trawl, the implications of these results for bycatch mitigation cannot be ignored. The lack of consistent behavioural changes and absence of any evasive behaviour from the group of common dolphins encountered suggests that the DDD did not have a major deterrent effect on common dolphins and would certainly not be capable of consistently displacing animals from the mouth of a pelagic trawl. These results are in contradiction to those described by IFREMER who found a strong deterrent effect by common dolphins in the Bay of Biscay for later models of the CETASAVER and to the starting sequence of the DDD (Anon., 2007). Although both devices were only tested on one dolphin group in the present study, the contrasting results suggest that intra-specific differences occur in the reaction of common dolphins to acoustic stimuli, which may be due to differences in spatial, temporal or other variables. The lack of consistent deterrent effects on all groups of animals in all locations raises questions about the efficacy of these devices in pelagic trawls. Reductions in bycatch have, however, been observed using these devices in some pelagic trials, although the reasons for these reductions are not fully understood (Anon., 2007). One possible explanation could be that acoustic devices permit animals to associate an escape route with the acoustic signal at the mouth of the trawl (Anon., 2007). This theory has yet to be proven, however, as it is currently not possible to effectively determine the presence of animals in trawls while the gear is deployed.

These results are in stark contrast to similar trials with the same CP and RP pingers tested here but carried out on bottlenose dolphins in the Shannon Estuary (Leeney *et al*., 2007), in which strong evasive behaviour was recorded in 75% of tests. Kastelein *et al*. (2006) suggested two reasons for the observed inter-species differences in reaction to acoustic alarms in their study, namely individual differences and species differences. As they only sampled one individual from two species, it was not clear how representative each study animal was for its species. The study presented here incorporated a wide range of individuals and groups, thus it is likely that the observed lack of reaction to the signals tested is characteristic of common dolphins in this region. Kastelein *et al*. (2006) also suggested that the need to flee from a sound may depend on the animal's perceived chances of being predated. Rapid habituation has been reported in recent acoustic deterrent trials with common dolphins (Anon., 2007). This study also suggested that deterrent effect declines with increased signal repetition, and increases with longer signal length. No such relationship was found in the present study as no deterrent effect was recorded for any combination of signal length, frequency or repetition.

The difference in responses of bottlenose dolphins and common dolphins to the same deterrent signals may be due to different acoustic sensitivities or thresholds of each species. Short-beaked common dolphins produce echolocation click trains at between 23-67kHz (Richardson, 1995) and whistles between 5-20kHz (Ansmann *et al*., 2007). Bottlenose dolphins are sensitive to sounds between 1-200kHz and produce echolocation clicks around 110-130kHz (Richardson, 1995). There are no data available on the hearing sensitivity of common dolphins but Kastelein and Hagedoorn (2003) recorded the audiogram of a striped dolphin and showed that maximum sensitivity (42dBµPa@1m) occurred at 64kHz. The range of the most sensitive hearing was from 23 to 123kHz and became less sensitive below 32kHz and above 120kHz. Assuming common dolphin sensitivities are similar then as the CP and RP generated modulated frequencies between 20-160kHz, the multiple signal output device from 20-130kHz and both the CETASAVER and the DDD, covered this auditory range it seems unlikely that differences in dolphin auditory sensitivities can explain the different reactions to these deterrents.

More research is required to explore whether the results presented here are consistent at different locations and with other common dolphin populations**.** The interactive RP pinger developed by BIM was successful to some extent in that it responded consistently to dolphin vocalisations and a functioning deterrent device of this nature is desirable to reduce the input of noise into the marine environment and it may also delay the potential effects of habituation. A consistently effective deterrent signal for common dolphins will be required if this device is to prevent animals from entering a pelagic trawl.

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