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Article *in* Cahiers de Biologie Marine · October 2018

DOI: 10.21411/CBM.A.D5B58D5B

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Cah. Biol. Mar. (2018) 59 : 473-479
DOI: 10.21411/CBM.A.D5B58D5B

Testing two types of acoustic deterrent devices (pingers) to reduce harbour porpoise, *Phocoena phocoena* (Cetacea: Phocoenidae), by catch in turbot (*Psetta maxima*) set gillnet fishery in the Black Sea, Turkey

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Abstract: Field experiments with Aquamark 100 and Aquamark 200 pingers were conducted in the bottom set gill net fishery for turbot in the Black Sea coast between March and June 2012. The aim of the experiment was to evaluate (i) the effectiveness of two types of pingers to reduce by catch rate of harbour porpoises, and (ii) the effects of pingers on the catches of the target fish species (*Psetta maxima*) and non-target fish species (*Raja clavata*, *Suqualus acanthias* and *Trigla lucerna*) in the turbot set gillnet fishery. A total of 246 specimens (95 *P. maxima*, 138 *R. clavata*, 8 *P. phocoena*, 4 *S. acanthias* and 1 *T. lucerna*) were caught during both Aquamark 100 and Aquamark 200 pingers trials. Catches of *Psetta maxima* and other fish species (*Raja clavata*, *Suqualus acanthias* and *Trigla lucerna*) were not affected by the sound of the pingers in the active nets. Catch of target *P. maxima* and non-target fish *R. clavata* were similar as were also for most caught species. 6 *P. phocoena* (2 in control and 3 in active nets with Aquamark 100) and 2 *P. phocoena* (1 in control and 1 in active nets with Aquamark 200) were caught in controls and active nets. There are no statistical differences between active and passive net catch per unit effort among the fish species and also cetaceans. As a conclusion, the acoustic signals clearly showed that these pinger types did not reduce by catch of harbour porpoise from the turbot gill net in the eastern Black Sea coasts, Turkey. The acoustic signals of both pinger types also did not affect the catch of target and non-target fish species.

Résumé : *Essai de deux types de dispositifs acoustiques de dissuasion (pingers) pour réduire la capture du marsouin commun,* Phocoena phocoena *(Cetacea: Phoconidae) par la pêcherie de turbot (*Psetta maxima*) au filet maillant en Mer Noire, Turquie*. Des expérimentations sur le terrain avec des pingers Aquamark 100 et Aquamark 200 ont été menées dans la pêcherie de turbot au filet maillant sur la côte de la Mer Noire entre mars et juin 2012. Le but de cette expérience était d'évaluer (i) l'efficacité de deux types de pingers à réduire le taux de prise des marsouins communs, et (ii) les effets des pingers sur les prises de poissons cibles (*Psetta maxima*) and les poissons non-cibles (*Raja clavata, Suqualus acanthias* et *Trigla lucerna*) dans le pêche au filet maillant. Un total de 246 spécimens (95 *P. maxima*, 128 *R. clavata*, 8 *P. Phoconea*, 4 *S. acanthis* et 1 *T. lucerna*) ont été capturés à la fois par les essais des pingers Aquamark 100 et Aquamark 200 au cours de l'étude. Les prises de *Psetta maxima* et des autres espèces de poissons (*Raja clavata, Suqualus acanthis* et *Trigla lucerna*) n'ont pas été affectées par le son des pingers dans les filets. Les capture de la cible *P. maxima* et le poisson non-cible *R. clavata* étaient similaires ainsi que pour la plupart des espèces capturées. 6 *P. phocoena* (2 dans les témoins et 3 dans les filets avec Aquamark 100) et 2 *P. Phocoena* (1 dans les témoins et 1 dans les filets avec Aquamark 200) ont été capturés.

Reçu le 6 novembre 2017 ; accepté après révision le 12 décembre 2017.
Received 6 November 2017; accepted in revised form 12 December 2017.

Il n'y a pas de difference statistique entre les captures nettes actives et passives parmi les espèces de poissons ou de cétacés. En conclusion, les signaux acoustiques montrent clairement que ces types de pingers ne réduisent pas les prises du marsouin commun à partir du filet maillant à turbot sur les côtes orientales de la Mer Noire en Turquie. Les signaux acoustiques de ces deux types de pinger n'affectent pas non plus la capture des espèces cibles et non-cibles.

