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# WP4 – Technical Report: Effectiveness assessment of cetacean bycatch reduction strategies and fishing technical measures proposal.

## Deliverable 4.3. Pilot project: Set nets and purse seine nets (pingers)

## CetAMBICion

Coordinated Cetacean Assessment,
Monitoring and Management Strategy
in the Bay of Biscay and Iberian Coast sub-region.

# Workpackage 4 Task 4.3

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The CetAMBICion project, coordinated by the Spanish National Research Council (CSIC) and which includes 15 partners from Spain, France, and Portugal, aims to strengthen collaboration and scientific work between the three countries to estimate and reduce cetacean bycatch in the subregion Bay of Biscay and Iberian Coast, in close collaboration with the fishing industry. Until 2023, the project will work to improve scientific knowledge on population abundance, incidental bycatch and on mitigation measures of the latter.

The project is part of the European Commission's DG ENV/MSFD 2020 (Marine Strategy Framework Directive) call, and the objectives are aligned with the Habitats Directive and the Common Fisheries Policy too.

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## Glossary

**Bycatch –** unintentional capture of non-target species. It may or may not lead to mortality.

**Depredation –** in fisheries it is the act where a predator partially or completely consumes a fish caught by fishing gear before it can be retrieved to the fishing vessel.

**Encirclement** – the process of animals getting surrounded and bycaught inside a purse seine net.

**Métier** – a fishing method with specific gear characteristics (i.e. mesh size, length, soaking periods)

**Monitoring –** the act of keeping under systematic checking review or observation of progress and quality of the trials for a period of time.

**Mitigation –** the act of reducing negative interactions (bycatch and/or depredation).

**Habituation –** the diminishing of an innate response to a frequently repeated stimulus.

**Haul** – the act of dragging a net in a fishing event

**Efficiency –** the ratio of the useful work performed by the acoustic alarms.

## Acronyms

**CetAMBICion** – Coordinated Cetacean Assessment, Monitoring and Management Strategy in the Bay of Biscay and Iberian Coast sub-region

**CPUE** – Catch Per Unit Effort

**DDD** – Dolphin Deterrent Devices

**DiD** – Dolphin interaction Devices

**iNOVPESCA** – Project Mar2020- “Redução de capturas acidentais de espécies marinhas protegidas em pescarias costeiras algarvias: inovação de procedimentos e técnicas de mitigação

**SO** – At-Sea Observer

**VO** – Vessel-crew observer

# 1 Introduction

## 1.1 Fisheries interactions with cetaceans

### 1.1.1. Europe

Fishing activities reduce available resources to natural marine predators (Hall et al., 2000; Kaschner and Pauly, 2005; Alexandre et al., 2022). Cetaceans, as top predators, are efficient in searching for food resources, always trying to reduce energy costs in time and distance to reach available prey. Thus, interactions between fishing gears and these marine mammals are inevitable as there is an overlap between fishing grounds and their habitats. Interactions can be direct and indirect. Direct interactions refer to when cetaceans come into direct or close contact with fishing gear which may or may not lead to bycatch (incidental capture through entanglement in fishing gear), or also in the form of depredation (removal or damage of catch and/or damage of gear by the cetaceans; Read et al., 2006, Jog et al., 2022). Indirect interactions refer to fishery-induced ecological changes and resource competition (i.e. habitat and prey overlap) which may lead to prey depletion influencing species and population dispersal (Aguillar, 2000). In this task, we focus on direct interactions. The negative aspects of direct interactions are of most concern, as they can be a serious threat to many populations of cetaceans if they result in incidental capture leading to serious injury or death. Given their slow reproductive rates and late maturity, population recovery can be long (Alexandre at al., 2022). Another aspect of direct interaction between cetaceans and fisheries is the interference of these species with the fishers' activity, either through depredation (i.e. removal of fish from fishing gear), which can negatively affect fisheries by resulting in loss of bait and captured fish, and/or through gear damage leading to economic loss, or even through scattering of fish (Wise et al., 2007; Marçalo et al., 2015; Alexandre 2019; Alexandre et al., 2022; Dias et al., 2022).

Air breathing marine megafauna individuals (e.g. cetaceans, birds, reptiles) are most frequently caught unintentionally by fishers when they become accidentally entangled, trapped, or hooked in the fishing gear. Even though bycatch events have been reported for most gears (Perrin et al., 1994; FAO, 2021), drivers of incidental capture for different animal groups (e.g. cetaceans, birds, reptiles) are mostly related to gear operational aspects and its targeted species, which may also be the main prey for certain megafauna species (Kaschner and Pauly, 2005; Plagányi and Butterworth, 2009) and the magnitude of fishing effort in certain regions. For instance, in Europe, fisheries of most cetacean bycatch concern are purse seining , bottom set nets (gill and trammel) and pelagic trawls (Morizur et al 1999;

Hall et al., 2000,López et al 2003;  Mannocci et al 2013; Marçalo et al 2015, Dias et al 2022; ICES 2022).

Cetaceans in European waters are protected through Habitats Directive (92/43/EEC, May 21st 1992) and some species such as the harbour porpoise, *Phocoena phocoena*, and the bottlenose dolphin, *Tursiops truncatus*, have a priority protection status (Annex IV). Therefore, Member States are guided to promote studies and report information on cetacean ecology and anthropogenic impacts on their populations, so more efficient management and conservation plans are created and improved mitigation measures are promoted.

This group of species is also assessed under the Marine Strategy Framework Directive (MSFD). Under this UE Directive, and in the particular case of mainland Portugal, targets for the achievement of Good Environmental Status (GES) have been proposed given the poor status of some populations (MM, 2020).

### 1.1.2. Portugal

Studies about fisheries interactions with cetaceans for the Portuguese mainland coast were scarce up to the first decade of the 21st century. Until then, information was based only on strandings, with the identification of the cause of death as well as diet analysis of their stomach contents. Results indicated, and particularly for the most abundant species in the area, the common-dolphin *Delphinus delphis*, that incidental bycatch occurred mainly in gill and trammel nets (Sequeira and Ferreira, 1994; Silva, 1999; Silva and Sequeira 2003; De Sousa, 2010). Most recently, within the scope of more dedicated projects, some studies identified areas of higher conflict between cetaceans and Portuguese fisheries, suggesting a considerable habitat overlap in certain areas (Vingada and Eira, 2018; Brouder, 2022). These works also identified associations of cetaceans with fisheries and estimated bycatch rates (Marçalo et al., 2015; Goetz et al., 2015; Alexandre, 2019; Alexandre et al., 2022; Dias et al., 2022). The common dolphin was identified as the species with most frequent direct interactions with fisheries (i.e. incidental bycatch or approximation to the gear), particularly in the purse seine fishery (Wise et al., 2007; Marçalo et al., 2015, Dias et al., 2022, Alexandre, 2019; Alexandre et al., 2022), as sardine is its favourite prey and also the target of the fishery, especially in the summer season (Silva, 1999; Marçalo et al., 2018). Furthermore,  the common-dolphin is the most abundant cetacean species in the area and is the most frequently bycaught in all gears (Vingada and Eira, 2018; Alexandre et al., 2022). The bottlenose dolphin, *Tursiops truncatus,* is the species with more direct interactions in the form of depredation, especially in the Southern coast, leading to considerable economic losses to artisanal fishers (Alexandre, 2019; Alexandre at al., 2022).

## 1.2 Species of cetaceans in mainland Portugal

Along the Portuguese mainland coast, 28 species of cetaceans have been identified, 21 Odontoceti (cetaceans with teeth, that include e.g. dolphins or porpoises) and 7 Mysticeti (cetaceans without teeth or baleen whales, that include e.g. minke whales). Some of these species are considered resident such as the common dolphin, striped dolphin *Stenella coeruleoalba*, bottlenose dolphin, harbour porpoise, Risso's dolphin *Grampus griseus*, and the minke whale *Balaenoptera acutorostrata*, while some others are occasional visitors (Table 1). Abundance estimates for Portuguese mainland waters are available for some species (e.g. as published in the MSFD assessment conducted in 2020; MM, 2020). However, abundance data is still scarce for many species which are therefore included in the category of "Insufficient information" in the Red Book of Vertebrates in Portugal (Cabral et al., 2006). For other cetacean species, potentially rare and of difficult observation, an evaluation status in the area was not made.

**Table 1**. Cetacean species registered in Mainland Portugal. Conservation status according to the Red Book of Vertebrates in Portugal (Cabral et al., 2006; In Portuguese).

| Nome comum | Nome científico | Ocorrência | Estatuto (Livro Vermelhos dos Vertebrados de Portugal) | Diretiva habitats |
|---|---|---|---|---|
| Golfinho-comum | *Delphinus delphis* | Residente | Pouco preocupante | B-IV |
| Golfinho-riscado | *Stenella coeruleoalba* | Residente | Pouco preocupante | B-IV |
| Golfinho-pintado | *Stenella frontalis* | ? | Não avaliado | B-IV |
| Golfinho-de-bico branco | *Lagenorhynchus albirostris* | ? | Não avaliado | B-IV |
| Golfinho de Fraser | *Lagenodelphis hosei* | ? | ? | B- IV |
| Golfinho-de-flancos-brancos | *Lagenorhynchus acutus* | ? | ? | B-IV |
| Roaz - corvineiro | *Tursiops truncatus* | Residente | Pouco preocupante | B-II, B-IV |
| Bôto | *Phocoena phocoena* | Residente | Vulnerável | B-II, B-IV |
| Baleia-piloto | *Globicephala melas* | ? | Informação Insuficiente | B-IV |
| Baleia-piloto-tropical | *Globicephala macrorhynchus* | ? | Informação Insuficiente | B-IV |
| Grampo | *Grampus griseus* | Residente | Informação Insuficiente | B-IV |
| Orca | *Orcinus orca* | ? | Informação Insuficiente | B-IV |
| Falsa-orca | *Pseudorca crassidens* | Ocasional | Não avaliado | B-IV |
| Cachalote | *Physeter macrocephalus* | Ocasional | Não avaliado | B-IV |
| Cachalote-pigmeu | *Kogia breviceps* | ? | Informação Insuficiente | B-IV |
| Cachalote-anão | *Kogia simus* | ? | Não avaliado | B-IV |
| Zífio | *Ziphius cavirostris* | ? | Informação Insuficiente | B-IV |
| Baleia-de bico- de-True | *Mesoplodon mirus* | Ocasional | Não avaliado | B-IV |
| Baleia-de-bico-de-Gervais | *Mesoplodon europaeus* | ? | Não avaliado | B-IV |
| Baleia-de-bico Sowerby | *Mesoplodon bidens* | ? | Não avaliado | B-IV |
| Botinhoso | *Hyperoodon ampullatus* | ? | Não avaliado | B-IV |
| Baleia-anã | *Balaenoptera acutorostrata* | Residente | Vulnerável | B-IV |
| Baleia-sardinheira | *Balaenoptera borealis* | Ocasional | Não avaliado | B-IV |
| Baleia-comum | *Balaenoptera physalus* | Ocasional | Não avaliado | B-IV |
| Baleia-de-Bryde | *Balaenoptera edeni* | ? | Não avaliado | B-IV |
| Baleia-azul | *Balaenoptera musculus* | Ocasional | Não avaliado | B-IV |
| Baleia-de-bossa | *Megaptera novaeangliae* | Ocasional | Não avaliado | B-IV |
| Baleia-basca | *Eubalaena glacialis* | Ocasional | Não avaliado | B-IV |

