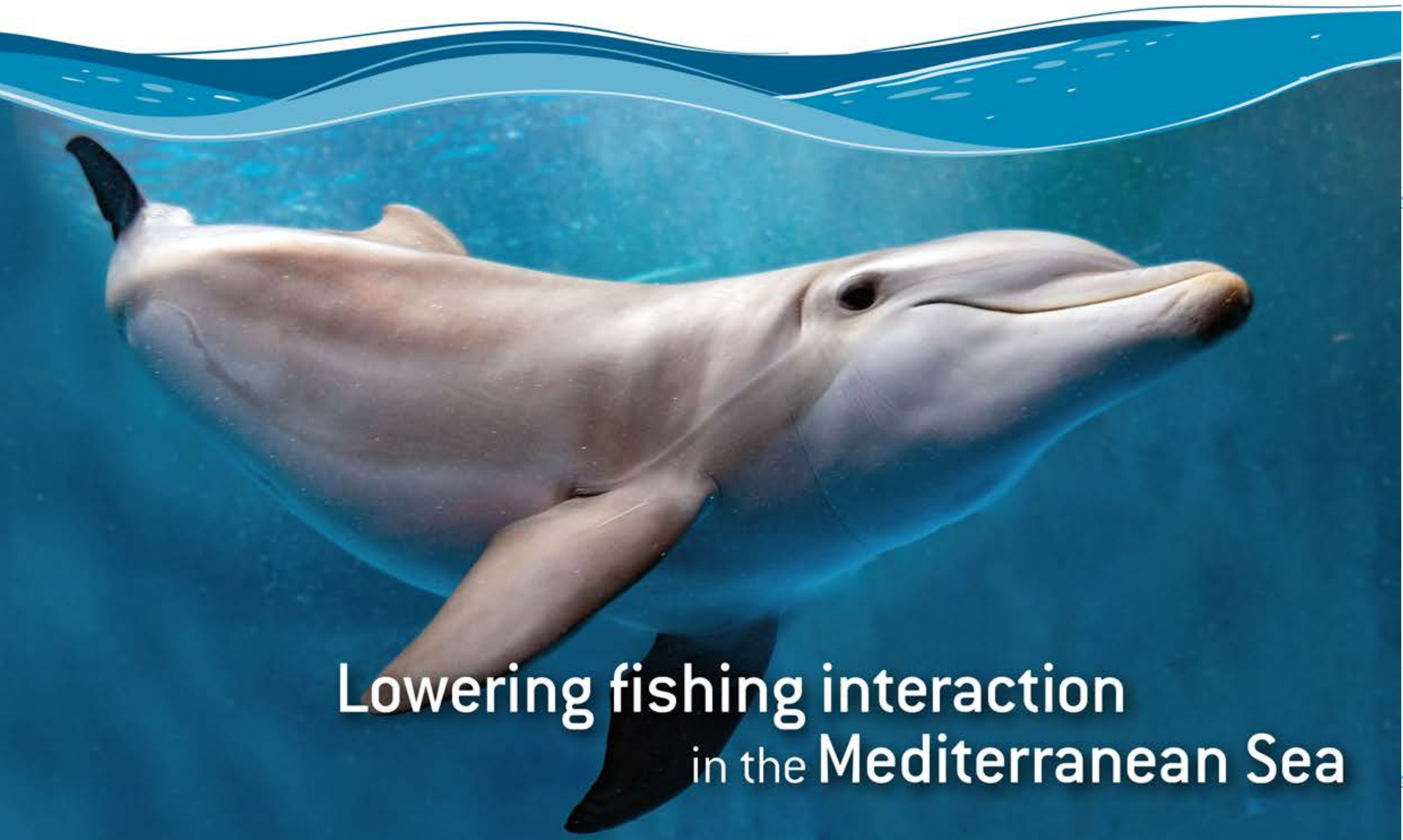
LIFE DELFI

Dolphin Experience: Lowering Fishing Interactions

LIFE18 NAT/IT/000942

Report on the set up of acoustic devices

Action C.1



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SUMMARY

PREMISE

Growing concerns have been raised about the interactions between dolphins and fisheries, as such dynamics generally have negative consequences for both conservation status of marine mammals status and economic profitability of fisheries. Amongst all interactions, the depredation (i.e. removal of fish caught on fishing gears) is of greatest concern, since dolphins are exposed to many risks (e.g. entanglement, injury and accidental capture) in an attempt to eat the fish already caught. On the other hand, depredation results in considerable economic losses, caused both by damage to the gear and by the removal or the mutilation of the fish caught in the net. Finally, many operators complain that dolphins act by dispersing and scattering fish, thus making them less available for capture.

The detrimental cetacean-fisheries interactions occur, or have occurred, almost throughout the Mediterranean Sea, involving the majority of cetaceans' species inhabiting the basin. However, the bottlenose dolphin (*Tursiops truncatus*) is likely the most affected species, due to its coastal and pelagic distribution that largely overlaps to the fishing areas (in particular those exploited by the artisanal fleet) and its opportunistic foraging strategy.

In principle, there are three main types of mitigation measures aimed at reducing negative interactions between dolphins and fisheries: 1) deterrent devices, mainly including pingers, which are acoustic devices designed to deter dolphin from the fishing gears; 2) gear modifications or alternative fishing gears, which are designed in such a way as to minimize or prevent dolphins' bycatch or depredation, and 3) spatio-temporal closures of fishing grounds or general effort reduction.

Among these, pingers are the most widely adopted mitigation strategy for cetaceans, due to relatively low cost compared to alternative strategies, great flexibility and ease of use. Pingers are active sound emitters that produce a variety of acoustic signals from the middle to the high frequencies (10 – 180 kHz) at relatively low intensity (Sound Pressure Level - SPL < 180 dB re 1 μPa at 1 m). They are intended to elicit an aversive response in the animals approaching the net or to alert them of the presence of the gear

Pingers have proven to be effective in reducing the depredation of the bottlenose dolphin, both in scientific trials and in commercial fisheries. However, many factors affect their effectiveness (pinger signal, background noise, pinger maintenance requirements, specie-specific response) and many other factors need to be taken into regards when implementing pingers (deployment according to the recommended specifications, compliance and enforcement, fishermen training and awareness, habituation, underwater noise pollution).

This report describes the application of a newly developed pinger (Dolphin Interactive Dissuader – DiD-01, by STM Products) to 3 different Italian fisheries usually affected by negative interactions with dolphins. Particularly, surveys at sea were carried out by CNR-IRBIM Ancona and FDC–Filiduci Wildlife Center between August and November 2020 to identify the best set-up of the DiDs in set nets, trawl and purse seine fisheries. The best application modalities in terms of efficiency and practical applicability were assessed by observations onboard both commercial and research vessels, as well as by face-to-face consultation with the fishers involved in the sea trials. Moreover, the performance and functioning of the DiDs were also evaluated by passive acoustic monitoring (PAM).

The protocols resulting from this study will serve as guidance for the further steps of Action C1-"*Acoustics Deterrent Devices*" LIFE DELFI project (LIFE18 NAT/IT/000942), which involves a large-scale and long-term pinger experimentation to reduce the conflict between bottlenose dolphins and fisheries.

1. INTRODUCTION

1.1 BACKGROUND

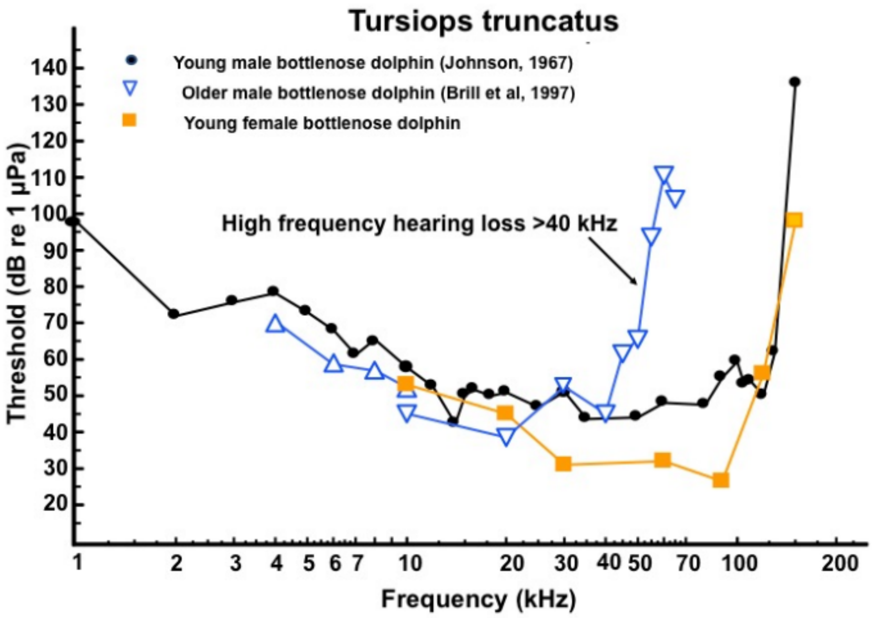
Pingers are probably the most widely researched and implemented technique for deterring small cetaceans interactions with fisheries. The term "pinger" usually refers to a range of non-impulsive acoustic deterrents devices that actively emit acoustic stimuli on or in the vicinity of fishing gear to prevent negative interactions such as depredation, entanglement, or by-catch of cetaceans (Reeves et al., 1996; Werner et al., 2006; Figure 1).

Figure 1: Example of different pingers models.

Since the marine mammals have different hearing sensitivities and may exhibit wide variation in responses to sound stimuli, the acoustic devices span a range of power output (measured in decibels [dB]) and frequencies (Hz); also, their duty cycle may be regular, random, or triggered by echolocating animals.

1. **Frequencies:** High-frequency outputs are usually aimed to be detected by animals with good high-frequency hearing such as delphinids (e.g. best sensitivity in bottlenose dolphin *T. truncatus* is between 15 and 110 kHz; Johnson,1967; Figure 2) and porpoises (e.g. harbour porpoise - *Phocoena phocoena*), whereas pingers operating at a lower frequency (from 3-5 to 10 kHz) are designed mainly for whale (e.g. Humpback whale - *Megaptera novaeangliae*). However, frequencies of acoustic signals usually emitted by pingers have been shown to not affect target catch levels (e.g. fish, crustaceans, and mollusks; Goetz *et al*., 2015).
2. **Power output:** pingers are classified as Acoustic Deterrent Devices (ADDs) as they work by broadcasting a range of acoustic signals (e.g. pulses, sweeps) at relatively low-intensity (Sound Pressure Level - SPL < 180 dB re 1 μPa at 1 m), regardless the species they are intended to deter (Long *et al*., 2015). Acoustic devices with higher sound outputs (SPL > 180 dB re 1 μPa at 1 m), which may inflict pain or discomfort to the animals, are typically categorized as Acoustic Harassment Devices (AHDs; López & Mariño, 2011).

3. **<u>Duty cycle:</u>** depending on the manufacturer's brand specification, each pinger has its signal duration, silent intervals between signals (inter-pulse interval or minimum silent interval between signals), as well as produces different acoustic signals (e.g. pure tones, amplitude-modulated tones, or frequency sweep; Table 1).