Keywords: Harbour porpoises ● *Phocoena phocoena* ● Pingers ● By catch ● Black Sea ● Turkey

Introduction

There are three cetacean species, the harbour porpoise, *Phocoena phocoena* (Linnaeus, 1758) common bottlenose dolphin, *Tursiops truncatus* (Montagu, 1821) and short beaked common dolphin, *Delphinus delphis* (Linnaeus, 1758) in the Black Sea (Zaitsev & Mamaev, 1997; Öztürk et al., 2004). In the Black Sea, many species and populations of small cetaceans were exploited in dolphin fisheries prior to 1966 in USSR, Romania and Bulgaria, and prior to 1983 in Turkey. Other anthropogenic impacts such as habitat degradation, pollution, physical modification of the seabed, disturbance and especially incidental catch in fishing gears have further reduced populations of Black Sea cetaceans (Birkun, 2002). Almost all of the cetaceans in the Black Sea, especially *P. phocoena* are caught in bottom set gillnets such as turbot (*P. maxima*), spiny dogfish (*Squalus acanthias* Linnaeus, 1758) and sturgeon (*Acipenser* spp.). The peak occurs during spring and summer months of the turbot season, including territorial waters of all six riparian countries (Birkun, 2002; Öztürk et al., 2004).

Turbot, *Psetta maxima* (Linnaeus, 1758), is one of the most important commercial demersal fish species for fishing in Turkey. Legal turbot fisheries with turbot gill nets are conducted year round except for between 15 April and 15 June (Anonymous, 2017) in the Turkish Seas. Turbot gill net fishing efforts are positively unknown in the Black Sea and these fishing nets are the most dangerous fishing gears for incidental mortality of Black Sea cetaceans (Radu et al., 2003). Overfishing and declining of water quality have also reduced the Black Sea fish stocks such as anchovy, sprat etc which represent Black Sea cetaceans preys (Kideys, 1994).

By catch of small cetaceans such as *P. phocoena*, *T. truncatus* and *D. delphis* is a major problem for commercial gill net fisheries around the World. By catch and entanglement in fishing gears such as gillnet, tanglenet and driftnet is the biggest threat to cetacean populations around the World and killing about 300.000 animals per year (Read et al., 2006). By catch level of Black Sea cetaceans has been studied in the Black Sea, especially for turbot gill net fishery (Öztürk et al., 1999; Birkun, 2002; Tonay & Öztürk, 2003; Radu et al., 2003; Gönener & Bilgin, 2009; Tonay, 2016). *P. phocoena* are the most frequently killed cetaceans in the turbot gill net fishery in the Black Sea.

The use of acoustic deterrent devices or pingers in fish nets can be considered as the most appropriate solution to keep the dolphins and/or porpoises away from the fishing nets. Namely, the International Whaling Commission (IWC, 2000) reported that the most reasonable hypothesis is that pingers reduce by catch rates by producing a sound that dolphins and porpoises find aversive. Today, different types of pingers have been produced to reduce the by catch level of cetaceans, sea birds and sea turtles from the fishing nets (Koschinski & Strempel, 2012; Dawson et al., 2013).

The reactions of harbor porpoises and bottlenose dolphin to pingers are quite different (Franse, 2005). Harbour porpoises can hear sounds with frequencies from 16 kHz up to 140 kHz, with a reduced sensitivity at 64 kHz. Also, most sensitive is the harbour porpoise for frequencies from 100 up to 140 kHz. The bottlenose dolphin can hear frequencies from 75 Hz up to 150 kHz (Johnson, 1967). The bottlenose dolphins are most sensitive for frequencies from 15 up to 110 kHz. The peak frequency for their echolocation pulses is 100 kHz (Au, 1993).

The present study with Aquamark 100 and Aquamark 200 pingers were conducted in the turbot bottom set gill net fishery between March and June 2012 along the Rize coast in the southeastern Black Sea, Turkey. The aim of the present study was to evaluate the effectiveness of Aquamark 100 and Aquamark 200 pingers to reduce by catch rate of harbour porpoises. This paper is also described information on the effects of two pingers types on the catches of the target fish, *P. maxima* and non-target fish species, *R. clavata*, *S. acanthias* and *Trigla lucerna* (Linnaeus, 1758), in the turbot set gillnet fishery in the Black Sea.