In the present study, attention is mostly given to both the common dolphin and the bottlenose dolphin in the area: the first is strongly associated to the purse seine fishery and is also the most abundant species in the area, having the highest mortality rates with bycatch evidence through strandings (ICES, 2021; Ana Marçalo pers. comm.); the second has a coastal and opportunistic behaviour, interacting with the set nets through depredation causing frequent economic losses to fishers (Marçalo et al., 2019; Alexandre at al., 2022). Some general biological and ecological aspects for both species are described below.

### 1.2.1 Common dolphin, *Delphinus delphis*

The common dolphin is one of the most abundant cetacean species in the North-East Atlantic and is considered to have an “Unfavourable-Inadequate” conservation status in EU waters under Habitats Directive (Murphy *et al.,* 2019). In the last MSFD assessment for Portuguese continental waters, this species did not achieve the Good Environmental Status (GES) both for the bycatch and abundance criteria (MM, 2020). However, for its global distribution range, this species has been recently assessed as "*Least Concern"* in the IUCN Red List of Threatened Species in 2020 (Braulik et al., 2021). It is widely distributed and occurs in waters from Scotland to southern Portugal, between 35° N and 55° N and is most commonly sighted in offshore waters deeper than 180 m and over the continental shelf (Reid, 2003; Murphy *et al.,* 2013). Common dolphin specializes in preying on highly energetic small pelagic fish, to satisfy their energetically expensive behaviour (Silva, 1999; Spitz *et al.,* 2010; Marçalo *et al.,* 2018). In the North-East Atlantic, seasonal shifts in distribution have been reported, with common dolphin occupying a more northerly distribution during the summer in response to changes the availability of their primary prey, the sardine *Sardina pilchardus* (Culik *et al.,* 2011; Silva *et al.,* 2014).

Individuals reach a maximum length of approximately 2.3 m. Its dorsal colour is black with both flanks displaying an ochre or light-brown coloured patch reaching half of the body (Figure 1). The posterior half exhibits a grey colour and the ventral side is white. The colour pattern is "X" or hourglass-shape in both lateral sides. This cetacean has a long beak comprising 40 to 50 conical teeth per hemi-maxilla. Common dolphins display a complex behaviour and, in Portugal, they feed mostly on sardine among other small pelagic fish. It has a homogeneous distribution along the Portuguese mainland coast (Figure 2) and is the most abundant cetacean species in mainland Portugal (Vingada and Eira, 2018; Hammond et al., 2021; Brouder, 2022). Records from the last decades highlight that this species is frequent in strandings along the coast.

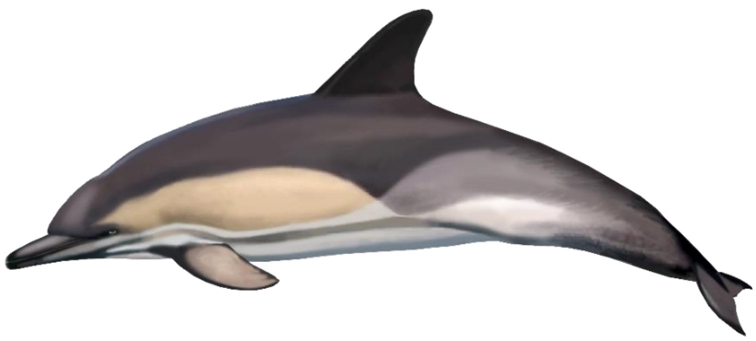


Figure 1 – Illustration of the common-dophin (*Delphinus delphis*). ©Tokio

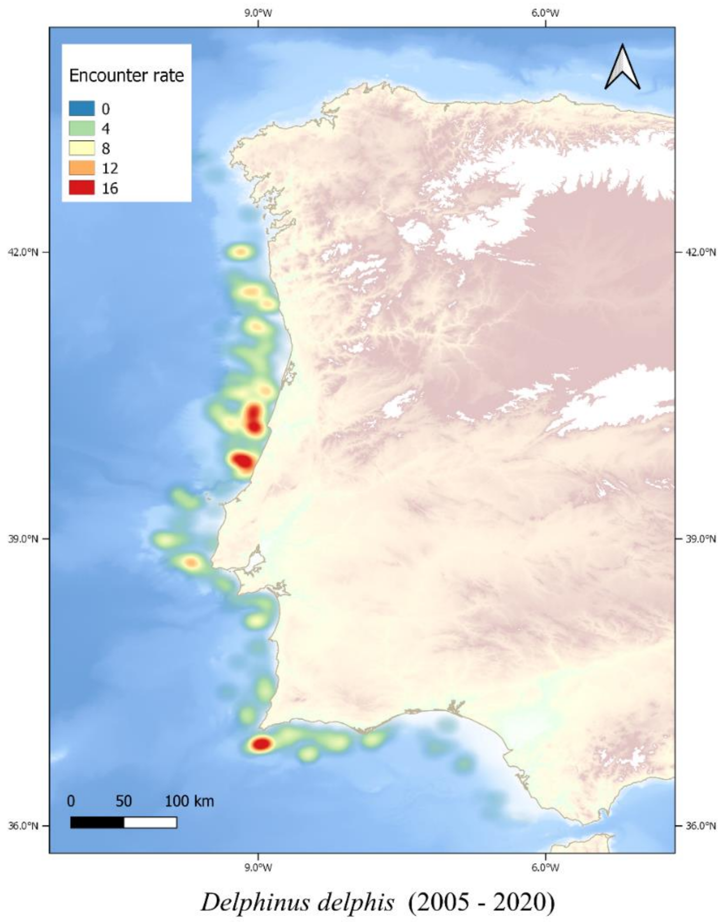



Figure 2 – Kernel distribution map of the encounter rate for the common dolphin from 2005-2020 taken from Brouder (2022).

### 1.2.2 Bottlenose dolphin, *Tursiops truncatus*

The common bottlenose dolphin, *Tursiops truncatus,* is a cosmopolitan cetacean species with a widespread distribution, inhabiting temperate to tropical marine waters and adapting to different habitats from marine, to estuarine or even ranging into rivers. The species is mainly coastal, but it is also found in pelagic/offshore waters, presenting different ecotypes with particular morphological, ecological and physiological characteristics (Wells and Scott, 2008). In the North-East Atlantic, it is observed off the coasts of UK, the Greater North and Celtic seas and Bay of Biscay and Iberian Coast, having patchy distribution in offshore and coastal areas (Hammond et al., 2017). In the Atlantic coast of the Iberian Peninsula the species is particularly coastal, as evident in the Sado Estuary (Portugal) where there is a small resident population, in Galicia (Spain) (dos Santos et al., 2005, Methion and López, 2018, 2019), and as evident through recent abundance and distribution surveys

(Hammond et al., 2017; Vingada and Eira, 2018; Brouder, 2022). Such coastal preferences may increase bottlenose dolphin exposure to anthropogenic pressures such as interactions with fisheries or pollution (Monteiro et al., 2016; Alexandre et al., 2022), and it is therefore urgent to monitor these populations at all levels and build effective conservation plans and mitigation measures to decrease threats.

In European waters, bottlenose dolphin is protected under the Habitats Directive (92/43/22C) and listed in Annexes II and IV together with the harbour porpoise, as priority species, which requires member states to designate special areas of conservation (SAC) to protect their populations.

Individuals are big and robust, reaching a maximum length of approximately 4 m. The bottlenose dolphin has grey coloration in most of its body, despite the slightly darker dorsal area in comparison with the abdomen (Figure 3). It has a small beak, with 20-25 conic teeth in each hemi-maxilla, and a relatively big and curved dorsal fin. The diet is composed of fish and cephalopods. Occurs frequently along the Portuguese mainland coast, although it displays a preference for southern areas (Figure 4).

Figure 3 – Illustration of bottlenose dolphin (*Tursiops truncatus*). ©Tokio

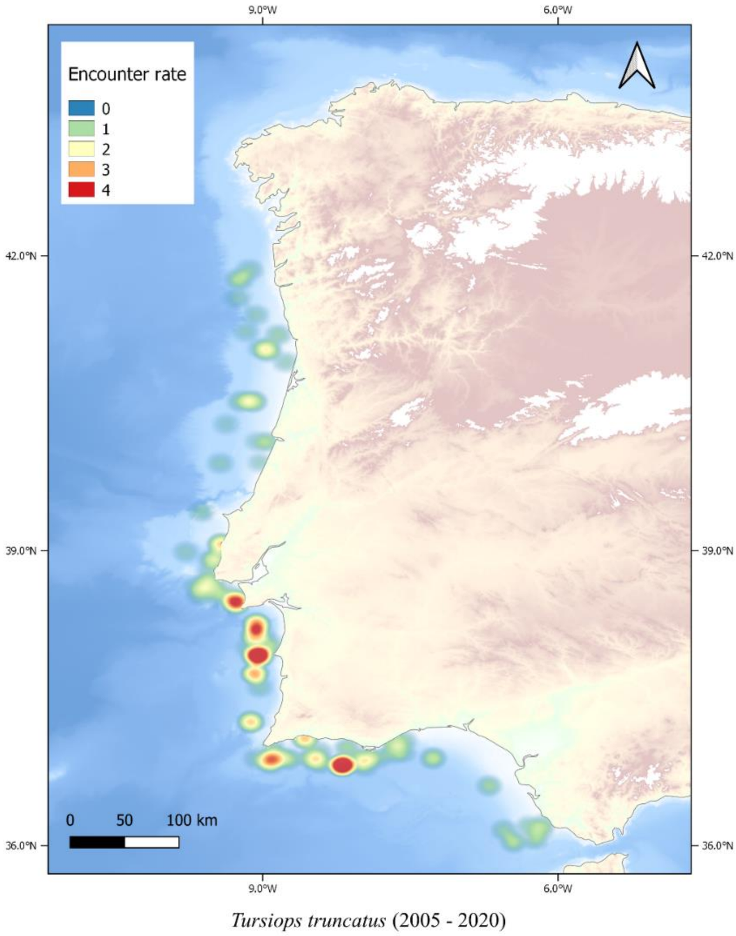



Figure 4 – Kernel distribution map of the encounter rate for the bottlenose dolphin from 2005-2020 taken from Brouder (2022).