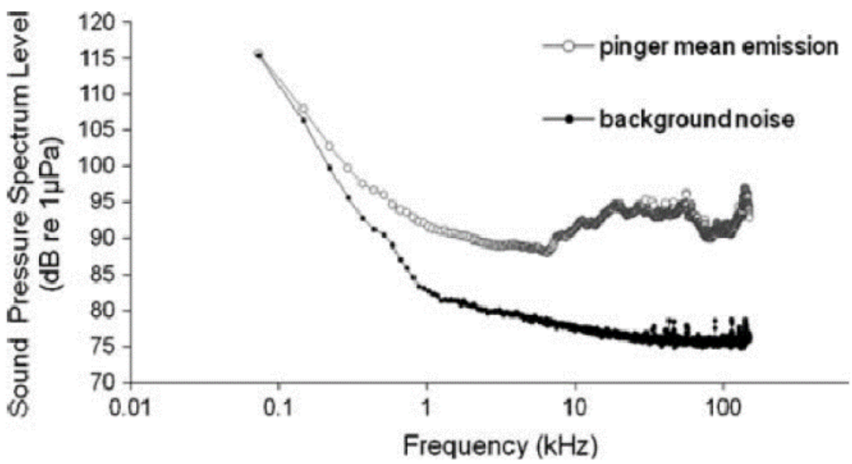


Figure 2: Hearing threshold curves of three bottlenose dolphins (up; Source: Darlene Ketten, Harvard Medical School); down, sound pressure spectrum level in the bandwidth 70–150 k Hz generated by the DDD02 Pinger and background noise (Source: Buscaino et al., 2009).

Table 1: Specific acoustic characteristics of the pinger currently on the market. N.A= Not Available

<table>
<tr><th colspan="2">Pinger</th><th>Frequency (kHz)</th><th>SPL (dB re 1 μPa @ 1 m)</th><th>Duration (ms)</th><th>Interval (s)</th></tr>
<tr><td colspan="2">Airmar - Gillnet Pinger Deterrent</td><td>10</td><td>132</td><td>300</td><td>4</td></tr>
<tr><td colspan="2">Aquatec - AQUAmark 848</td><td>5 - 30</td><td>165</td><td>N.A.</td><td>N.A.</td></tr>
<tr><td rowspan="4">Fishtek</td><td>Porpoise & Dolphin deterrent pinger</td><td>50-120</td><td>145</td><td rowspan="3">N.A.</td><td rowspan="3">N.A.</td></tr>
<tr><td>Whale deterrent pinger</td><td>3-20</td><td>135</td></tr>
<tr><td>Porpoise deterrent pinger</td><td>10</td><td>132</td></tr>
<tr><td>Dolphin Anti-Depredation pinger</td><td>40</td><td>175</td><td>400</td><td>0.4-1</td></tr>
<tr><td rowspan="4">Future Oceans</td><td>Whale Pinger</td><td>3</td><td>145</td><td>N.A.</td><td>N.A.</td></tr>
<tr><td>Dolphin Pinger</td><td>70</td><td>145</td><td>300</td><td>4</td></tr>
<tr><td>Porpoise & Dolphin Pinger</td><td>10</td><td>132</td><td>300</td><td>4</td></tr>
<tr><td>Anti-Depredation Pinger</td><td>70</td><td>175</td><td>N.A.</td><td>N.A.</td></tr>
<tr><td colspan="2">MAREXI - Acoustic Pinger V2.2</td><td>10</td><td>132</td><td>300</td><td>4</td></tr>
<tr><td>STM</td><td>DDD-03L
DDD-03N
DDD-03H
DDD-03U
DID-01</td><td>5 - 500</td><td>165</td><td>500 – 9000</td><td>Random</td></tr>
</table>

According to Dawson *et al.* (2013), at least four main hypotheses were proposed to explain how pingers work by reducing negative interactions between small cetaceans and fishing gears:

- signals are generally aversive and act by displacing animals from the vicinity of the pingers;
- pinger sounds encourage echolocation or otherwise alert the animals to the presence of the net, hence increasing the ability to avoid the fishing gears;
- acoustic stimuli interfere whit the animals' sonar, causing them to leave the area;
- pingers act as a deterrent on prey (e.g. herring) rather than directly on cetaceans (e.g. harbour porpoise).

Of these, the first two are the most supported by scientific evidence (Carlström *et al.*, 2002; Culik *et al.*, 2001; Leeney *et al.*, 2007). Published studies specifically addressing whether pingers function by "jamming" echolocation or making it less effective are not available in current literature. The fourth hypothesis, raised by Kraus *et al.* (1999), was not supported by subsequent observations; on the contrary, several studies showed that pingers sound have no adverse impact on the catch (Goetz *et al.*, 2015).

However, the idea of using pingers as acoustic devices to deter marine mammals has existed for many decades, with one of the earliest reported attempts Jon Lien during the 1980s. Lien and colleagues developed a portable, low-power acoustic device (4 kHz fundamental frequency, with a source-level of 135 dB re 1 μPa @ 1m, Figure 3) which was successful in reducing whale entanglements (Lien et al., 1992). Afterwards, several research groups and private companies have sought to utilize aversive underwater sounds for a variety of target species and in different fisheries, with different results.

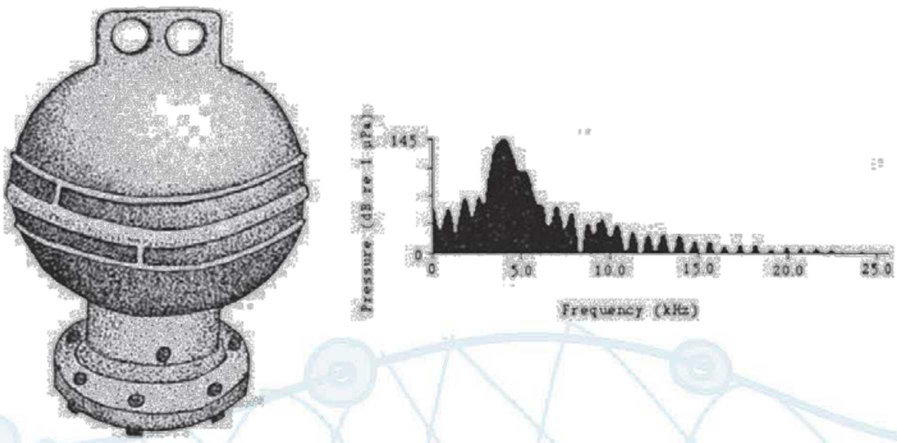


Figure 3: One of the first acoustical alarm device for preventing whale collisions with fishing gear and relative spectrogram showing its sound characteristics (Source Lien et al., 1992)

Nowadays, a body of evidence indicates that pingers provide the most simple and effective solution for the reduction of bycatch in set net fisheries of species that are generally neophobic or easily startled, such as harbour porpoises (*Phocoena phocoena;* Figure 4), while no univocal and equally robust results regarding the other species or fisheries exist. (Dawson *et al.*, 2013; Dolman *et al.*, 2016; Larsen *et al.*, 2007; Trippel *et al.*, 1999).

Concerning bottlenose dolphin the majority of studies addressed the reduction of depredation and damage to fishing nets instead of bycatch mitigation, though mitigating the former helps to solve the latter as well (Figure 5). Therefore, the effectiveness of pinger is usually assessed by comparing commercial catches, fish damage, and net damage between control and "active" nets (i.e. equipped with pinger). Also, studies may include both visual observation (e.g. behavioral observation *in situ*, photo-identification) and acoustic recording (hydrophone to record dolphin echolocation signals) to evaluate behavioral response to acoustic deterrent devices (Waples *et al.*, 2015).

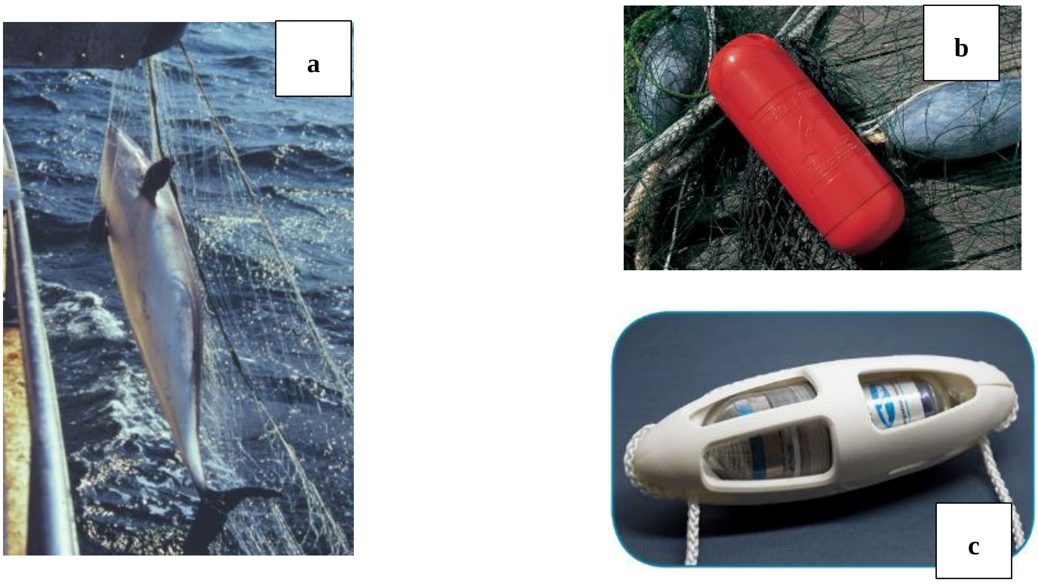


Figure 4: Bycatch of harbour porpoises in gillnets (a) and main pingers model used to reduce it: Dukane Netmark 1000 (b) and Future Ocean "Netguard" Porpoise & Dolphin Pinger (c).

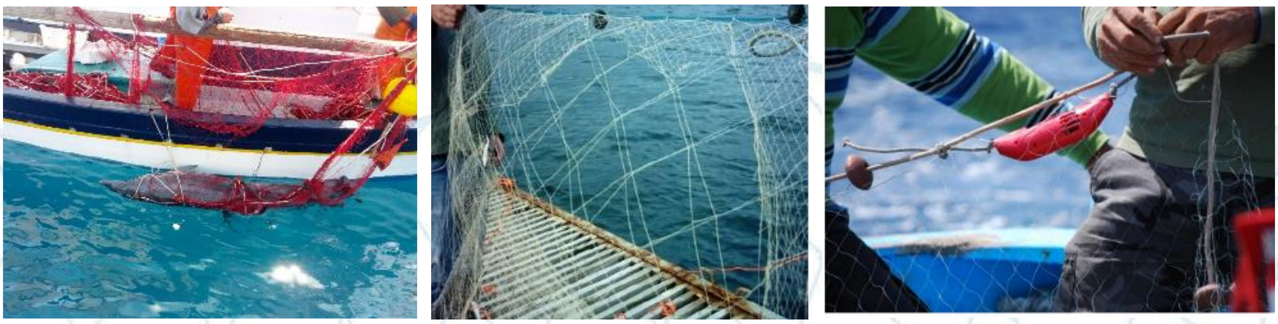


Figure 5: Bycatch of bottlenose dolphin in trammel nets (left), characteristic features suggesting the depredation of dolphins on trammel nets (center) and one of the pingers model used to reduce net depredation in Southern Italy (Dolphin Anti-Depredation Pinger by FishTek; right).

1.2 PINGER EFFICIENCY

There are several reports and scientific papers aimed at testing the effectiveness of pinger in reducing interactions between bottlenose dolphins and fisheries. Overall, research findings, described below, suggest that pingers can significantly help to reduce the bottlenose dolphin interactions in set nets fishery (eg. gillnets and trammels), whereas for trawl or purse seine studies were less conclusive or are lacking.

1.2.1 Set nets

Several experiments carried out across the distribution range of *T. truncatus* in the Mediterranean Sea demonstrated a considerable reduction in net damage and limited loss of commercial catches when pingers are correctly employed (Table 2).