Materials and Methods

Newly purchased two pingers types (Aquamar 100 and 200) were used as sources of acoustic alarm devices. The characteristics of the two pingers are from the manufacturer and the battery is mounted inside the device and the life is 2 years (Table 1). The Aquamark 100 and 200 porpoise deterrent pinger by Aquatec Subsea Limited, are acoustic pingers designed to reduce the unintentional catch of harbour porpoises in commercial gillnet, tanglenet and driftnet fisheries. The Aquamark 100 is also targeted specifically at the harbour porpoise. It complies with EU Council Regulation 812/2004 (Set 1) for static nets (EU, 2004).

Turbot gill nets used in the commercial turbot fishery were used for samplings and there was a scientific researcher on board with professional turbot gill net fishermen during the study. Characteristics were: length of one turbot gill net 72 m, each set consisted of 9 nets (about 650 m). Pingers trials were conducted with one set each for controls without pingers and active net with pingers (Aquamark 100 or 200). The distance among the pingers along the set net was about 200 m. So, the active net was always equipped with four pingers; one acoustic device fixed each end of turbot gill net set, one at about 200 m and one at about 400 m, attached just above the float line. A total of 23 turbot gill net fishing operations with Aquamark 100 pingers (active net) and 23 control nets (without pingers) were conducted between March 2012 and June 2012. A further 9 turbot gill net fishing sampling with Aquamark 200 pingers (active net) and 9 control nets (without pingers) were conducted from April 2012 and June 2012 along the Rize coasts between 10 and 50 m water depth (Fig. 1). Turbot gill net operations with control and active nets were conducted on same day at different depths and with the same characteristics nets as mesh size (320 mm), mesh depth (7 meshes), thickness of the twine (210 d / 2x3 no) and hanging ratio (E = 0.36) (Fig. 2). To calculate effects of pingers on catch of target (*P. maxima*) and non-target (*P. phocoena*, *R. clavata*, *S. acanthias* and *T. lucerna*) species for turbot gill net fisheries during the banned time fishing operation were conducted with a special permit.

Catch per unit effort (CPUE) or danger index was

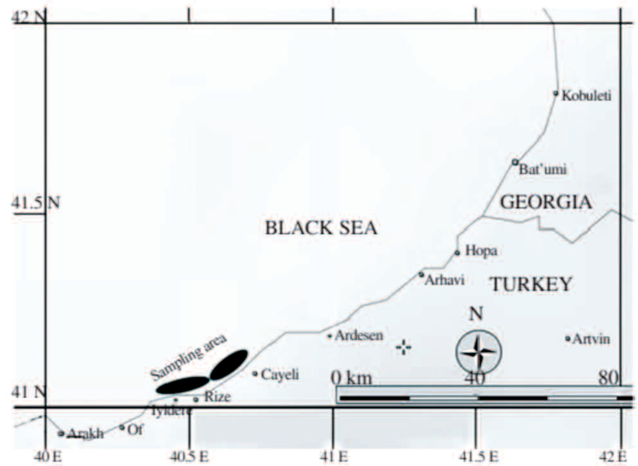

Figure 1. Turbot gill net fishing operations sampling area along the Rize coast in the southeastern Black Sea, Turkey

calculated as the number of individuals divided by the total set net length (km) x soak time in day (24 hours). Catch per unit effort (CPUE; individuals / km × day) for each species (target: *P. maxima*, by catch: *R. clavata*, *S. acanthias*, *P. phocoena* and *T. lucerna*) were used for comparison of active and passive net.

The F and T test was used to determine the CPUE difference of the target and non-target species between active and passive nets. Statistical analyses were performed with the software package PAST version 1.94b (Hammer et al., 2001). Statistical significant level was used as 0.05.

Results

The catch per unit effort (CPUE; individuals / km × day) results of target and non-target species caught by control net without pingers and active net with Aquamark 100 and Aquamark 200 pingers between March 2012 and June 2012 in the turbot set gillnet fishery along the Rize coast in the southeastern Black Sea, Turkey showed in Table 2.