## 1.3 Scope

In the project "CetAMBICion" (Coordinated Cetacean Assessment, Monitoring and Management strategy in the Bay of Biscay and Iberian Coast subregion), the work package 4 (WP4), aims to propose coordinated measures to reduce cetacean bycatch. The objective of task 4.3 is to perform pilot trials to assess the efficacy of bycatch reduction devices in set (gill and trammel) nets and in purse seine nets where considerable incidental bycatch and/or depredation rates occur (Marçalo et al., 2015; Marçalo et al., 2019) as well as to define procedures in their use. The proposal for this case study was built upon the positive experience and collaboration of UALG with the fishing sector in a prior project (Mar2020 - iNOVPESCA; 2018-2021; Marçalo et al., 2021). Direct interactions between the purse seine fishery and cetaceans, mainly common dolphins, occur along the whole Portuguese coast, with occasional bycatch (Marçalo et al., 2015, Dias et al., 2022). On the other hand, for set net fisheries (gill or trammel nets), direct interactions are frequent with bottlenose dolphins mainly in the Southern coast, where the damage to the catch and fishing gear caused by depredation are highly reported by fishers (Marçalo et al., 2019, Alexandre et al., 2022). However, occasional incidental bycatch for different small cetacean species (e.g. common dolphins, bottlenoses, harbour porpoises and striped dolphins) are also reported in set nets (Alexandre et al., 2022). Thus, pilot trials aimed at continuing and updating information about cetacean interactions and mitigation strategies using dolphin deterrent devices (DDD) in set nets and purse seine nets off coastal southern Portugal (Algarve).

The present report constitutes a deliverable for WP4 and addresses the outcome of the pilot trials proposed within CetAMBICion task 4.3 on set nets (gill and trammel nets) and purse seine nets.

# 2 Materials and Methods

## 2.1 Area of study

The study area included the waters off southern mainland Portugal (Figure 5), also known as the Algarve. The study area comprises a small area in the south-west coast (~50 km), from Odeceixe (37 ∘ 26’ N - 8 ∘ 47’ W) to Cape São Vicente (37 ∘ 1′ N - 8 ∘ 59′ W), and the Southern coast (~170 km extension), from Cape São Vicente to Vila Real de Santo António (37º11’ N - 7º25’ W). This coastal region has a very narrow continental shelf (5–20 km wide) influenced locally by upwelling events, mostly occurring in the south-western area. The southern area is also influenced by the more saline and warm waters of the Mediterranean Sea (Cunha, 2001; Bettencourt et al., 2004). Geographically, the Algarve is divided into two sub-regions, known as the windward region from Odeceixe to Quarteira (37º04’ N 8º06’ W) towards the west, and the leeward region from Quarteira to Vila Real de Santo António, towards the east (Figure 1).

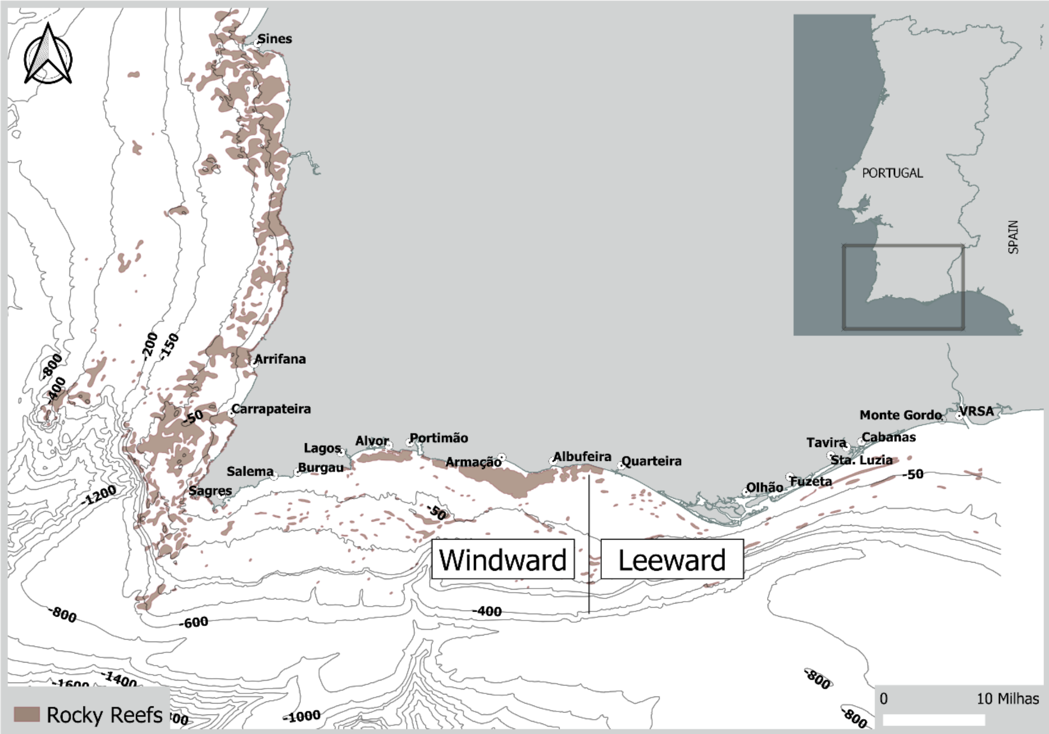



Figure 5 – Map of the study area (Algarve, Mainland Portugal) with the most important fishing harbours. Dark areas off the coast are hard bottom.

## 2.2 Data collection and monitoring

Negative direct interactions (namely bycatch and depredation) between cetaceans and fishing gears were studied based on data collected using two sampling or monitoring methods: (1) Scientific Observers at sea (SO); and (2) Vessel crew Observers (VO) – more specifically, paper logbooks designed specifically for the project (Annex 1) filled voluntarily by fishers following instructions from the project. For both methods, data obtained included: fishing gear and net characteristics (length and mesh size of the net), environmental conditions (Beaufort wind and Douglas sea state scales), vessel activities during the fishing trip (timing of haul operations, namely net shooting, hauling, soaking times), location at the beginning of the haul, fish catch (weight in kg per species), cetacean presence in the proximity of any fishing operation and type of interaction (bycatch with or without mortality and/or depredation). We monitored fishing hauls with (i.e. treatment) and without (i.e. control) the use of acoustic devices for interaction (depredation and/or bycatch with mortality). The number of hauls for each fishery and for each treatment was "*ad libitum*" throughout the period of testing, depending on the fisher choice to use or not the acoustic device. The technical team maintained a constant contact with the fishers to monitor the number of hauls for each treatment.

## 2.3 Equipment - Acoustic devices

The acoustic devices used in this study were "Dolphin Deterrent Devices" (DDD), models DDD 03 and DiD (Figure 6), produced, and distributed by STM Products (Italy). The DDD 03 is an electronic device with a microprocessor of 16 bits that controls the emission circuit for randomized signals. These acoustic devices activate when submerged in water, where the sounds start being emitted with sequences of random frequencies that vary from 5 to 5000 kHz and a potency of emission not higher than 165 dB (1μPa@1m). The random frequencies should decrease habituation (the capacity of acclimating to the acoustic sound to the point it does not have the deterrent effect (https://www.stm-products.com/en/products/fishing-technology). The model DiD (Dolphin interactive Device) is an upgrade form of the DDD. The DiD has an internal function that only activates the acoustic emissions when cetaceans are in the vicinity, and not when it falls into the water. The DiD create a surprise effect on the animals and decrease even further the risk of habituation (https://www.stm-products.com/en/products/fishing-technology). For all models, their efficiency is best from 10-20 meters deep and up to maximum depths of 200 meters, but never touching the ground. These acoustic devices measure 21 mm x 61 mm and weight 905 g. For set nets (gill and trammel nets), the models DDD 03N and the DiD were used, whereas, in the case of purse seine nets, the model DDD 03H was used. All these models are certified as not being physiologically harmful to cetaceans as stated by the manufacturer (Annex 2). More details on their characteristics and use can be found in the report of CetAMBICion WP4.1.


Figure 6 - Acoustic devices models DDD 03N (left), DiD (centre) and DDD 03H (right) used in the incidental bycatch mitigation pilot trials.

## 2.4 Experimental design

### 2.4.1 Set nets

Initial studies within the scope of a previous project, namely project iNOVPESCA (June 2019 to March 2021), were conducted along the Algarve coast, off Quarteira, Olhão and Culatra. Within the scope of project CetAMBICion, these areas were extended to Portimão and Monte Gordo, from April 2021 to June 2022. The fishing vessels monitored were based at each of these landing ports and made daily fishing trips. The acoustic devices for this fishery were mostly applied to the metiers that suffered most depredation from bottlenose dolphin according to information from local fishers and previous studies (Alexandre, 2019; Alexandre et al., 2022). Particularly, dolphin predation on set nets (gill and trammel nets) and associated loss of catch and gear damage were claimed most frequent in fisheries targeting hake, *Merluccius merluccius*, red mullets, *Mullus* spp. and occasionally soles, *Soleidae,* and cuttlefish, *Sepia officinalis*.