- Buscaino et al. (2009) carried out experiments to assess the efficiency of DDD-02 pingers (manufactured by STM Products) in the gillnet fishery of the Egadi Archipelago (Sicily; Italy); net equipped with pingers reported significantly fewer damages (31%) and contained a higher catch biomass (28%) than the control nets (Table 1). During the study period, dolphin presence was recorded in 11 hauls out of 29 (38%).
- In a large-scale experimental trial carried out from 2001 to 2003 around the Balearic Island (Spain), a significant reduction in dolphin-net interactions in active nets, ranging from 49% to 70% depending on the pinger model, was observed; no significant effect on profit per unit of effort (PPUE) was recorded (Brotons *et al.*, 2008). In the same area, Gazo *et al.* (2008) recorded fewer holes (87%) attributed to bottlenose dolphin depredation in the trammel nets equipped with Aquamark 100 pingers than in nets without pingers.
- A pilot project tested the effectiveness of FishTech Banana Pingers® (175dB) on coastal gill and trammel nets, providing preliminary and potential results for the artisanal fishery of Aeolian Archipelago (Sicily, Italy; Bonanno Ferraro *et al.*, 2018). Also, an increase in yield and a reduction of interaction, along with a decrease of catch damage, were recorded in nets equipped with pingers (Bonanno Ferrero *et al.*, 2018).
- In Greece, Northridge *et al.* (2003) recorded significantly fewer holes (69%) attributed to dolphin depredation in trammel nets equipped with DolphinSaver pingers than in control nets.
- Another study focusing on trammel nets was carried out in Sinop Bay (Turkey), where significant differences were recorded between the active and control nets both in terms of catch per unit effort (CPUE) and damage of nets (Gönener and Özdemir *et al.*, 2013).

No dolphins were caught in any of the aforementioned studies, neither in the “pingered” nets nor in the control ones. This might support the hypothesis that bottlenose dolphins can detect gillnets at sufficient distances to avoid entanglement (Kastelein *et al.*, 2000). All these studies suggested that, even though pingers do not eliminate the bottlenose dolphin interactions, they can significantly help to reduce them.

Table 2: Studies using pingers to deter bottlenose depredation in set-nets. N.A= Not Available

Pinger	Spl	Gear	Target Species	Sets	Response in active nets	Location	Source
Save Wave Dolphinsaver	155	GNS	N.A	146	• Significant reduction in depredation and number of holes in the nets	Aegean Sea, Greece	Northridge *et al.*, 2013
Aquatech Aquamark 210	155	GNS	N.A	1193	• no difference in economic benefit • from 49% to 70 depredation reduction	Baleraic Islands, Spain	Brotons *et al.*, 2008b
Dukane NetMark 1000	130						
Save Wave Dolphinsaver	155						
Aquatech Aquamark 100	145	GTR	*M. surmuletus*	45	• 87% fewer holes • no difference in fish catch • 50% depredation reduction	Balearic Islands, Spain	Gazo *et al.*, 2008
STM DDD-02	174	GNS	*B. boops*	58	• 31% fewer holes • 28% more fish catch	Egadi Archipelago, Italy	Buscaino *et al.*, 2009
SaveWave White & Black	<155	GTR	*M. barbatus*	33	• 70% fewer holes • 34% more fish catch	Sinop Bay, Turkey	Gönener and Özdemir *et al.*, 2013
Fishtech Dolphin Anti-Depredation Pinger ("banana pinger")	175	GNS	*S. maena,* *O. Melanura*	9	• depredation reduction	Aeloian Islands, Italy	Bonanno Ferrero *et al.*, 2018
		GTR	Coastal demersal species	26	• no depredation recorded • catch reduction in control net		

However, the long-term effectiveness of pingers is still controversial since bottlenose dolphins may potentially habituate to the pinger sounds and consequently start to ignore them or even become attracted to them (e.g. Cox *et al.*, 2003; Northridge *et al.*, 2003).

1.2.2 Trawl nets

The effectiveness of pingers in reducing bottlenose dolphin interaction is less clear in trawl fisheries (Dawson *et al.*, 2013). During the BYCATCH Project, carried out in compliance with the monitoring program of cetacean bycatch in EU waters provided for EC Regulation 812/2004, the DDD03-H pinger (STM-Products Ltd.) was tested on commercial midwater pair-trawlers in the Central Adriatic Sea (De Carlo *et al.*, 2011, 2012; Figure 18). Devices were mounted in 37 hauls on the headrope of one of the two net wings.The recorded sightings diminished significantly when pingers were placed on the net: bottlenose dolphin interaction occurred about in the 11% of the hauls monitored with pinger, while for the hauls without pinger dolphins presence was registered in about 20% of the cases. However, the observed difference was not statistically significant. Nonetheless, based on these observations, some local fishermen started to use pingers voluntarily.

Recently, Santana-Garcon *et al.* (2017) evaluated the interaction dynamics between bottlenose dolphin and demersal trawls using video cameras in Pilbara (Australia) demersal trawl fishery. Dolphins were engaged in 5908 interaction over 50 day-trawls in 2013 and were observed entering deliberately into the nets to foraging during most of the interaction events (<90%), even when pingers (DDD-03H) were deployed. Therefore, the number of interactions provided no significant evidence for behavioral changes through the use of pingers. “Quieter” pingers (i.e. with lower sound intensity if compared to those “louder” mentioned above) also failed to reduce interactions in Pilbara trawl fishery, since Savewave pingers were found to be ineffective in keeping dolphins out of the trawl net. However, there is likely low confidence in this finding due to the small sample size (7 hauls with pingers and 11 without).

1.2.3 Purse seine

There is a general lack of information on pinger use in purse seine fisheries, since the mitigation measures for this fishery has focused on reducing dolphin mortality, primarily by increasing the likelihood of dolphin escape through the so-called ‘back-down’ maneuver with the addition of ‘Medina’ panels (described by Hall and Roman (2013) or by eliminating the practice of setting around dolphin pods associated with target tuna species in the eastern Pacific Ocean (EPO) (Hamilton & Baker, 2019).

1.3 LIMITS AND POSSIBLE SIDE EFFECTS OF PINGERS

1.3.1 Habituation

Although pingers have been proven to have a deterrent or depredation reducing effect on bottlenose dolphin and other cetaceans species, several authors have raised the issue of whether habituation would cause a reduced reaction to pingers over time and compromise effectiveness in reducing interactions. Habituation (i.e. "gradual waning of responses when a repeated or ongoing stimulus lacks any significant consequences for the animal"; Richardson *et al.*, 1995) results in a loss of effectiveness in avoiding dolphins from the nets, as they may become accustomed to noise emitted by devices over the time, thus interpreting the sound like a "dinner bell" and approaching the fishing gears to find easy prey (e.g. Read *et al.*, 2003). Several technical solutions were proposed in an attempt to minimize habituation risk, mainly including the deployment of pingers models broadcasting signals at randomized time intervals (e.g. save wave dolphin save), randomizing signal frequencies (e.g. Fishtek Bp154) or modulated FM wave (e.g. DiD-01).

1.3.2 Habitat exclusion

The deterrent strategy of pingers has raised concerns regarding habitat exclusion, especially in areas where there is a population having a restricted distribution or spatially limited home ranges. Therefore, the displacement effect seems to be more pronounced on neophobic species, such as harbour porpoise (Hamilton & Baker, 2019), while it is still no clear on bottlenose dolphins, as they are frequently sighted near pinger without showing any escape behavior (Buscaino *et al.*, 2009).

1.2.3 Noise Pollution

Another concern about pinger use relates to the possible side effects caused by the increasing level of anthropogenic sound – specifically intended to deter cetaceans from an area, into an already noisy environment. Particularly, if pinger use becomes widespread, the combined effect of a massive number of pingers might impact the physiology and auditory system of some cetaceans (Kastelein *et al.*, 2006; Novaceck *et al.*, 2007). It is still unclear whether acoustical devices produce some negative effects on dolphin hearing (Reeves *et al.*, 2001), since many factors can influence these potential side effects, such as duration of exposure, sound level, and spectral content (Buscaino *et al.*, 2009).

1.2.4 Economic concerns

From an economic perspective, pingers may be expensive (individual units can cost between approximately 200 - 1000€; FAO, 2018), especially for small-scale fisheries, as set-nets require several devices along a net string. According to Northridge *et al.* (2011), louder pinger (e.g. DDD-03) may help address this concern as their use would drastically reduce the numbers required by an individual vessel. Conversely, the expense is less of an issue for trawlers or seiners, who will only require few devices at a time (generally from one to four).

However, battery life and management pose a secondary economic concern for the fishermen. Rechargeable devices may prove easier to manage than those that require battery replacement (such as the Aquamark devices); in fact, rechargeable batteries can last over two or three years when correctly managed (generally the number of charge cycles is provided by the manufacturer).

1.4 DOLPHIN INTERACTIVE DISSUADER – DID-01

To minimize the aforementioned side effects of the traditional (i.e. continuous) acoustic devices, a newly responsive pinger has been recently introduced on the market. The device, called Dolphin Interactive Dissuader (hereinafter DiD) and manufactured by STM Product Inc. (Verona, Italy), is specifically designed to emit signals only in response to dolphin echolocation clicks. This means that the pinger is only activated when an internal hydrophone detect clicks from a dolphin, while the device normally remains in a standby or listening state. This technical feature offers a range of benefits. First, by limiting the number of emitted signals, DiDs are specifically intended to reduces the likelihood that dolphins become accustomed to the acoustic stimuli. As a consequence, less noise pollution would be produced by these new pingers, since fewer acoustic signals are emitted. Moreover, the battery charge duration would last longer if compared to a traditional continuous pinger.

Besides the built-in hydrophone, the device has a logic part with a 16-bit microprocessor that controls the automatic switch-on when sunk in the water, low battery alarm, power circuit command randomizing the output signals. These are emitted from 5kHz up to 500kHz at 168 dB re 1uPa @ 1 m as randomized high-speed FM tones ranging from 100µs up to seconds. Table 3 provides a detailed list of the main technical features of the DiD pingers.

The emission range of a single device covers an 800m radius around the pinger a radius of 800 meters and extends downward for 80 meters, with an approximately toroidal emission field, as shown in Figure 6.

Table 3: Technical specification of DiDs.

TECHNICAL FEATURES	
Emission frequency	From 5 to 500 kHz
Emission power	168 dB re 1uPa @ 1 m
Maximum reception capability	125 dB re 1uPa @ 1 m in the 50 – 70 kHz
Maximum reception distance	800 – 1200 m with echolocation pulses > 200 dB
Minimum operative depth	10 - 20 m
Maximum operative depth	200 m
Horizontal spacing	600 – 800 m
Power internal source	5 rechargeable 1.2 NiMH batteries
Batteries autonomy	> 300 hours in hearing mode About 12 hours in continuous emission mode
The average life of a device	500 – 1000 battery charge/discharge cycles
Dimension	210 x 61 mm
Weight	990 g

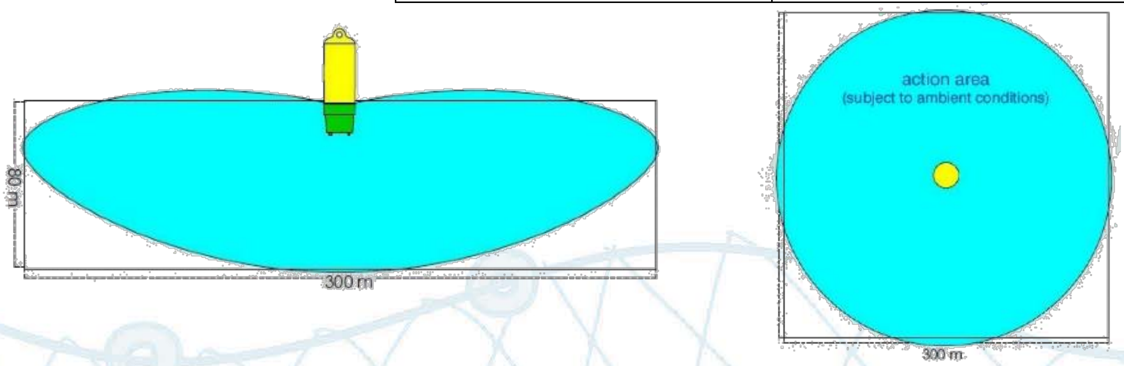


Figura 6:DiD-01 sound emission range

1.5 AIM OF THE REPORT

This work was draft within the framework of Action C1 - "Acoustics Deterrent Devices" of the LIFE DELFI project (LIFE18 NAT/IT/000942), to provide a preliminary and technical overview on the use of DiD in different fisheries usually affected by negative interactions with dolphins (e.g. depredation, entanglement, and accidental capture).