Table 1. Features of Aquamark 100 and Aquamark 200 pingers used as sources of acoustic alarm

Features	Model	
	Aquamark 100	**Aquamark 200**
Fundamental frequency	20-160 kHz	5-160 kHz
Source Levels (SL) re 1 μPa @ 1m	145 dB	145 dB
High frequency harmonics	yes	yes
Pulse duration	200-300 ms	
Interpuls interval	4-30 seconds, randomized	4-30 seconds, randomized
Dimensions	164 mm x 58 mm (Ø)	164 mm x 58 mm (Ø)
Battery	1 D - cell alkaline	1 D - cell alkaline
Distance between pingers along nets	200 m	200 m

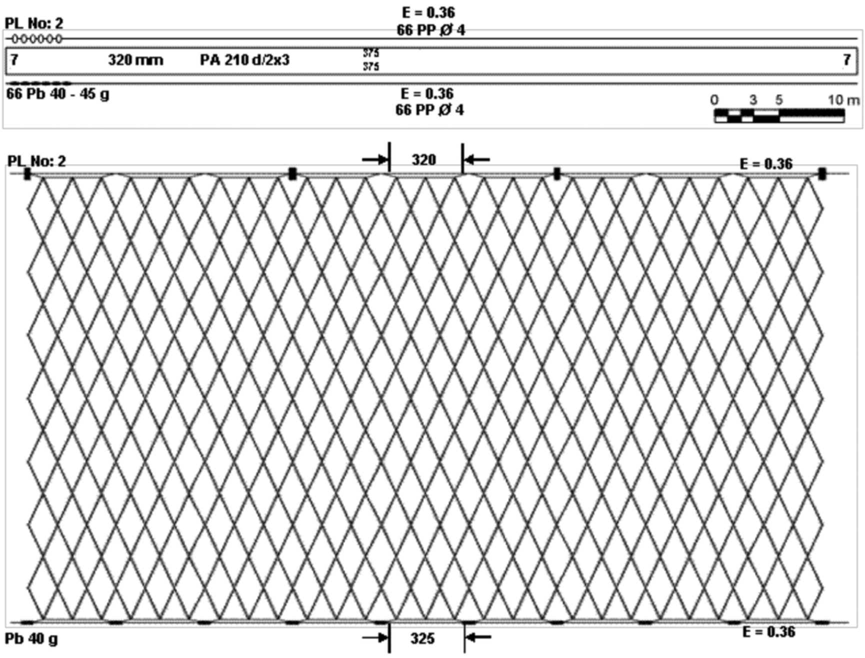

Figure 2. Characteristics of turbot gill net used in monthly samplings.

Aquamark 100 pinger trials

A total of 71 *P. maxima* (43 controls and 28 active nets), 77 *R. clavata* (29 controls and 48 active nets), 6 *P. phocoena* (2 controls and 3 active nets), 2 *S. acanthias* (1 control and 1 active net) and 1 *T. lucerna* with active net was obtained during the Aquamark 100 pingers trials. Mean CPUE of *P. phocena* was estimated as $6.4 \times 10^{-3} \pm 4.6 \times 10^{-3}$ (95% conf.: -3.1×10^{-3} - 16.0×10^{-3}) for active group with Aquamark 100 pingers and it was estimated as $10.6 \times 10^{-3} \pm 7.6 \times 10^{-3}$ (95% conf.: -5.1×10^{-3} - 26.3×10^{-3}) for control group without pingers. The results of F and T tests showed that there was no statistical difference between the mean CPUE values of these two groups (P = 0.6416). Mean CPUE of *P. maxima* was estimated as 0.166 ± 0.0291 (95% conf.: 0.1066 - 0.2272) for active group and it was estimated as 0.116 ± 0.0340 (95%

Table 2. The catch per unit effort (CPUE; individuals / km × day) of target and non-target species caught by control net without pingers and active net with Aquamark 100 and Aquamark 200 pingers between March 2012 and June 2012 in the turbot set gillnet fishery along the Rize coast in the southeastern Black Sea, Turkey. Active net: with pingers (Aquamark 100 and Aquamark 200), Passive net: without pingers.