The application of the device in the set nets (gill and trammel nets) followed the same procedure in all trials conducted (Figure 7). The manufacturer suggests that performance is guaranteed if application distances in set nets are of 200-400 meters for the DDD 03N model and of 400-800 meters for the DiD model. However, the maximum distance was applied to increase the sample size (by increasing number of unique vessels), and the distances were kept until the end of the trials as acoustic devices performance was not affected (see results section on acoustic device efficiency which was monitored along the study and indicated the evaluation of the performance). Trips were monitored by scientific observers at sea in 11.3 % of all the sampled trips, which also contributed to account for battery autonomy and performance (average battery charge duration was of 48 hours soaking time). In these trips monitored by scientific observers, devices were checked for battery life span with a voltmeter, and when needed were collected to be charged and delivered back to fishers (Annex 3). From 2021 onwards, battery chargers were delivered to fishers together with a battery life protocol, based on the average battery charge duration previously tested.

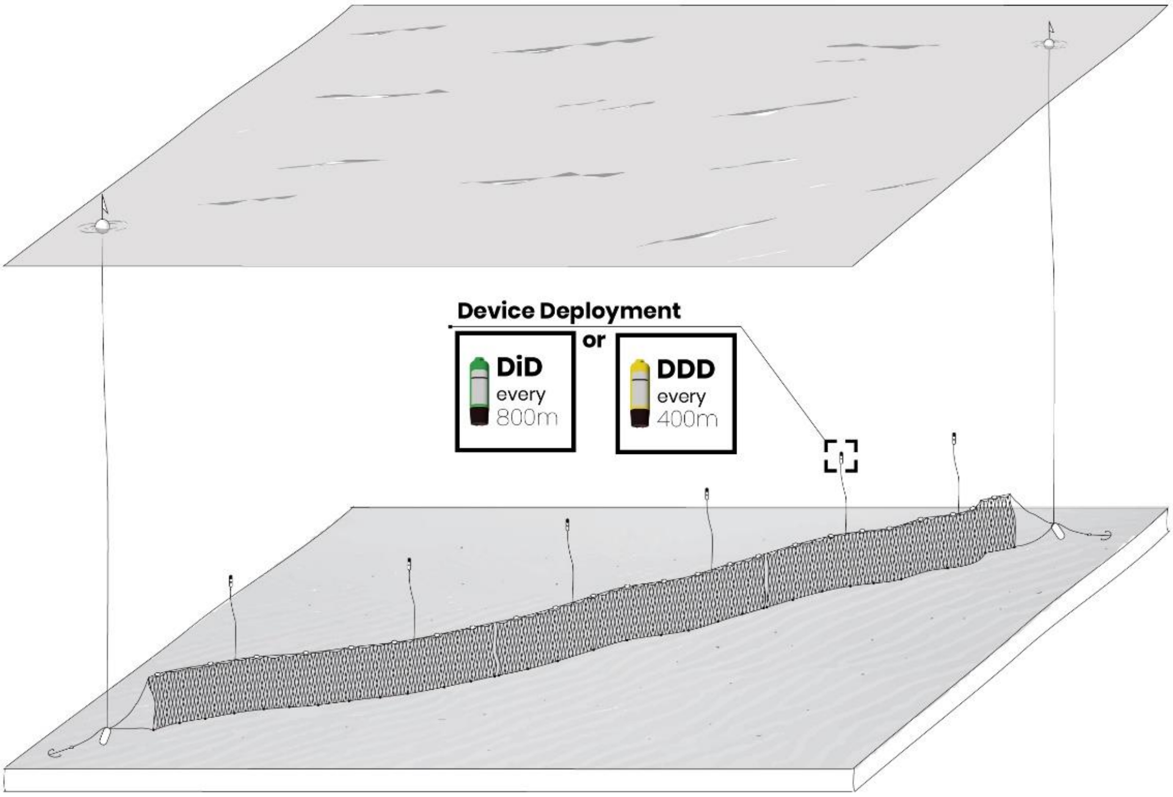



Figure 7 Experimental diagram showing the application and spacing of acoustic devices in set nets (gill and trammel nets).

### 2.4.2 Purse seine nets

The study was conducted along the Algarve coast and during the period when purse seiners target sardine (usually from spring to early fall), which is the period with higher fishing effort and risk of common dolphin incidental bycatch (Marçalo et al., 2015, Dias et al., 2022). Here, we present data obtained during two years of sampling, June-October 2020 (within project iNOVPESCA) and June-October 2021 (within project CetAMBICion). The fishing vessels monitored made daily fishing trips.

The application of the device in the purse seine nets followed the same procedure in all trials conducted (Figure 8). The manufacturer suggested the use of 3 devices per purse seine net, but with a preliminary consultation with skippers, the decision leaned over the use of just one device for practical reasons (i.e., implications for fishing operations by fishers). However, up to the end of the trials, one device provided good performance, thus this protocol was maintained. Each unique vessel was equipped with one acoustic device and one charger, after initial trips when a scientific observer checked for battery life span and battery charging protocol by the fishers.

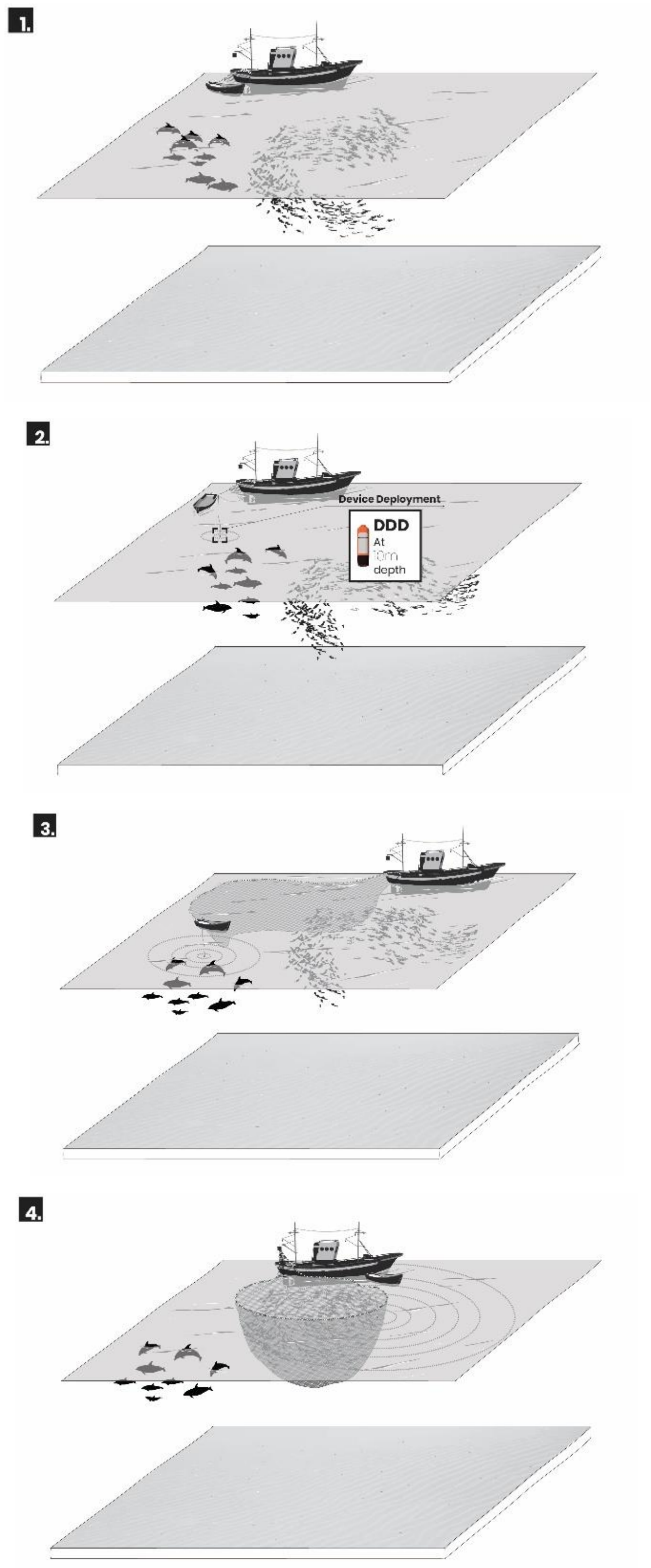



Figure 8 - Experimental diagram showing the application of the acoustic device in the purse seine net when taken in the skiff in a hypothetical scenario with dolphins in the vicinity of the vessel. 1. Prior to net shooting, 2. Beginning of net shooting with acoustic device put into the water, 3. Continuing net shooting, 4. End of net shooting.

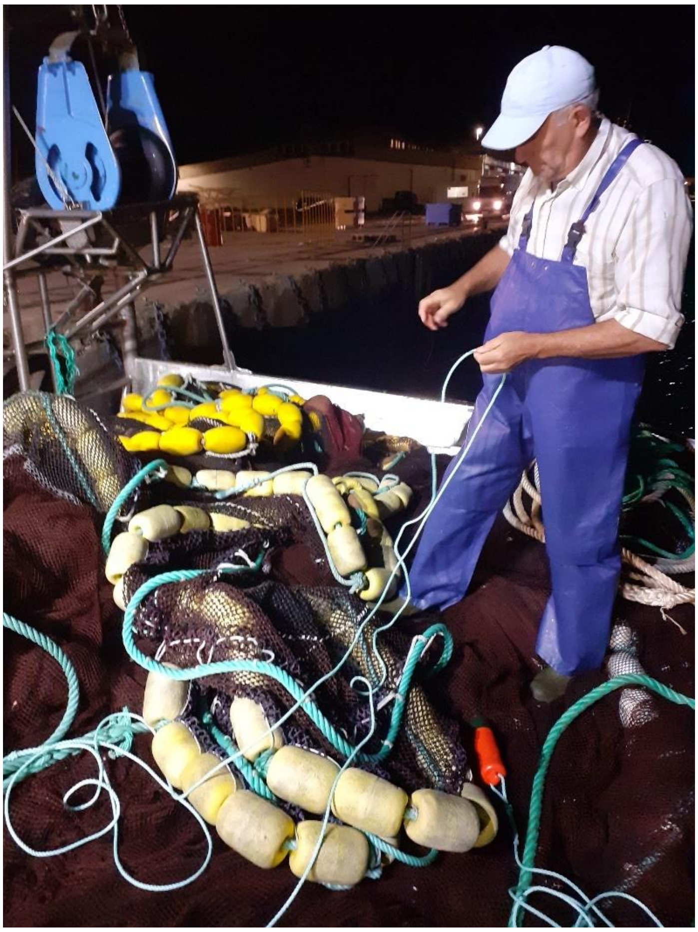


Figure 9 - Fisher preparing the application of acoustic device in purse seine net at the harbour before departure. The application is in the tip/edge of the purse seine net that falls first into the water during net setting.