Specifically, the following document section describes the methodologies implemented by CNR and FWC during the tuning campaign on the setting of the Dolphin Interactive Dissuaders (DiD) in set-nets, bottom trawl, and purse seine fisheries. The campaign involves both surveys at sea onboard commercial fishing vessels and research vessels. The efficacy and functioning of the pinger were also evaluated by passive acoustic monitoring (PAM).

Overall, the results obtained in this preliminary investigation will be used as guidance to implement in the further steps of Action C1, which involves a large-scale and long-term pinger experimentation to reduce the conflict between bottlenose dolphins and fisheries.

2 SET-UP OF PINGERS ON DIFFERENT FISHING GEARS

2.1 SET-NETS

Set-nets are the most common fishing gears employed in the Mediterranean Sea by the artisanal fisheries for the catch of a high number of demersal, benthic, and pelagic species (Lucchetti *et al.*, 2020). They are composed of netting walls anchored to the sea bottom and held vertically in the water by floats on the upper line (headrope) and weights on the ground-line (footrope). Such nets gears are also defined as passive fishing gears, as they exploit the movements of target species and do not require an active movement of the gear.

According to the net characteristics and design, it is possible to define three main types of set-nets: gillnet, trammel net, and combined net (Figure 6). Gillnets are made up of a single panel of net held vertically in the water by floats and weights, whereas trammel nets are set nets formed by three overlapping net panels; among them, the inner one has less stretched and much smaller meshes than the two external panels. Finally, combined nets are bottom-set nets composed of two parts: an upper one being a standard gillnet and a lower part being a trammel net.

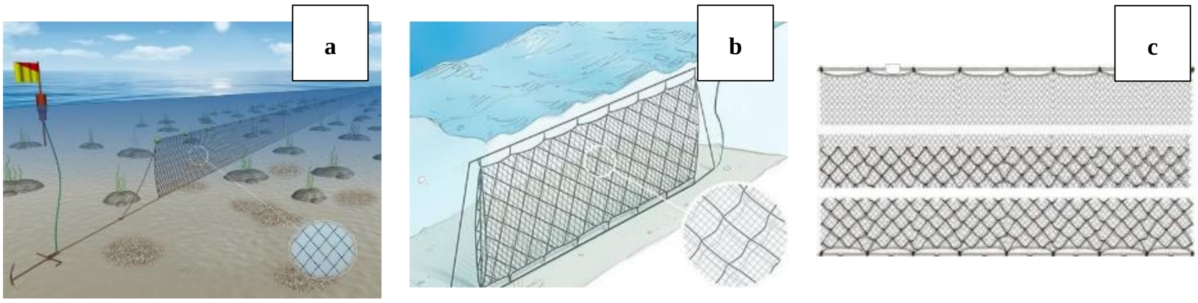


Figure 6: Main types of set-nets in current use in the Mediterranean Sea: gillnets (a), trammel nets (b), and combined nets (c).

2.1.1 Survey 1: Central Adriatic Sea

The tuning phase of the pinger set up in set nets fishery was carried out through a total of 3 experimental trials onboard the research vessel (R/V) Tecnopesca II of CNR. The R/V has an overall length of 16.25 m, a tonnage of 24 GT, and an engine power of 340 kW. The research vessel was equipped with all the instruments typical of a fishing boat including depth sounder, net winches, and auxiliary engines. Initially, sea trials were planned to be carried out onboard the R/V G. Dallaporta (810kW, 35.30 m LOA, and 285 GT), which is the main research vessel employed by CNR-IRBIM Ancona. However, the provisions to deal with the epidemiological emergency from COVID-19 did not allow the use of this vessel.

The crew generally consisted of a skipper, an engineer, a technician, and 2 researchers. The trials were carried out off the south coast of Ancona (Central Adriatic Sea, Italy), on sandy-muddy bottoms at a depth ranging from 15 to 70 meters, as shown in Figure 7.

A gillnet consisting of a single netting panel made of nylon monofilament (Ø=0.20 mm) was used. The net had a nominal height of 3.05 m (40 meshes), although its effective vertical opening in the water was around 2.5 m. The nominal mesh bar for the netting panel was 38 mm. The floatline was not reinforced with external floats; the lead line weighed 40 g/m. The horizontal hanging ratio was approximately 0.50, corresponding to 4 meshes rigged every 15 cm. The total length of the gillnet used was 2400 m. The detailed technical plan of the net is shown in Figure 8. This net is commonly employed to catch several benthic species such as tub gurnard (*Chelidonichthys lucerne)*, common sole (*Solea solea)*, and sparids in the study area (Figure 9).

Table 4: Main characteristics of the R/V Tecnopesca II.

NAME	R/V Tecnopesca II
HARBOUR	Ancona
LOA	16.25 m
GT	24
ENGINE POWER	340 kW
CREW	5

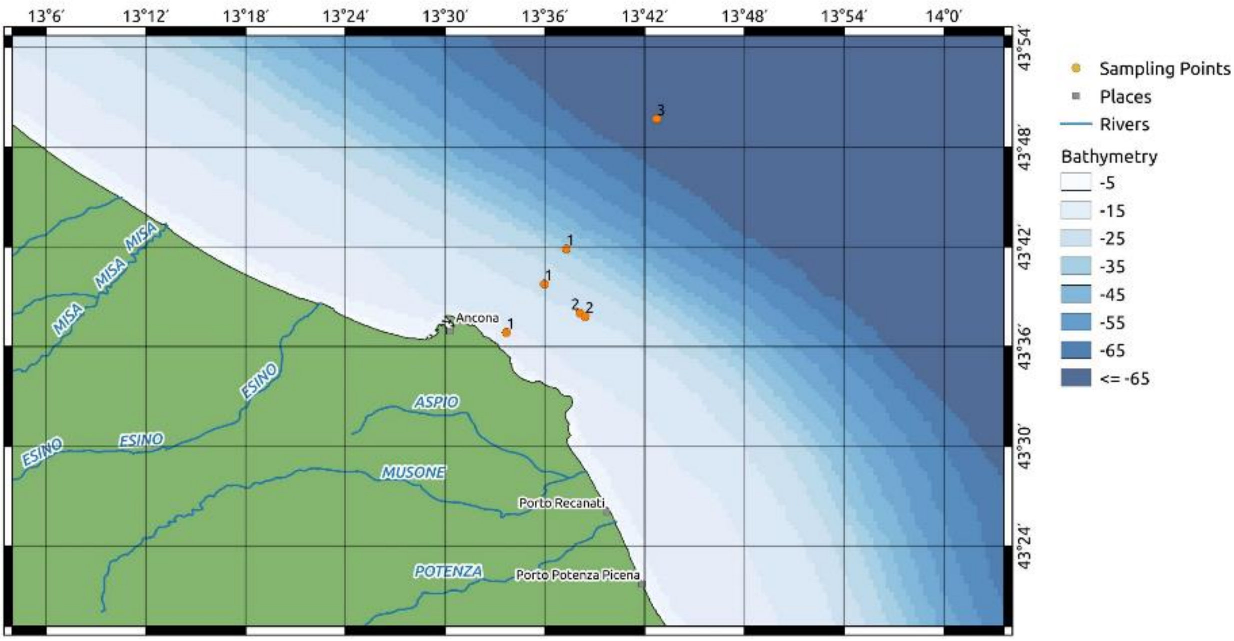


Figure 7: Sampling sites of the study area (Ancona, Central Adriatic Sea).

50 m PP Ø 6 mm		E= 0.5	
		1315	
40	PA Ø 0.20 mm		76 mm
		1315	
50 m PP Ø 6 mm		E= 0.5	40 g/m

Figure 8: Technical plan of a panel of the gillnet used in the surveys at sea.

Figure 9: Left, a tub gurnard (C. lucerna) caught in the gillnet and on the right hauling operations.

2.1.2 Survey 2: South Tyrrhenian Sea

Two preliminary sea trials were also conducted in the Aeolian Archipelago (South Tyrrhenian Sea) by Filicudi Wildlife Center (FDC; Table 5). The investigation on the use of DiDs in the local set-nets fishery started in Autumn 2020 and involved both gillnet and trammel net. The first was a single-layered gill net made of nylon monofilament fibers, 3 m high and 680 m long. This net is usually employed on stony bottoms (30–40 m in depth) to catch species like bogues (*Boops boops*), saddled seabream (*Oblada melanura*) and picarel (*Spicara sp*.).The trammel was one of the most utilized gears in coastal areas of the archipelago and targeted red scorpion fish (Scorpaena scrofa), striped red mullet (Mullus surmuletus), cuttlefish (Sepia officinalis) and common spiny lobster (Palinurus elephas); for more technical details of this net see Battaglia et al. (2010).

Table 5: Details of hauls monitored in Aeolian Archipelago

Date	Gear	Net length (m)	Net height (m)	N° pingers	Depth (m)	Bottom type
19/10/2020	Gillnet	680	3	1	34	Stony
20/10/2020	Trammel net	350	3	1	30	Stony-sandy

2.1.3 Pinger rigging

The rigging modalities of the Dolphin Interactive Dissuader on the gillnet was influenced by two main factors, such as the spacing between two devices and their minimum operating distance from the bottom of the pingers.

Since the horizontal emission radius of a DiD-01 extends for 300/400 m, the minimum distance between two adjacent devices must not be less than 600-800 m. To further maximize the acoustic coverage, it is also recommended to place the first device about 300 meters from the beginning of the nets. Therefore, a total of 3 DiDs were deployed to cover the whole 2400m net in the Central Adriatic Sea (Figure 10), whereas one device was used in the Aelioan archipelago (nets length ranged from 350 to 680 m).