Species	CPUE (individuals / km × day)		
	Active net	Passive net	*P* values
	Aquamark 100		
Squalus acanthias	0.004 ± 0.0036	0.006 ± 0.0058	*P* = 0.7412
Psetta maxima	0.167 ± 0.0291	0.116 ± 0.0340	*P* = 0.2264
Trigla lucerna	0.000 ± 0.0000	0.004 ± 0.0043	-
Raja clavata	0.110 ± 0.0326	0.150 ± 0.0482	*P* = 0.4857
Phocoena phocoena	0.006 ± 0.0046	0.011 ± 0.0076	*P* = 0.6416
	Aquamark 200		
Squalus acanthias	0.000 ± 0.0000	0.025 ± 0.0169	-
Psetta maxima	0.180 ± 0.0597	0.117 ± 0.0556	*P* = 0.4497
Trigla lucerna	0.000 ± 0.0000	0.000 ± 0.0000	-
Raja clavata	0.136 ± 0.0473	0.467 ± 0.2225	*P* = 0.3249
Phocoena phocoena	0.009 ± 0.0091	0.012 ± 0.0122	*P* = 0.8397

conf.: 0.0459 - 0.1871) for control group. The results of F and T tests showed that there was no statistical difference between the mean CPUE values of these two groups (P = 0.2664). Mean CPUE of *R. clavata* was estimated as 0.109 ± 0.0326 (95% conf.: 0.0420 - 0.1771) for active group and it was estimated as 0.150 ± 0.0482 (95% conf.: 0.0505 - 0.2503) for control group. The results of F and T tests showed that there is no statical difference between the mean CPUE values of these two groups (P = 0.4858). Mean CPUE of *S. acanthias* was estimated as $3.6 \times 10^{-3} \pm 3.6 \times 10^{-3}$ (95% conf.: -3.8×10^{-3} - 0.0111) for active group and it was estimated as $5.8 \times 10^{-3} \pm 5.8 \times 10^{-3}$ (95% conf.: -6.3×10^{-3} - 17.9×10^{-3}) for control group. The results of F and T tests showed that there is no statical difference between the mean CPUE values of these two groups (P = 0.7415).

Aquamark 200 pinger trials

A total of 24 *P. maxima* (15 controls and 9 active net), 61 *R. clavata* (12 controls and 49 active net), 2 *P. phocoena* (1 control and 1 active net) and 2 *S. acanthias* with active net was obtained during the Aquamark 200 pingers trials. The mean CPUE of *P. phocena* was estimated as $9.1 \times 10^{-3} \pm 9.1 \times 10^{-3}$ (95% conf.: -0.0119 - 0.0300) for active group with Aquamark 100 pingers and it was estimated as 0.012 ± 0.0122 (95% conf.: -0.0159 - 0.0404) for control group without pingers. The results of F and T tests showed that there is no statical difference between the mean CPUE values of these two groups (P = 0.8397). The mean CPUE of *P. maxima* was estimated as 0.167 ± 0.0597 (95% conf.: 0.1066 - 0.2272) for active group and it was estimated as 0.1800 ± 0.05556 (95% conf.: 0.0423 - 0.3176) for control group. The results of F and T tests showed that there is no statical difference between the mean CPUE values of these two groups (P = 0.4497). The mean CPUE of *R. clavata* was estimated as 0.136 ± 0.0473 (95% conf.: 0.0273 - 0.2454) for active group and it was estimated as 0.467 ± 0.3225 (95% conf.: -0.2763 - 1.2109) for control group. The results of F and T tests showed that there is no statical difference between the mean CPUE values of these two groups (P = 0.3249).

In total of 246 specimens (95 *P. maxima*, 138 *R. clavata*, 8 *P. phocoena*, 4 *S. acanthias* and 1 *T. lucerna*) were caught both in Aquamark 100 and Aquamark 200 pingers trials during the study. Note that 37 *R. clavata* were obtained in only one turbot gill net during Aquamark 200 pinger trials. Catch of target, *P. maxima* and non-target fish, *R. clavata* were similar and these were also the mostly caught species. Therefore, acoustic signals clearly showed that pingers did not reduce by catch of harbour porpoise in the turbot gill net in the eastern Black Sea coasts, Turkey. The acoustic signals of two pingers had also no effect on the catch of target and non-target fish species.