The acoustic device was placed at the edge of the net that falls first into the water during purse net shooting (Figure 9) or was taken by the fisher in the skiff and is put in the water in the beginning of net hauling (Figure 8.1). The net shooting is a fast operation that lasts no more than 5 minutes (Figure 8.2-8.4). The device remains in the water during the shooting and encircling until the end of the purse inversion, thus the soaking time of acoustic device is no longer than 20-25 minutes.

## 2.5 Analysis

Depredation rates are calculated by dividing the number of hauls where depredation occurred over the total number of hauls observed; varies between 0 and 1.

Bycatch rates are calculated by dividing the number of hauls where bycatch occurred over the total number of hauls observed; varies between 0 and 1.

Catch per Unit Effort (CPUE) was calculated by dividing the total catch by fishing effort. In the case of set nets (gill and trammel nets), fishing effort was considered as the soaking time. Whereas in purse seine nets, fishing effort was considered as the time from the beginning of the search to the end of the fishing activity (which in turn is marked by the end of fish transfer to the vessel) (Marçalo et al. 2015).

We analysed the data using a Generalized Additive Models for Location, Scale and Shape (GAMLSS), with two stage "Zero Adjusted Poisson" (ZAP) distribution and a logit link function. This model allowed to fit in a single function 1. a logistic Generalized Linear Model (GLM) that estimated the proportion of hauls with interaction (bycatch or depredation) and then the hauls where the interaction occurred; 2. a zero-truncated Poisson GLM for the mean number of events or individuals per haul. The differences in the presence-absence of interaction in purse seine nets (bycatch) and in set nets (depredation or bycatch), which was considered the response variable, were analysed between treatments (control vs acoustic device). Models were run separately for set nets (gill and trammel nets) and purse seine nets. We also tested models in both fisheries for factors (or explanatory variables) that could influence the interaction of cetaceans. These factors were latitude, longitude, depth, year, season, month, soaking time, total CPUE, vessel, and observer scheme (Scientific Observers at sea (SO) or Vessel crew Observers (VO)). Model for set nets (gill and trammel nets) also considered the variables CPUE of striped, red mullet and CPUE of hake.

Starting with a model that included main effects of all explanatory variables, we used backwards selection to identify the best model, i.e., at each step the least important non-significant variable was dropped and the model was re-run. The best model was the one that presented the lowest Akaike Information Criterion value [AIC, Akaike (1974)].

To visualise hotspots of interaction (as defined above), a density raster (i.e., heatmap) was created using the Kernel Density Estimation tool on QGIS (Version 3.10.0) (QGIS Development Team, 2019). Kernel Density estimation is a non-parametric method to estimate the probability distribution, *f(x)*, of a random variable, *X*. The Kernel function used was based on the quartic kernel function (as described by Silverman, 1986, pp. 76, equation 4.5), which follows the function:

$Quartic\ density\ function$:

$$P(x) = \frac{15}{16}(1 - d2)^2$$

The probability of having an interaction event (bycatch in purse seine nets; depredation or bycatch in set nets) was analysed using a binomial test considering presence-absence of cetacean interaction for hauls using acoustic device (treatment) and hauls not using devices (controls), obtaining 95 % confidence intervals.

All analysis was performed using the R software (R Core Team 2016).

Acoustic device efficiency, a variable to predict habituation, was estimated by dividing the number of fishing operations where acoustic devices were used and where no interaction occurred, i.e., nor depredation nor incidental bycatch over the total number of fishing operations where acoustic devices were used.

To test for the potential influence of acoustic devices in catches, average CPUE in purse seine nets and average square-root transformed CPUE in set nets were compared between control (without acoustic device) and treatment (with acoustic device) hauls using a Kruskal–Wallis test followed by pair-wise multiple comparison among groups using Dunn's method. A significance level of 0.05 was considered in all tests.

# 3 Results

## 3.1 Set nets

### 3.1.1 Monitoring effort of trials

From January 2019 to June 2022, a total of 877 trips with set nets (gill and trammel nets) were monitored (each trip was a fishing day with one haul). Monitoring effort of trials with the two different acoustic device models was 360 days/hauls for DiD model (151 days/hauls control and 209 days/hauls as treatment) and 517 days/hauls for DDD model (185 days/hauls control and 332 days/hauls as treatment) (Table 2). Soaking times were longer in hauls with DiD devices as some vessels in the trial targeted hake (gillnets and mesh size 80 mm) and soaking times were prolonged for this metier. The interaction with cetaceans (depredation or incidental bycatch) was observed in hauls with and without (control) acoustic devices for both models. At-sea observer effort (SO) was 22 % in 2019 and about 8 -9 % from 2020 to 2022 of all trips monitored, the remaining monitored by vessel crew observers (VO). The higher at-sea observer effort in the first year of testing (2019) was intentional to select and train vessel crew members to perform the data collection.

Table 2 Total monitoring effort in trials with two different models of acoustic device (experimental treatment) and without (control treatment) in set nets (gill and trammel nets): Number of trips; Number of hauls, depth (mean and standard deviation); Number of hauls with cetacean interaction (bycatch, depredation) and with presence of cetacean during fishing operations; Soaking time (mean and standard deviation); TTR - *Tursiops truncatus*, DDE - *Delphinus delphis*. All bycaught animals were dead upon net retrieval.

| | Control (without acoustic devices) | Treatment (with acoustic devices) |
|---|---|---|
| ***Model DDD*** | | |
| Number of trips | 185 | 332 |
| Number of hauls | 185 | 332 |
| Depth (meters) | 29.1 ± 33.6 | 31.6 ± 37.6 |
| Soaking time (hours) | 9.4 ± 10.1 | 6.0 ± 6.9 |
| Number of hauls with cetacean bycatch | 1 (1 TTR) | 0 |
| Number of hauls with cetacean presence during fishing operations | 34 | 45 |
| Number of hauls with depredation | 38 | 33 |
| ***Model DiD*** | | |
| Number of trips | 151 | 209 |
| Number of hauls | 151 | 209 |
| Depth (meters) | 65.1 ± 19.8 | 115.3 ± 65.2 |
| Soaking time (hours) | 15.2 ± 7.6 | 15.1 ± 7.6 |
| Number of hauls with cetacean bycatch | 2 (2 TTR) | 1 (1 DDE; acoustic device not functional) |
| Number of hauls with cetacean presence during fishing operations | 76 | 169 |
| Number of hauls with depredation | 56 | 38 |

The number of unique vessels participating in the trials varied between métiers, acoustic device models and fishing port, with a higher number of vessels in the trials of the project CetAMBICion than in iNOVPESCA (Table 3).

Table 3 ‑ Number of unique vessels in trials with set nets (gill and trammel nets), per fishing port per project and acoustic device model. GNS – gillnet; GTR - Trammel net

| | Number of vessels; Métier; Device model | | | |
|---|---|---|---|---|
| **Ports** | **iNOVPESCA June 2019-March 2021** | **CetAMBICion April 2021-June 2022** | **Target fish species** | **Mesh size (mm)** |
| Olhão | 1; GNS; DiD | 2; GNS; DiD | Hake | 80 |
| Culatra | 1; GNS, GTR; DDD | 2; GNS; DDD | Red mullet; Hake | 50, 52, 55 |
| Quarteira | 1; GNS; DDD | 1; GNS; DDD | Red mullet | 60 |
| Portimão | - | 1; GNS; DiD | Red mullet | 75 |
| Monte Gordo | - | 2 ; GNS; DiD | Red mullet | 50, 52, 55 |
| **Total** | **3** | **8** | | |

Based on Figure 10A, interaction, either depredation or bycatch, occurred along the whole study area, and whether in very coastal areas in the leeward region (east), or in deeper and not so coastal waters in windward region (west). However, the presence of interaction was higher in the control treatment (left panel) compared with the treatment using alarms (right panel). The Kernel modelled density map (Figure 10B), shows intensity of hauls where interaction (i.e., depredation or incidental bycatch) occurred, highlighting the location of incidental bycatch.