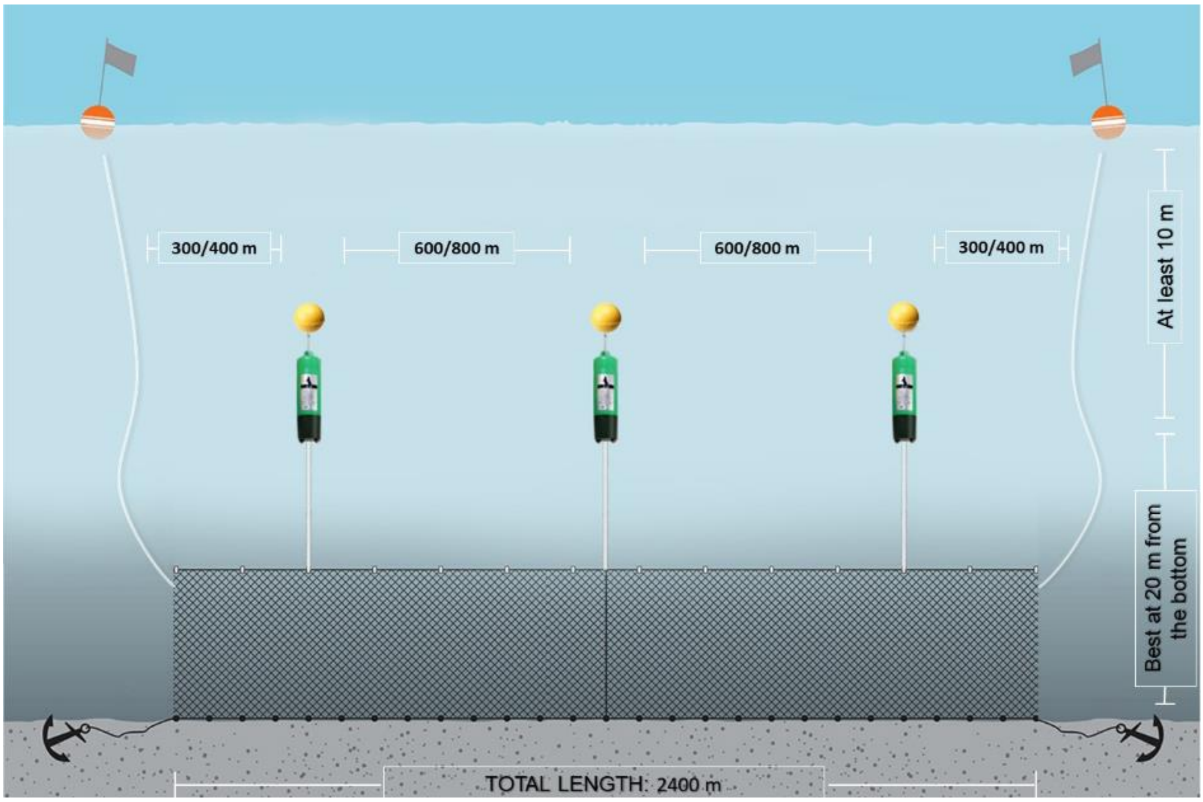


Figure 10: Pinger positioning and spacing on the 2400 m gillnet employed in the sea trials in the Central Adriatic Sea.

As DiDs minimum operating distance from the sea bottom is about 20 meters (Table 3), it is not recommended to attach the pingers directly to the netting panel or the floatline, due to the limited height (gillnets maximum height: 4m; combined nets: 10m, according to the European Regulation 1241/2019). Therefore, pingers were attached to the net using floating branch lines of variable length according to the depth of the study area. Branchlines consist of polyethylene ropes (Ø=8mm) equipped with two stainless steel snaps at both ends, to easily connect them to the net and float. The latter is required to neutralize the weight of the pinger (940g); it is recommended to use a PVC deep water buoy (Ø =400mm; net buoyancy= 2 kg) to provide positive buoyancy. An additional lead weight (1 kg) must be placed on the leadline for each branch, to prevent detachment of the net from the sea bottom due to water currents. Finally, the pinger must be connected to the buoy by a snap (Figure 11).

The configuration just described was developed to provide the best functionality and handiness in fishing operation, since the branches can be quickly attached to the net during the hauling and removed when the nets are retrieved. Moreover, ropes and buoys, as well as pingers, can be easily kept apart after being removed, to prevent their entanglement or snagging in the mesh of the nets.

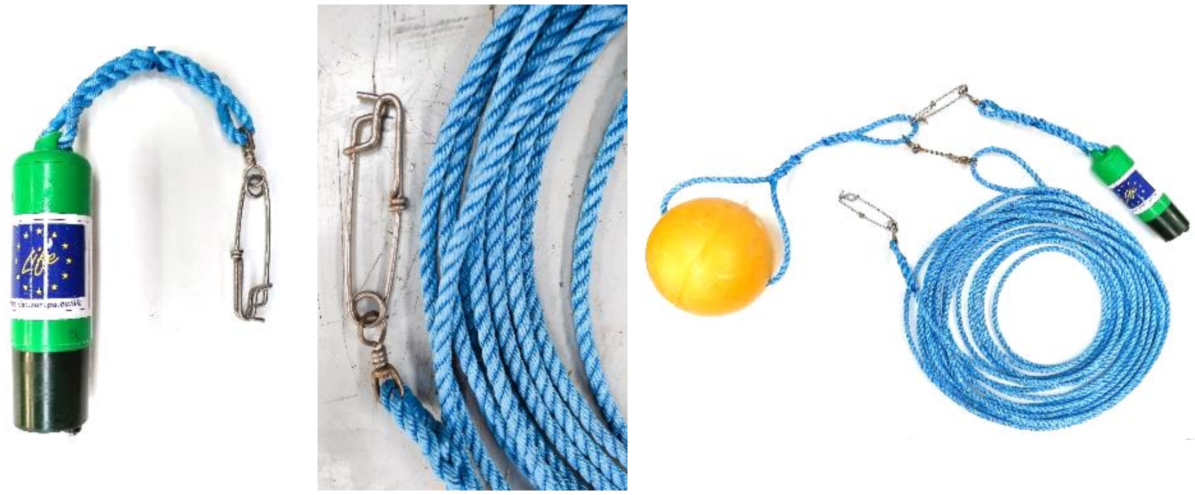


Figure 11: Details of the best setup to attach the DiD on gillnets.

2.1.4 Passive Acoustic Monitoring

During the 3 sea trials with set nets off the coast of Ancona (Figure 7), acoustic data of the DiDs were acquired continuously by a hydrophone lowered directly from the research boat at a depth ranging from 5 to 10 m (Figure 12). To minimize the acoustic interference during the sampling activity, all engines and onboard equipment (particularly the echo-sounders) were turned off.

An Aquarian Scientific AS-1 hydrophone, providing a linear response between 1 Hz and 96 kHz, was used to receive the acoustic signals and a Focusrite Scarlett 2i2 USB Audio Interface (at 16 bit/192kHz) was employed to acquire them (Figure 13).

The digitized signal was then displayed on the laptop monitor and stored using the Baudline time-frequency browser (www.baudline.com) in a Linux environment.

Passive monitoring of the DiDs was also carried out in the Aeliona archipelago, where acoustic data were acquired by a homemade underwater acoustic recorder. This instrument featured a built-in hydrophone, 48Hz at 16-bit sound card, and SD memory card, which allowed for up 3 hours of recording. The recorder was attached to the linkage rope between anchor and buoy to a depth of 3 m.

Figure 12: Passive acoustic monitoring of the pingers: lowering the hydrophone (left) and acoustic sampling (right).

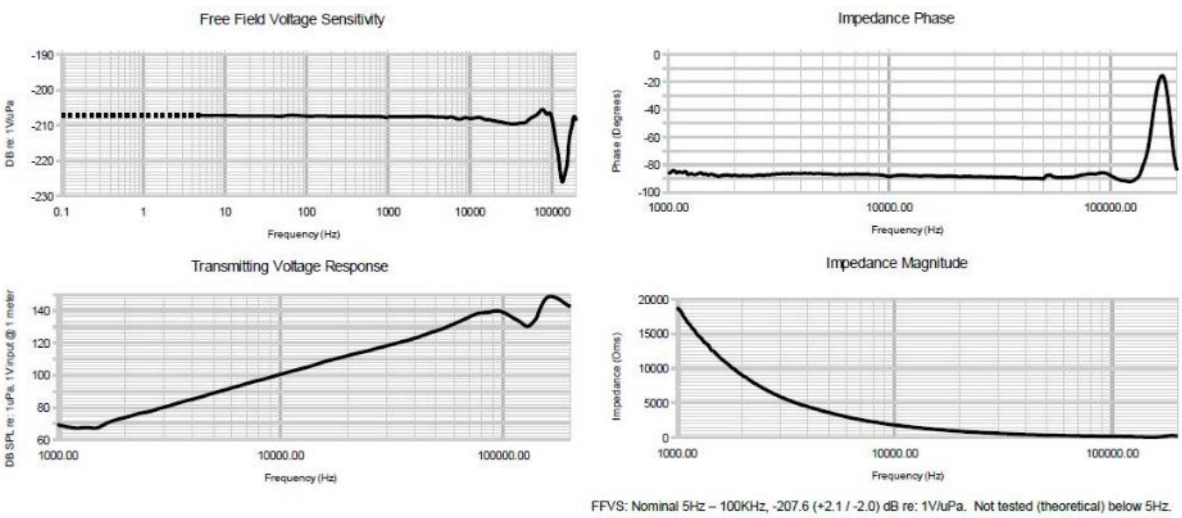


Figure 13: Frequency response of the Aquarian Scientific AS-1 hydrophone.

The acoustic recordings were then analyzed by headphones listening and visual analysis of the spectrograms using the Audacity audio editor software (https://www.audacityteam.org/).

A total of 605 minutes of recording were acquired between August and November 2020. The main characteristics of the acoustic sampling plan are listed in Table 6.

The first trial (ID Haul= 1; August 2020) aimed to assess the activation or lack of activation of the DiD undergoing high frequencies pulses (30 – 60 kHz). Particularly, a Dolphin Dissuader Device (DDD-03H, manufactured by STM Products, Verona – Italy) was lowered from the vessel to trigger a DiD placed at various distances from the boat (50, 100, and 150 m). Spectrograms of the acoustic recordings acquired in the first survey showed clear triggering events due to the exposure of the Did to the acoustic signal emitted by the DDD, as shown in Figure 14.

Table 6: Summary of the acoustical sampling scheme. Area 1= Central Adriatic Sea, Area 2= Aeolian Archipelago

Date	ID Haul	Location	ID Track	Rec. duration (min)	DiDs monitored	Depth (m)	Pingers deployment depth (m)
01/08/2020	1	1	1_A	30	1	12	6
			1_B	30	1	22	12
			1_C	30	1	32	15
19/10/2020	2	2	2_A	140	1	34	25
20/10/2020	2		2_B	180	1	30	20
26/10/2020	3	1	3_A	60	2	20	10
			3_B	30	1	20	10
			3_C	45	1	20	10
26/11/2020	4		4_A	60	1	70	35