Discussion

Pinger is a device with a low intensity (source level: < 150 dB re 1 μPa at 1 m) and emits signal in the middle to high frequencies (2.5 - 10 kHz) with higher harmonic frequencies (up to 160 - 180 kHz) (Franse, 2005). These ultrasound pulses are in the sensitive hearing range of the small cetaceans (harbour porpoises and bottlenose dolphins) and keep the dolphins and harbour porpoises away from fishing gears (Culik et al., 2001; Dawson et al., 2013). In the only one previous study concerning use of pingers to reduce by catch level in the Black Sea, it was found that Dukane NetMark™1000 pingers were effective in reducing *P. phocoena* by catch in turbot gill net fisheries without significantly affecting target fish, *P. maxima* and non-target fish, *R. clavata*, catch (Gönener & Bilgin, 2009). But, as opposed to the previous this, Aquamark 100 and 200 pingers were not efficient in reducing the by catch level of harbour porpoise. However, as before, these two pinger types also did not affect the catch of target and non-target fish species. The differences between the two studies can be explained by the different sea conditions, the different biotic and biotic factors, the geographical region and the different characteristics, especially frequency level of used pingers. Urich (1983) reported that soft bottom is not a good reflector and therefore different reflections from the different bottom structure in the different geographical area can be caused different results between the studies. Moreover, the reasons of different results between the testing of different type of pingers may be due to several different variabilities. Kindt-Larsen (2008) reported that the effect of pinger depend on several different factors, e.g. source level of the pinger, frequency, background noise, propagation losses, directivity of the pinger and directional hearing harbour porpoise. Furthermore, the differences between the two studies may be due to differences in the devices used in the experiments. Aquamark 100 and 200 pingers have higher fundamental frequency and higher source level than the Dukane NetMark™1000 pingers. The Dukane NetMark™1000 pingers emit a tonal signal with a fundamental frequency of 10–12 kHz and with significant harmonics up to 100 kHz. The manufacturer cites a source level of 132 dB (re 1 μPa at 1 m). Whereas, Aquamark 100 and 200 pingers emit a tonal signal with a fundamental frequency of 5/20–60 kHz and with significant harmonics up to 160 kHz. The manufacturer cites a source level of 145 dB (re 1 μPa at 1 m). Au (1993) reported that harbour porpoises can hear sounds with frequencies from 16 kHz up to 140 kHz.

Several studies have shown that different types of pingers are able to significantly reduce the by catch of small cetaceans in gillnets (Kraus et al., 1997; Gearin et al., 2000; Barlow & Cameron, 2003; Dawson et al., 2013). Moreover, Larsen & Krog (2007) and Kindt-Larsen (2008) reported that aquamark 100 pinger reduced the by catch of harbour porpoise in the Danish Waters. However, Gazo et al. (2008) reported that aquamark 100 pinger did not stop bottlenose dolphins from approaching the trammel fishing nets and also did not have any effect on target fish species in north-eastern Majorca (Balearic Islands). Also, Burke (2004) reported that there is no effect of acoustic deterrent devices (Save Wave alarms) on dolphin by catch and depredation in the Spanish mackerel gillnet fishery. Moreover, Kindt-Larsen (2008) used porpoise alerting sound pingers (PAS pingers; 110 kHz, source level = 125 - 138 dB p-p re 1μPa at 1 m, 50-2500 clicks per sec) in the Danish hake fishery during July and August 2006 and reported that PAS pingers can not reduce bycatch rate of harbour porpoise. These results were similar to ours.

There is currently no clear published evidence (except for Culik et al., 2001) demonstrating whether pingers have a possible attracting effect on fish. However, it is known that clupeids can hear ultrasound signals (Mann et al., 1997) and pingers attract some fish species in the net (Buscaino et al., 2009). Culik et al. (2001) reported that lien pingers (generate 76 to 77 sounds min^{-1} at 115 dB, the base frequency 2.7 kHz with harmonics of up to 19 kHz) attracting herring, *Clupea harengus* Linnaeus, 1758 in the Baltic Sea near the island of Rügen, Germany.

There is scientific evidence that pingers may reduce the bycatch of harbour porpoises and other small cetaceans in some fisheries. However, it is still too early to say whether pingers will be effective or not in reducing by catch over the long term in the Black Sea. More focused, long term research on these topics is needed due to possible by effects especially habituation to pinger signals. More information is needed on which animals are engaged in depredation or by catch, e.g. individuals or entire group; older or younger animals, or both; males or females, or both.

In a conclusion, this study showed in essence two things: that catch of target and non target fish species is not affected by pingers, and also that the effect of pingers on reducing the by catch of marine mammals is very specific and depends on the pinger type.

Acknowledgements

The authors thank fishermen Sami Akmermer, Kazım Akmermer Uğur Akmermer and Ahmet Kalkavan for their help during the field studies. We would also like to thank two anonymous referees for their suggestions and criticism that clearly improved an earlier version of this manuscript. This study was supported by the Recep Tayyip Erdogan University, Scientific Research Project (BAP 2010.103.03.2).

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