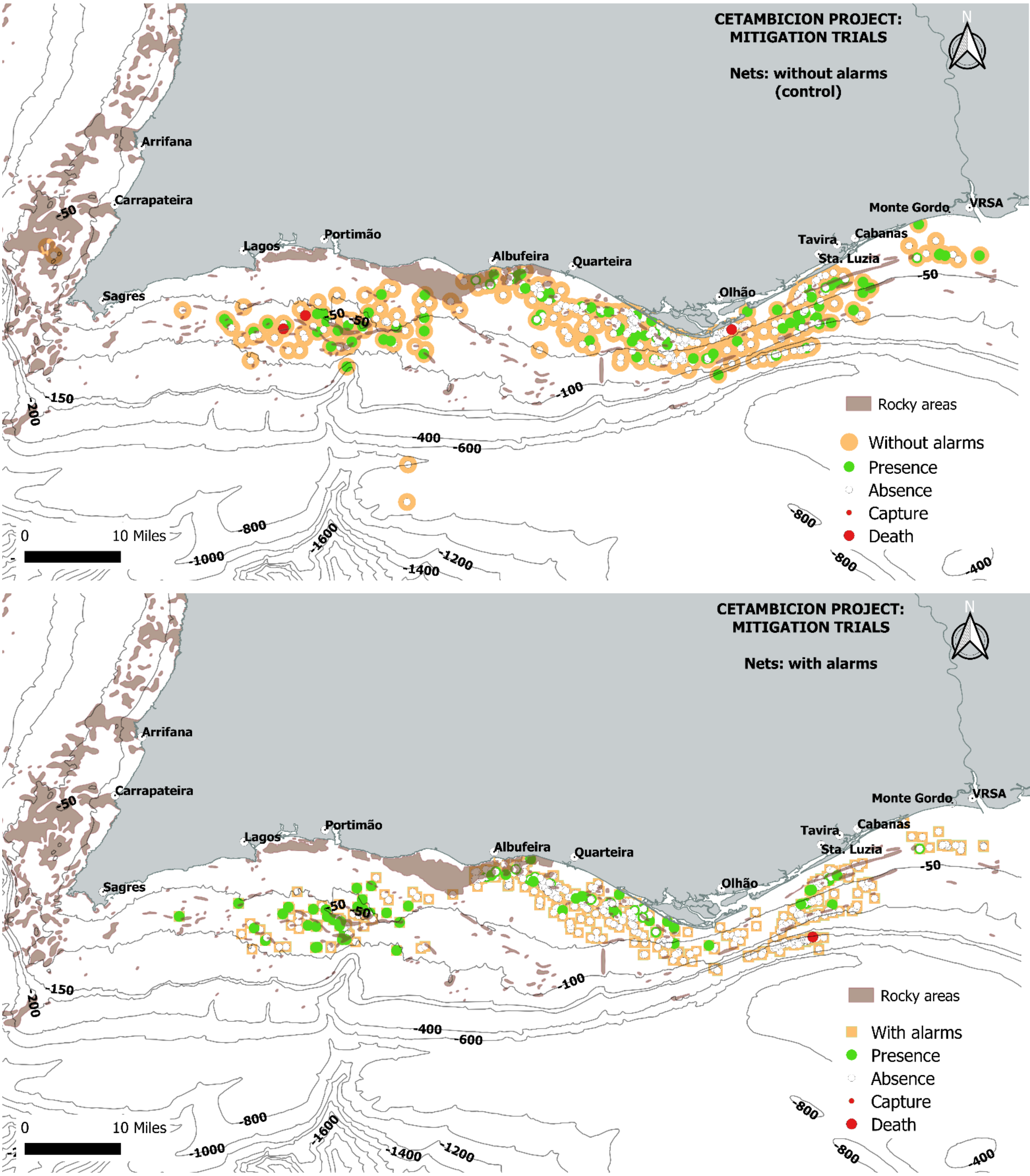



Figure 10A Distribution of fishing hauls in the net trial without (i.e., control treatment; Top) and with (i.e., experimental treatment; Bottom) acoustic devices (or alarms) in set nets. Control hauls (orange circles) and experimental hauls (orange squares); Hauls with absence of interaction (i.e., no depredation nor incidental bycatch; open); Hauls with interaction (i.e., depredation; green); Hauls with observed bycatch of cetaceans (small red circle); Hauls with observed bycatch with mortality (large red circle)

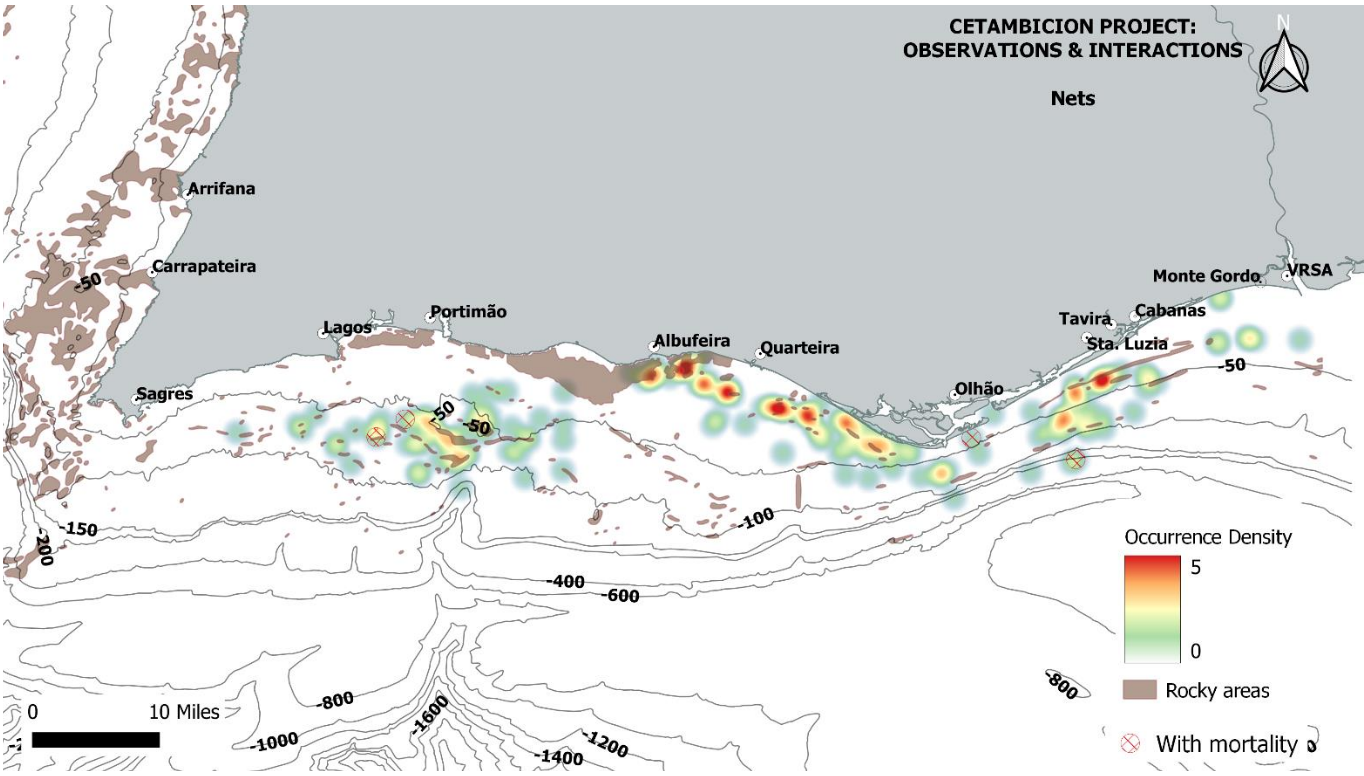



Figure 10B Distribution of all fishing hauls in the monitoring trial (including hauls with and without acoustic devices) in set nets. Kernel modelled density map only of hauls with depredation, and indicating hauls with bycatch with mortality (red grid pattern)

Monitoring effort (number of hauls with or without treatment) in the trials was more or less uniform along the year (Figure 11). Higher seasonal discrepancies are observed in 2019 and 2022 as they were both incomplete years (in 2019 the trials started in June and in 2022 finished in June).

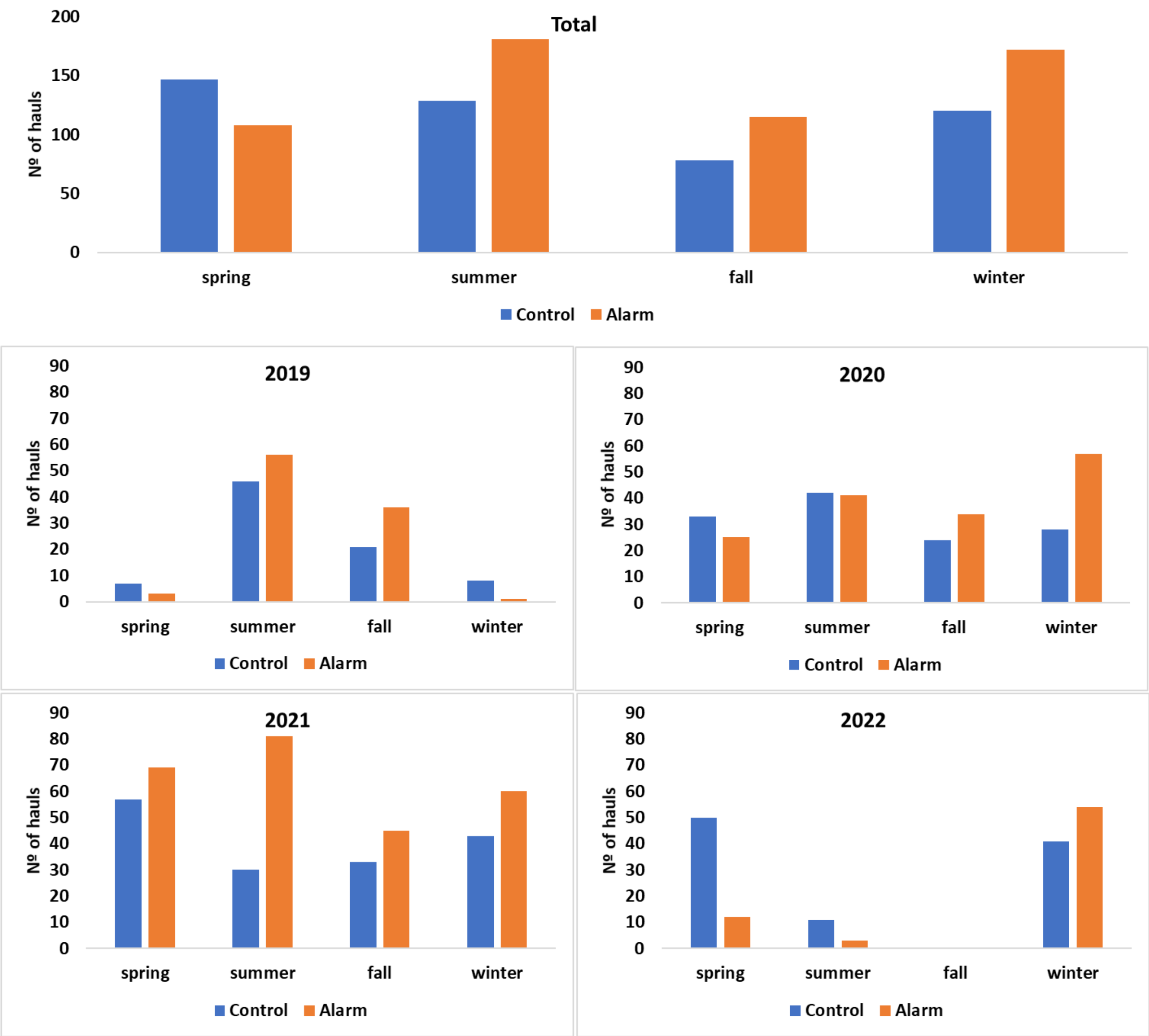



Figure 11 Distribution of monitoring effort in trials with (i.e., experimental treatment; in orange) and without treatment (i.e., control; in blue) of two models of acoustic devices in set nets (gill and trammel nets), per season (per year and overall) over the study duration.

### 3.1.2 Interaction rate

Concerning depredation, for the DDD acoustic device model, the rate in control hauls was of 0.18, while in hauls using acoustic devices was of 0.099. Comparatively, bycatch rates were of 0.005 and 0 for the control and acoustic device treatments, respectively. For the DiD acoustic device model, depredation rates were of 0.36 and 0.18 for control and acoustic device treatments, respectively. For the DiD testing, bycatch rates were of 0.01 and 0.005 for the control and acoustic device treatments, respectively. It is important to refer that hauls with bycatch were rare as only 4 animals were captured and released dead during the trials (Table 2). Three of these animals were captured in control hauls and one animal captured in one haul using acoustic devices (in the DiD testing). However, it was noted by scientific observers onboard in the haul using DiDs where the bycatch of one cetacean occurred, that the device nearest to the animal was not functional.