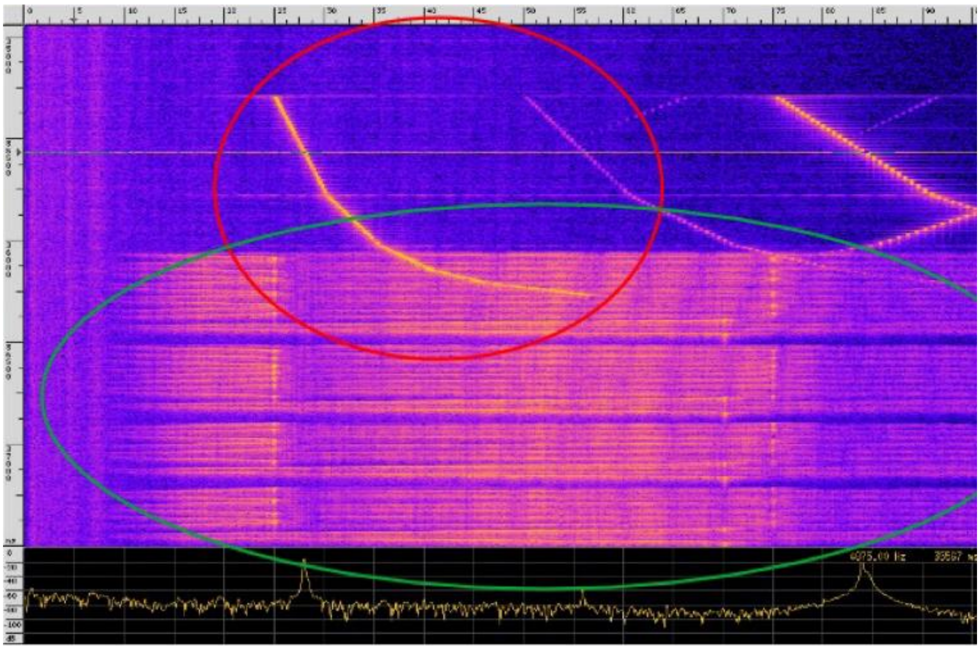
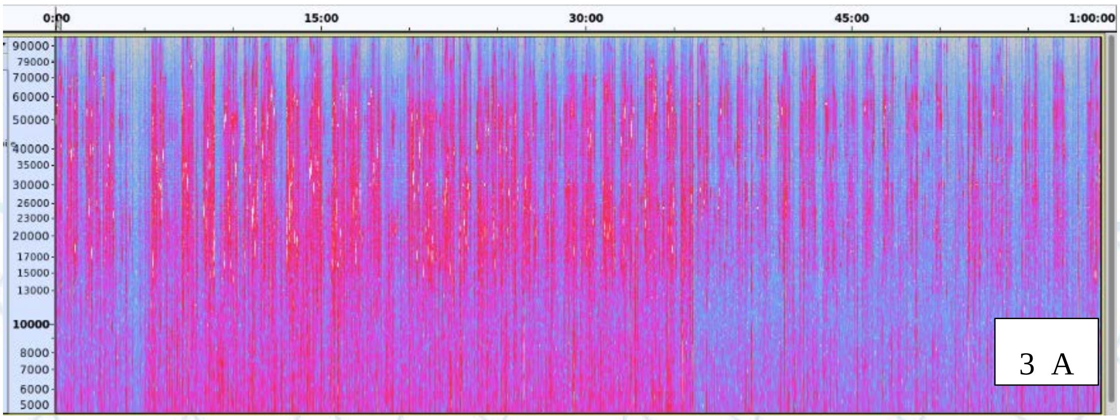


Figure 14: Spectrogram of DiD's response (circled in green) to a triggering event (red). The horizontal axis displays frequency in kHz, the vertical axis represents time.

Spectral analysis of the acoustic data from the other sea trials in the Central Adriatic Sea (ID Haul: 3 and 4) showed almost a continuative activity of the acoustic deterrents. Indeed, DiDs were affected by repetitive and frequent activations, both when they were monitored in multiple or single configurations. For example, in the 3_C track (one DiD present) the emission time reached up to 58% of the observation period, while in the track with two pingers (3_A) practically no silence periods were detected due to the spectral overlapping of the two devices. Similar pinger behavior was observed both in the recordings from Aeolian Archipelago (ID Haul 2) and the last trial in the Adriatic Sea (ID Haul: 4), as DiDs were still active up to 50% of the monitoring time (Figure 15).



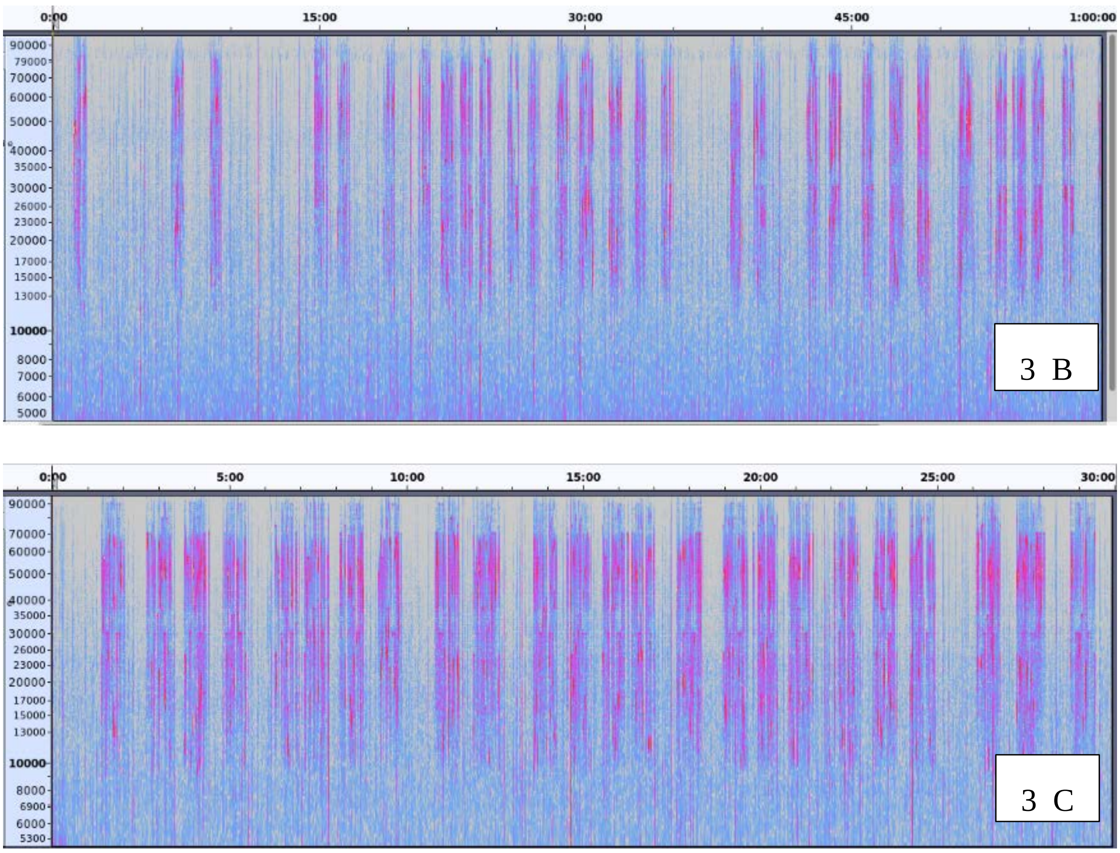


Figure 15: Overviews of the spectrograms of the second haul. The vertical axis displays frequency in Hertz, the horizontal axis represents time. More pronounced lines (in purple) represent an activation cycle, while white/light blue the silence periods.

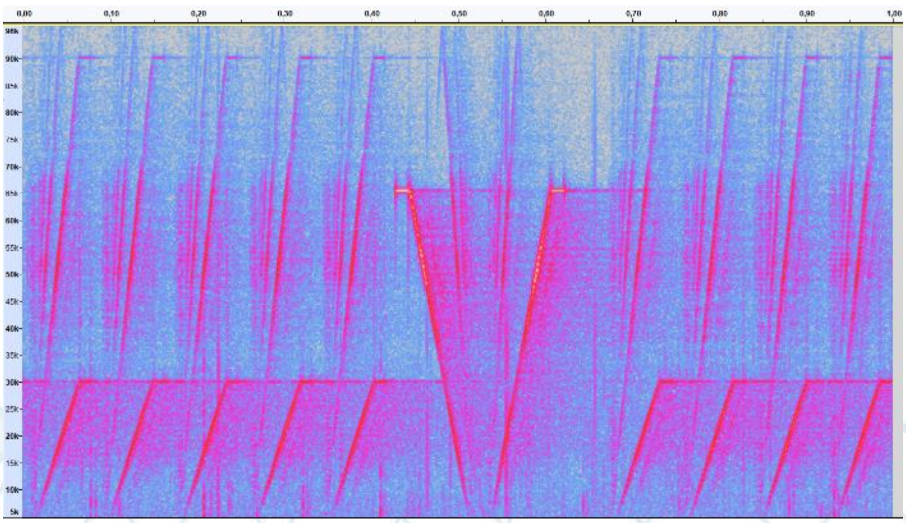


Figure 16: Spectrogram of the 1000 ms time frame from the 2_C track. The vertical axis frequency in Hertz, the horizontal axis displays the time. More pronounced lines (in purple) represent the pulsed signals of the DiDs.

First, cetacean occurrence during the survey was never detected, either visually in situ or by analyzing the tracks acquired via PAM. Therefore, we exclude that the triggering events were caused by dolphin echolocation clicks. It seems more likely that the pingers were triggered, at least partially, by pseudo-echolocation clicks (high pulse amplitude within 50-100 µs, Figure 17).

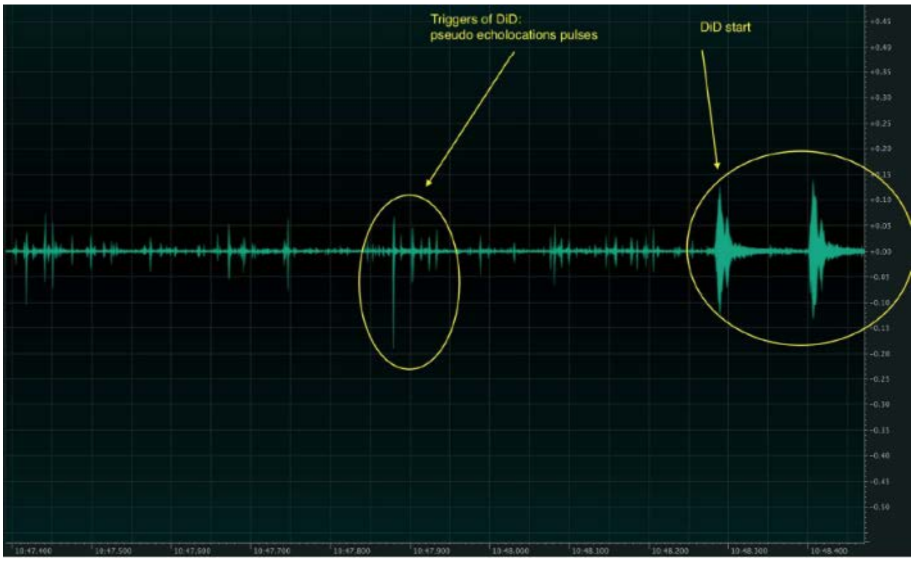


Figure 17: Waveform of a 1000 ms time frame (2_C track) showing a trigger event induced by pseudo echolocation pulse. The vertical axis displays the amplitude, the horizontal axis represents time.

However, the origin of these pulses remains unclear, as they may be caused by both environmental (e.g. wave motion) and anthropogenic (e.g. echo-sounders of other boats present in the area, multibeam, gas pipelines). Also, some trials were carried out by placing the pingers at non-optimal operative depth (> 10 m below the sea surface and > 20 m from the sea bottom), therefore these conditions likely contributed to affect the correct functioning of the pingers.

In conclusion, further monitoring is needed to investigate the possible cause behind the continuative activation on DiDs, including long-term recording using an autonomous underwater recorder moored to the nets for all the haul duration (> 12 h).

2.2 PURSE SEINE

A purse seine usually consists in a large rectangular wall of netting framed with floatline and leadline, typically much longer than it is deep, having purse rings hanging in the lower edge of the gear, through which runs a purse line, which allows the pursing of the net (Figure 18). Fishing operations involve surrounding and then encircling the fish schools with a long net to form a circular wall of netting, which is deep enough to discourage escape underneath it. The encircling must be done rapidly enough to prevent fishes to escape before the ends are closed; later on, the catch is collected by hauling the net so that the fish are easily brailed out.

Despite the configuration varies in target species and country of use, purse seining in the Mediterranean Sea is developed mainly for catching both large and small pelagic species that are shoaling. In both cases, the nets are often used together with additional equipment, such as fish finder devices or attraction and concentration systems. Seiners for small pelagic (i.e. anchovy and sardine) use generally a light source for attracting and concentrating schools of fish before encircling them. Vessels targeting large pelagic may set around either free-swimming spotted schools, in the case of tuna species, or individuals previously attracted by utilizing floating aggregating devices, also called FADs, like the seiners targeting dolphinfish (*Coryphaena hippurus*).