Modelling results indicated that, for both types of acoustic devices (DDD or DiD), the differences in the presence of interactions per haul are statistically significant between hauls with and without devices (Table 4). Hauls with **acoustic devices reduces significantly the occurrence of interaction between dolphins and set nets (gill and trammel nets).**

Table 4 Coefficients from GAMLSS Model for interaction of cetaceans and set nets, in the trial with and without either of two models of acoustic devices (DDD and DiD). Here the intercept represents the rate of net interaction for the control (without alarm) condition. Significant terms are highlighted in bold.

| **Alarm Model** | DDD | | | | DiD | | | |
|---|---|---|---|---|---|---|---|---|
| **Term** | Estimate | SE | Z | p | Estimate | SE | Z | p |
| *Intercept* | -0,709 | 0.099 | -7,161 | 2,69E-12 | -0,567 | 0,1271 | -4,46 | 1,10E-05 |
| Alarm-active | 0,8505 | 0,2578 | 3,3 | **0,00103** | 0,9547 | 0,2456 | 3,887 | **0,00012** |

### 3.1.3 Factors affecting the interaction.

Table 5 present results from the GAMLSS applied to nets and particularly the selected models for both acoustic devices tested. Results indicated that for the DDD acoustic device, the interactions between cetaceans and set nets are significant and positively related to year, and negatively related to depth, soaking time, total CPUE, CPUE of red mullet and the vessel performing the trial. The final model (chosen based on the lowest AIC) explained 18.6 % of the deviance. In the case of the DiD device, the interactions between cetaceans and set nets were significant and negatively related to CPUE of hake, and positively related to the monitoring scheme performed (meaning that they were higher with vessel crew observers), with an explained deviance of the final model of 7.5 %.

Table 5 Results of the final GAMLSS models for factors explaining the interaction of cetaceans with set nets, in the trial with and without either of two models of acoustic devices (DDD and DiD). Akaike Information Criterion (AIC) and Simulation-based calibration (SBC) for best models are presented. Significance codes: 0.05; * 0.01; ** 0.001; *** 0

| **Model** | **Significant Variables** | **Explained Variance (%)** | **AIC** | **SBC** |
|---|---|---|---|---|
| *Nets – DDD*<br>Interaction_cetaceans ~ latdec + depth_m + soaking + CPUE + cpue_stripedredmullet + year + factor(vessel) | depth**, soaking **, CPUE**, CPUE_Red_mullet***, year *, vessel*** | 18.6 | 328.1 | 379.3 |
| *Nets – DiD*<br>Interaction_cetaceans ~ latdec + CPUE + CPUE_hake + factor(observer_scheme) | CPUE_Hake*, Observer scheme * | 7.5 | 121.9 | 137.1 |

## 3.1.4 Probability of interaction

For the DDD acoustic device model trials, interactions occurred on average in about 10 % of hauls using the device and in 20% of hauls not using the device (controls), while for the DiD acoustic device trials, interactions occurred on average in about 18 % of hauls using the acoustic device and in 37 % of controls. The binomial testing considering presence-absence of cetacean interaction (mostly bottlenose depredation of the nets as described above), showed that there were significantly lower rates of dolphin-set net interactions in hauls using either model of acoustic devices: rate reductions were 48 % for the DDD and 50 % for the DiD acoustic device models (Table 6).

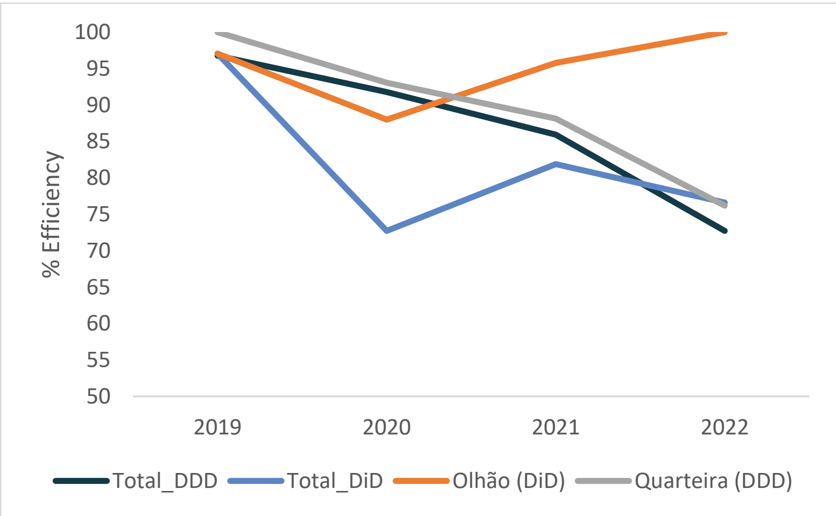
Table 6 Results from binomial test testing probability of interaction of cetaceans with set nets, with the trial with and without either of two models of acoustic devices (DDD and DiD). In parenthesis are the 95 % Confidence intervals (CI)

| **Model** | With alarms | Without alarms |
|---|---|---|
| *Nets – DDD* | Average (95 % CI) | |
| Probability of interaction (%) | 9.6 (6.7 - 13.3) | 20 (14.6 - 26.4) |
| *Nets – DiD* | | |
| Probability of interaction (%) | 18.2 (13.2 - 24.1) | 36.6 (29 - 44.8) |

### 3.1.5 Acoustic device efficiency

Efficiency of both acoustic device models in reducing negative interactions (depredation or bycatch with mortality) during the trial period decreased over time (Figure 12 top panel). Over the three years of trial, efficiency decreased from 100% to 75% on average, except for Olhao (DiD) one of the ports using the acoustic devices with the longer testing period, where efficiency overall did not decrease despite some variations throughout the study period. In Quarteira (DDD), another port with longer testing period, the efficiency follows the same pattern of all vessels using this model.

As for seasonal variation, general efficiency of acoustic devices was higher in the spring in the case of DiD model, and in the summer and fall for DDD model (Figure 12 bottom panel). Overall, seasonally, mean efficiency per season is above 70%.



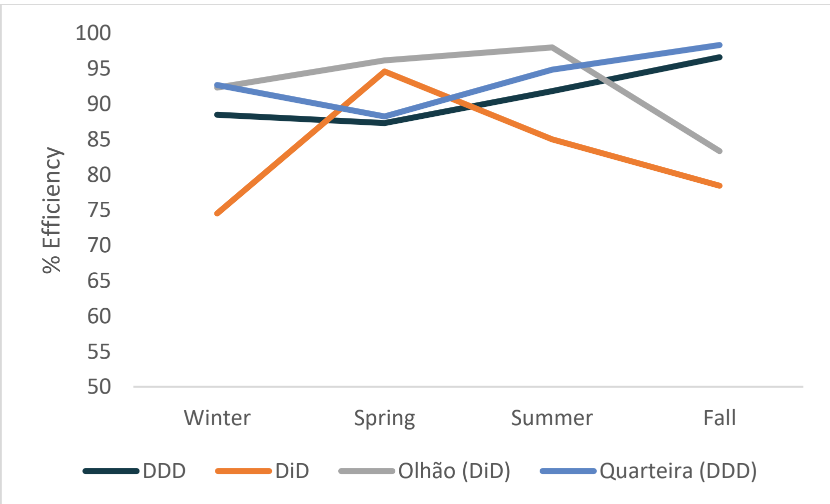




Figure 12 Acoustic device efficiency over the study for the two models of acoustic devices in set nets (gill and trammel nets) and for the two ports with longer period of testing (top panel) and seasonal efficiency (bottom panel).

### 3.1.6 Catch per Unit Effort (CPUE)

When comparing total CPUE between hauls with and without acoustic devices, either for DDD or DiD (Figure 13 left and centre panels, respectively), no significant differences are found. However, when comparing CPUE between net hauls with and without occurrence of depredation (Figure 13 right panel), regardless of the haul being of treatment or control, CPUE was significantly lower in hauls with depredation.

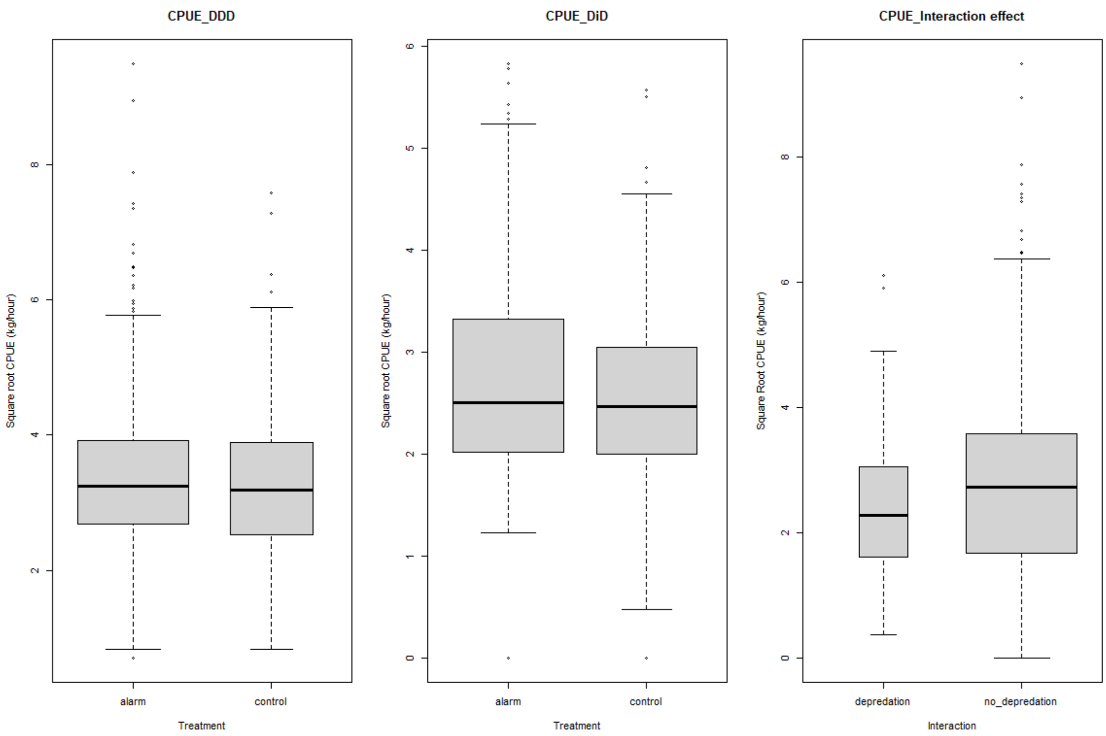



Figure 13 Catch per unit effort for the different treatments (control or acoustic device) for the two different acoustic device models in the trial with set nets (gill and trammel nets) (left and center panels) and for hauls with depredation and no depredation (right panel). Square-root transformed CPUE; the median, first and third quartile, range of observed values and outliers are shown.