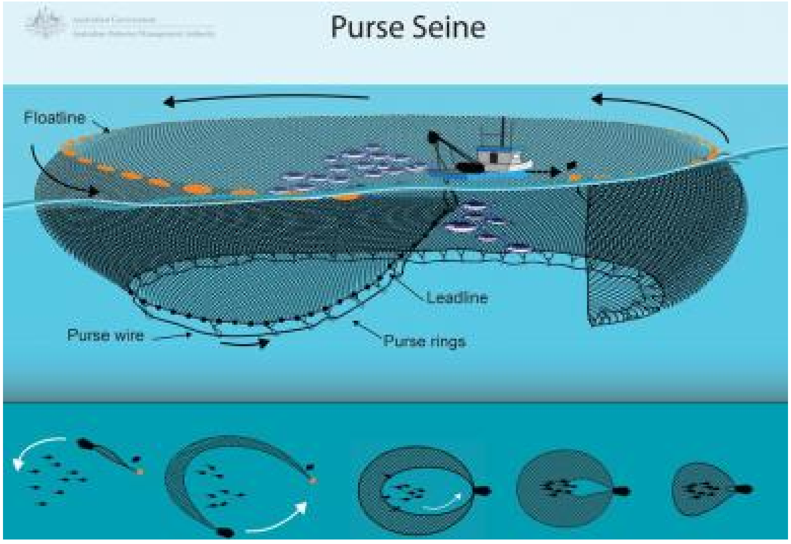


Figure 18: Purse seine: main components and purse seining operations (setting the net and hauling) (Source: Australian Fisheries Management Authority).

2.2.1 Survey

To assess the best pingers configuration, a total of 3 sea trial were carried out by Filicudi Wildlife Center - FWC on board a traditional purse seiner (*cianciolo*) operating in the Aeolian archipelago (Southern Italy) for surface and midwater species such as horse mackerel

(*Trachurus sp.*) and bogues (*Boops boops*). Details on sea trials and the main characteristics of the vessel employed are shown in Table 7 and 8respectively.

Table 7: Details of the haul monitored.

Date	Fishing time			Latitude	Longitude	Depth [m]	Distance from the coast [m]
	Start	End	Duration				
10/10/2020	23:08	23:58	50 min	38°34.722'	14°52.676	56	600
12/10/2020	22:50	23:35	45 min	38°34.972'	14°52.611'	63	500

Table 8: Main characteristics of the purse seiner employed in the survey.

NAME	M/P Carasco
MATR. N°	001MZ880
HARBOUR	Lipari
LOA	12.97 m
GT	8
ENGINE POWER	300 kW
CREW	5

The gear employed was a commercial purse seine with mechanical closure (known in Italy as *cianciolo*) typically used in the study area, entirely made up of black polyamide (PA) netting (Figure 18). The net consisted of two netting panels: the upper had a 17,9 mm nominal mesh size, while the lower was built with a nominal mesh size of 16 mm. The total length of the net was approximately 200 m and its drop was approximately 40 m.

Figure 19: Cianciolo used in the Aeolian archipelago for surface and midwater species (left) and their lead line and purse rings (right).

Fishing operations were carried out at night, with the assistance of an auxiliary boat providing a powerful light source (*lampara*) to concentrate schools of pelagic fish (mainly horse mackerel and bogues). The gear was set around a fish shoal beginning with the launch of the lampara, to which one end of the net was attached. The main vessel then moves to encircle the fish school, laying out the net as it goes, until it returns to the position of lampara. Once encirclement is finished, the two ends of the purse line cable are hauled with the winch as quickly as possible to close the net at its bottom (pursing). The catch was subsequently brailed on board by hand by fishers (Figure 20).

Figure 20: Cianciolo operations: setting the net (left) and hauling (right).

2.2.2 Pinger rigging

For *cianciolo* operations, one pinger is enough to ensure adequate coverage of the entire fishing area, as the net diameter is generally lower than 600/800 m. Therefore, during the onboard test in the Aeolian archipelago, a single DiD was employed. The pinger was lowered by a 20 m rope secured to the stern of the lampara at the beginning of the fishing operations and was retained only after they finished. No additional weight or floats to the pinger were needed: it was easily hanged to the rope through the support on the top of the device, as shown in the illustration below.

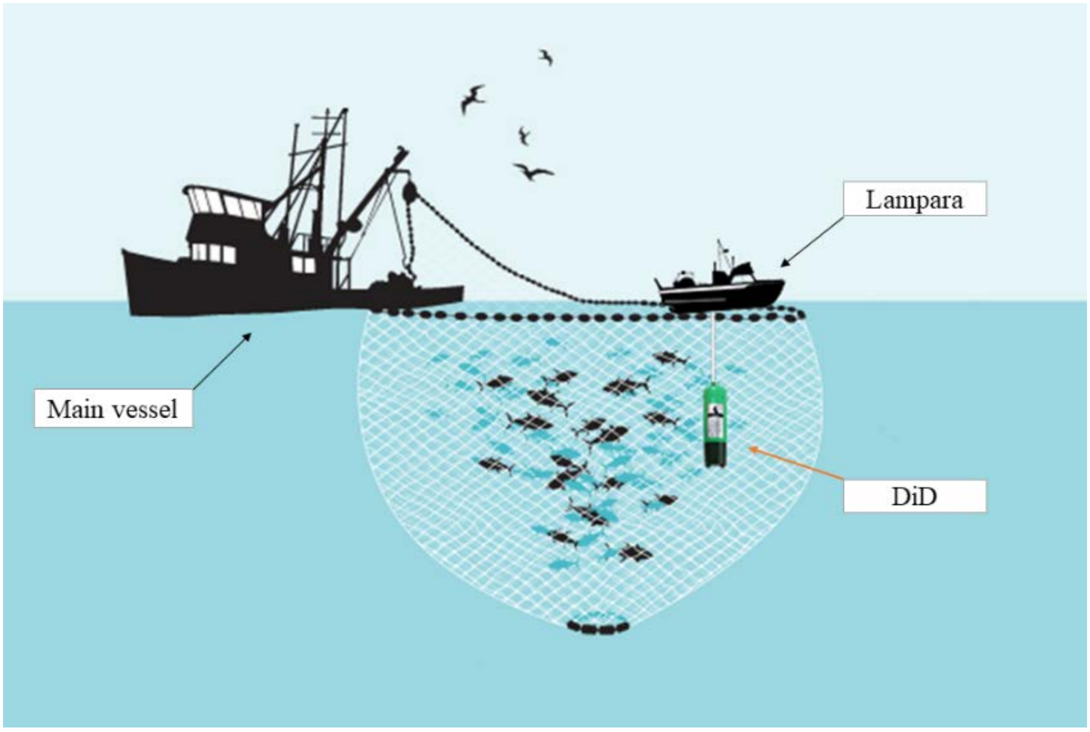
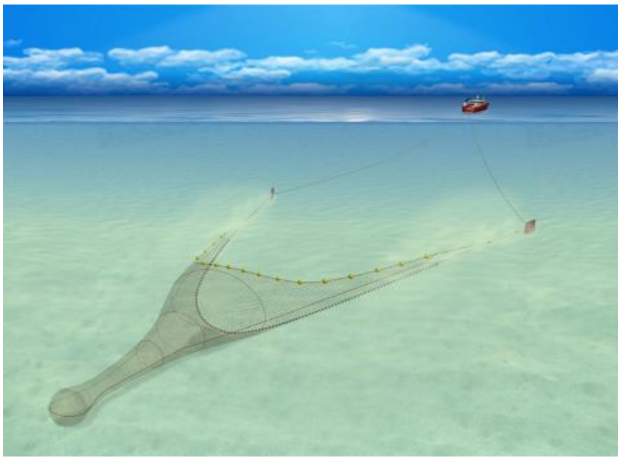


Figure 21: Set-up of the DiD in cianciolo fishery.

This specific configuration was evaluated together with fishers to provide multiple benefits; first, lowering the device from the lampara avoid pinger to hinder the fishing operations (e.g. getting entangled in the net), as the boat is not actively involved in towing the seine. Moreover, the set-up was intended to maximize pingers efficiency by maintaining them functional during entire fishing procedures, thus preventing both accidental captures during the pursuing and depredation when the fish are crowd against the seine. Lastly, the lampara is normally placed in an optimal position to ensure proper coverage of the entire fishing area.

2.3 TRAWL

Trawl nets are actively towed by the vessel and consist of a cone- or pyramid-shaped body closed at the back by a cod-end. Nets can extend at the opening by the wings or can be mounted on a rigid frame. The horizontal opening is either obtained by otter boards or by a beam or frame of variable shape and size. Based on the vertical strata in which can be towed, trawls are usually classified into two main categories, i.e. pelagic trawls and bottom trawls (Figure 22). In bottom trawling, the net is towed along or close to the seafloor, whereas pelagic trawling targets fishes that are living in the upper water column of the sea, thus this type of trawl does not come into contact with the sea bed.



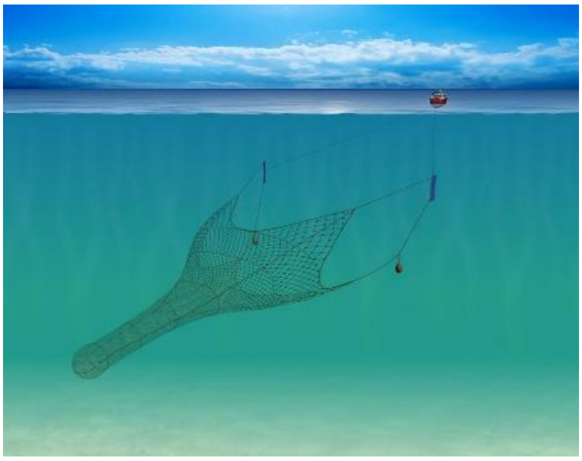


Figure 22: The two main trawling fisheries in the Mediterranean Sea: Bottom Otter Trawl (left) and Midwater Trawl (right).

2.3.1 Survey

The tuning phase of pingers set-up was carried out aboard a bottom trawler operating on sandy bottoms ranging from 40 to 90 m depth at 15–50 nm far from the coast of Ancona (Central Adriatic Sea;). The species targeted by this trawler are generally hake (*Merluccius merluccius*), monkfish (*Lophius piscatorius*), and other valuable demersal species. The trials, which were conducted in December 2020 (Table 10), were part of routine fishing activities of the trawler. Pingers were deployed on trawl net in 2 commercial hauls per day, for a total of 3 days.

The gear employed was an Italian commercial trawl typically used in the study area, entirely made up of knotless polyamide (PA) netting (see Sala & Lucchetti (2011) for the design of the trawl). The length from the wing tips to the codend was approximately 60 m, with 600 meshes in the top panel at the footrope level. The codend was made of the same netting material (knotless PA, 54 mm nominal mesh size) with a stretched length of 5 m.

Table 9: Summary of the hauls carried out during the tuning phase of the DiDs

ID haul	Date	Towing time			Latitude		Longitude		Depth [m]		Mean Speed [knots]
		Start	End	Duration	Start	End	Start	End	Start	End	
1	14/12/2020	11:10	13:25	135	43°21.66'	43°14.53'	13°51.44'	13°57.97'	25	33	3.52 ± 0.04
2	14/12/2020	13:45	15:55	130	43°14.16'	43°19.77'	13°59.81'	14°04.18'	44	49.5	3.59 ± 0.04
3	15/12/2020	09:55	12:05	130	43°20.68'	43°23.15'	14°04.69'	14°07.16'	49	59.4	3.57 ± 0.02
4	15/12/2020	12:45	15:00	135	43°27.43'	43°19.04'	14°07.64'	14°10.47'	66	60	3.63 ± 0.02
5	16/12/2020	11:07	13:37	150	43°21.23'	43°29.10'	13°54.65'	13°48.65'	25	24	3.79 ± 0.05
6	16/12/2020	14:45	17:10	145	43°28.76'	43°20.53'	13°48.94'	13°53.27'	23	20	3.92 ± 0.02

Table 10:Main characteristics of the bottom trawler employed in the survey.

NAME	Airone Bianco II
MATR. N°	AN04053
HARBOUR	Ancona
LOA	24 m
GT	91.5
ENGINE POWER	480 kW
CREW	5

2.3.2 Pinger rigging

One device is enough to cover the entire net and the area in its vicinity, the same as for purse seine fishery. The pinger was rigged on the headrope of one of the two net wings with the aid of two snap-hooks, thus without causing any hindrance to usual fishing operations. a polythene rope (diameter= 8mm) was looped around the device to facilitate the attachment of the snap hooks at the two extremities (Figure 23).

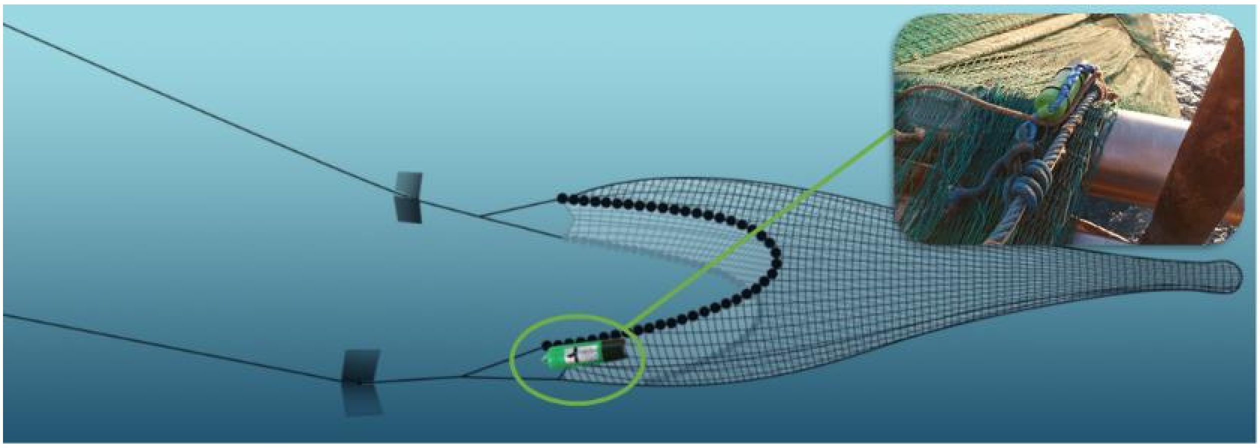


Figure 23: Detail of the loop of rope (up) and DiD positioning on trawl net (down).

Pinger was then mounted directing the lower part (black), where the electrodes are located, towards the codend. Alternatively, pingers can be attached to the trawl net using two short lengths of rope, as showed in Figure 24. However, no additional floats are required to rig the pinger.

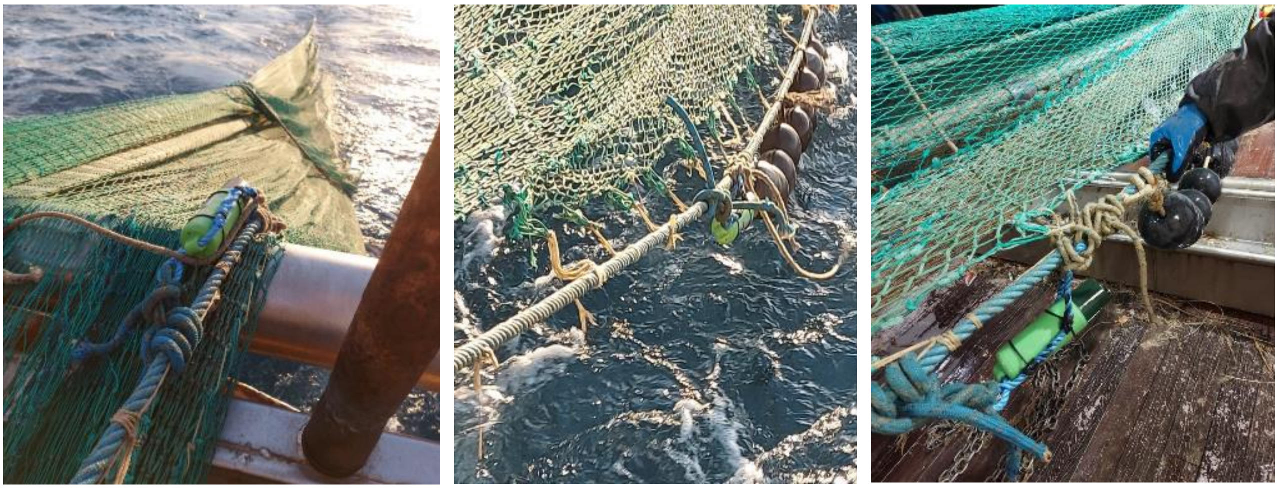


Figure 24: DiD attached on the trawl net by short lengths of rope.

For pelagic trawl, pinger set up was not evaluated through onboard observation. However, the rigging modality of the DiDs on pelagic trawl nets are approximately the same described above for bottom trawl, as one pinger must be placed on the floatline one of the two wings. For further information see De Carlo *et al*. (2012), which investigated the use of a pingers (DDD-03H by STM, with the same shape and dimension of DiDs) on pelagic trawl fishery in the framework of the monitoring program of cetacean by-catch in Italian pelagic trawlers in compliance with European Regulation 812/2004 (Figure 25).

Figure 25: Set-up of DDD-03H on pelagic trawl net; excerpt from De Carlo et al., 2011.

3 PRACTICAL TIPS FOR USERS

After introducing the 3 case studies and related pinger setup, some good practices and general rules are described below, to ensure the correct functioning and maintenance of the Dolphin Interactive Dissuader.

3.1 BATTERY RECHARGE

Before use, the devices need to be fully charged using the appropriate charger. Depending on the needs and methods of use, the manufacturer supplies multiple or single chargers (Figure 26).

The multiple charger allows to charge simultaneously up to 4 or 9 devices and show in the display the charge level of the device when inserted. Moreover, these chargers ensure good stability to the equipment being recharged, which also allows recharging onboard fishing vessels in addition to indoor use. However, the relatively high price of the multi batteries chargers can be hardly affordable, making this equipment less attractive to the fishers than single ones .

The single chargers are supplied with the purchase of each pinger, therefore no additional expense is required. However, the terminals of this equipment have less stability, so it is necessary that recharging takes place in a static place and not in motion. Furthermore, the single charger does not allow you to check the charging status, although an acoustic signal from the pinger indicates the end of the charging phase. Therefore, voltages can only be checked using the STM Voltester (a standard multimeter will not work) which shows the voltage value of the batteries and is equipped with a colorimetric scale to graphically check the battery status (Figure 27). This instrument also needs to be bought separately.

Figure 26: Different battery chargers supplied by STM Products.

A full charge, regardless of the charger used, will take 8-20 hours and should last for more than 300 hours in hearing mode and about 12 hours in continuous emission mode. When fully charged the pinger should give a voltage reading of at least 6.7 (Figure 27).

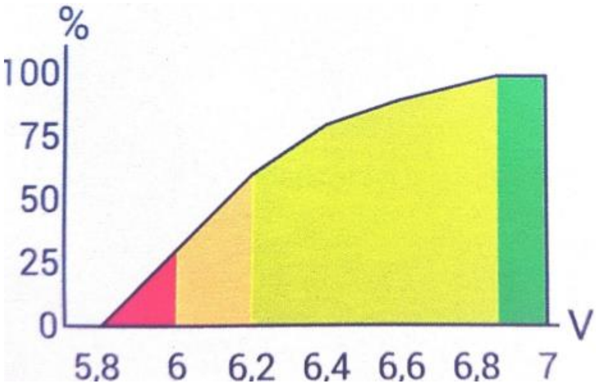


Figure 27: Voltage reading using the STM Voltester. As evidenced in the diagram, the internal batteries must be recharged when the voltage reaches 6V, because below this value the performance of the device is strongly reduced.

3.2 MAINTENANCE

To ensure a longer lifespan of the internal batteries, the pingers need to be recharged regularly, avoiding long periods of inactivity. If the batteries are not to be used for a long period, a residual voltage must always be left, because their performance may be significantly reduced below 5.8 V or, in the worst case, the batteries could be permanently damaged.

After use, it is highly recommended to wash it with fresh water and carefully dry the pinger head, to prevent rust on the two electrodes (positive and negative). Although they are made of AISI 316 stainless steel, oxidation of the electrodes prevents correct recharging of the internal batteries due to the lack of electrical contact. If there are any traces of rust is present, they must be removed with a brass brush.

4 FINAL CONSIDERATIONS

Given the preliminary results obtained so far, a series of final considerations can be drawn regarding the use of Dolphin Interactive Dissuaders.

- To meet the minimum operational requirements reported in the user manual, DiDs should/must be deployed at least 15-20 meters below the sea surface and 20-30 meters above the sea bottom. This limitation might prevent their application/implementation in many artisanal fisheries (e.g. set-nets), as they usually exploit areas in the proximity of the coast, even at low depth.
- Due to the low number of observations performed during the tuning campaign, the scientific explanation behind the continuative activations of DiDs without apparent stimuli has not yet been identified. To address this issue, further sea trials will be performed in spring 2021 by the CNR-IRBIM Ancona. Specifically, long term monitoring (>12 hours) with autonomous underwater recorders (sampling rate 348 kHz at 16-bit) will be carried out, to fully characterize the emission spectrum of DiDs as well as their functioning over prolonged working conditions.
- The EU Reg. 2020/967 - *laying down the detailed rules on the signal and implementation characteristics of acoustic deterrent devices* - establishes technical specifications and conditions of use of pingers in Annex 1. These include a maximum threshold of the Sound Pressure Level-SPL at 145 dB re 1 μPa @ 1 m for devices with digital signal synthesis. Therefore, DiDs exceed this restriction, as they emit acoustic signals at 168 dB re 1 μPa @ 1 m. However, the advice of the Scientific, Technical, and Economic Committee for Fisheries (STECF, 2019) considered that the development of new acoustic deterrent devices should not be constrained by technical specifications. Following this opinion, EU Reg. 2020/967 in art. 3 establishes that Member States, by derogation of the EU Reg. 2019/1241, may authorize the use of acoustic deterrent devices that do not fulfill the technical specifications or conditions, provided there is evidence that such devices are at least as effective in reducing incidental by-catch of cetacean species as those listed in Annex I of the EU Reg. 2020/967.

  In this sense, the experimentation activities foreseen by Action C1 of Life DELFI Project will help to frame the issues above, by providing new and clear information on the pingers, that might facilitate the procedures relating to the exemptions required for their commercial distribution as well as the implementation of guidelines for sustainable and effective use of such mitigation measure in capture fisheries at national levels (Italy and Croatia).
- Lastly, the complex situation generated by the Covid-19 outbreak, which has prevented regular activities in all European countries from the beginning of March 2020, has also affected the progress and implementation of the Life DELFI project in the period covered by this report. Particularly, the regulatory protocol for measures to combat and contain

the spread of the Covid-19 enacted by CNR-ANCONA took into consideration the need for maintaining the necessary spacing conditions while working onboard research vessels, reducing the number of researchers on board (from 4 to 2), and avoiding enclosed common areas (bunks, rooms, laboratories, etc.). Therefore, the tuning campaign initially planned onboard R/V G. Dallaporta, were carried out onboard another R/V owned by CNR (Tecnopesca II), which allowed to enforcement and compliance with the protocol above.

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