## 3.2 Purse seine nets

### 3.2.1 Monitoring effort in trials

From June 2020 to October 2021 a total of 461 fishing days/trips with 518 hauls with purse seine nets were monitored (Figure 14A). As shown in Figure 14A, effort for both treatments (control- left panel or using acoustic device- right panel) was dispersed along the same areas. Furthermore, cetacean presence during fishing operations was observed in both treatments. However, bycatch occurred only during the control treatment (left panel).

The Kernel density map shown in Figure 14B, models the density of hauls with cetacean presence during fishing operations. Areas of increased presence of common dolphins during purse seine fishing activities are coastal, especially off Sagres and also to the west of Quarteira.

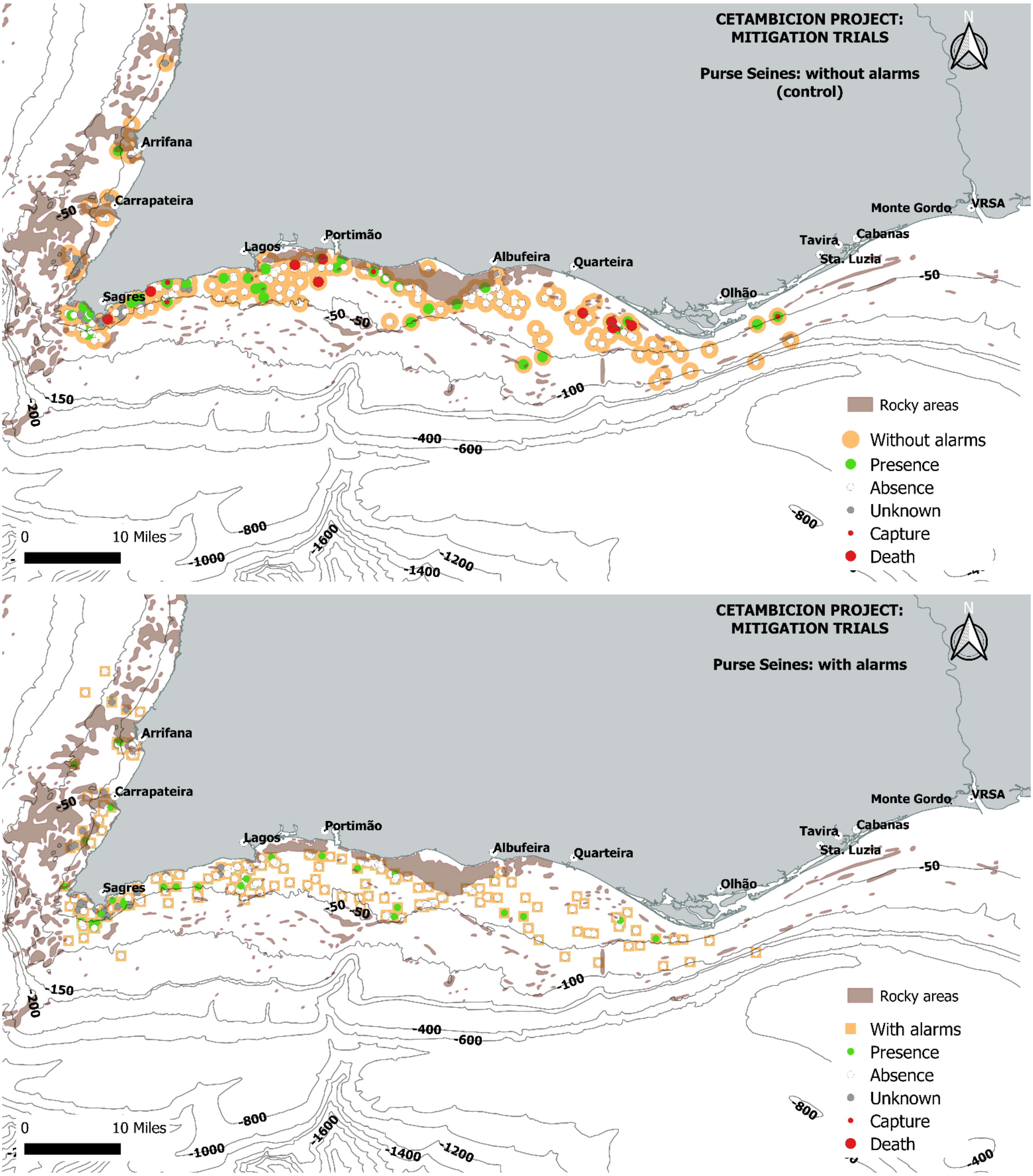



Figure 14A Distribution of fishing hauls in the purse seine nets trial without (Control; Top) and with (Experimental; Bottom) acoustic devices (or alarms). Control hauls (orange circles) and hauls with device (orange squares): Hauls with absence of observed cetaceans during the operations (open); Hauls with presence of cetaceans during fishing operations (green); Hauls with observed bycatch of cetaceans (small red circle); Hauls with observed bycatch (large red circle); Unknown refer to hauls with absence of information.

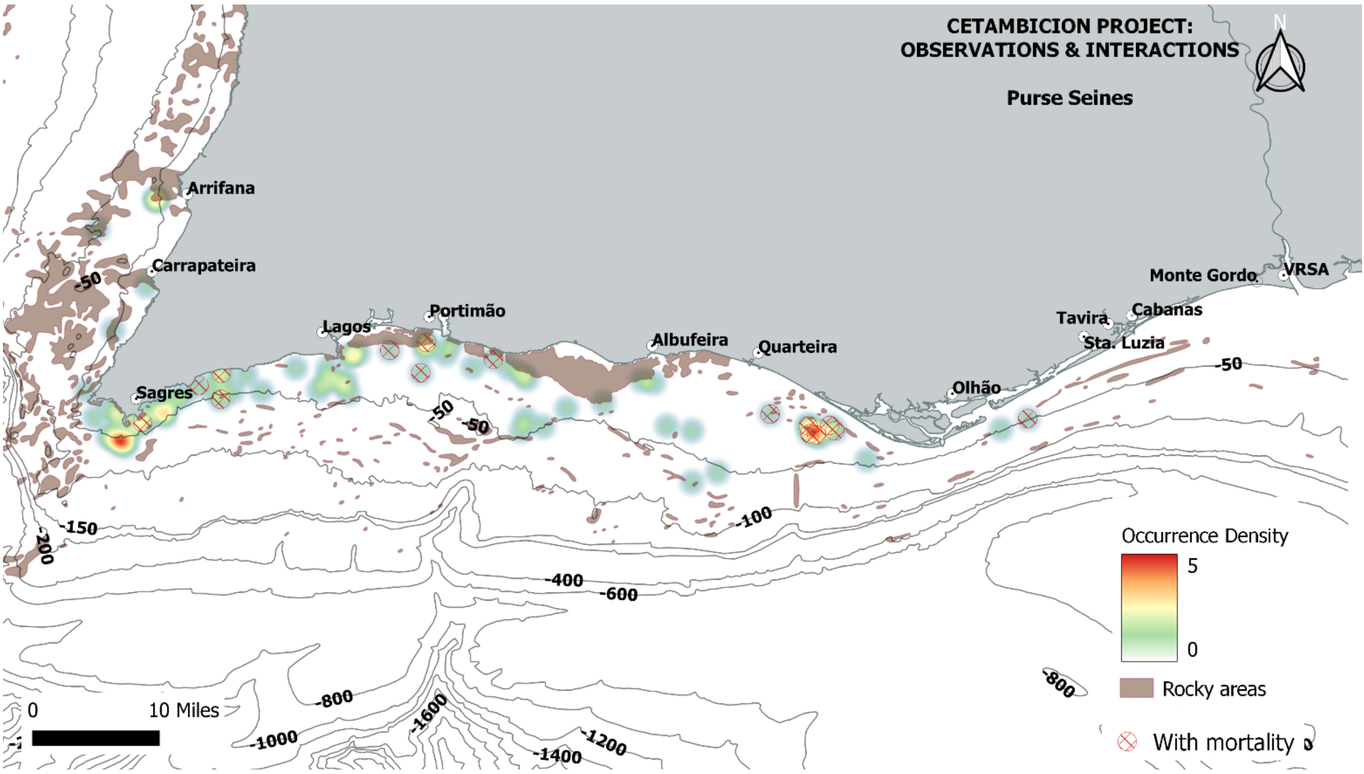



Figure 14B Distribution of all fishing hauls in the monitoring trial (including hauls with and without acoustic devices) in purse seine nets: Kernel density map with hauls with presence of cetaceans during fishing operations, and indicating hauls with bycatch with mortality (red grid pattern)

Tables 7 and 8 show the total effort for both treatments (hauls control *vs* hauls acoustic device), where 268 hauls were controls and 250 hauls used acoustic devices. Incidental capture was observed only in control hauls when no acoustic device was used, and all animals bycaught were common dolphins. From the 38 incidental captures, 29 animals were released alive and 9 did not survive. Presence of cetaceans (common dolphin) during fishing operations occurred in 18 % of control hauls and 14 % of treatment hauls. Bycatch occurred in about 6 % of control hauls. At-sea observer (SO) effort was 8 % in 2020 and 4 % in 2021 of all trips monitored, the remaining monitored by vessel crew observers (VO) (Table 8).

Table 7 Total monitoring effort in trials acoustic device (experimental treatment) and without (control treatment) in purse seine nets: N° trips; N° hauls, Average depth, and respective standard deviation; Cetacean interaction (bycatch or presence only)

| | Treatment | |
|---|---|---|
| | Control (no acoustic devices) | Experimental (with acoustic devices) |
| ***Model DDD*** | | |
| No. of trips | 228 | 233 |
| No. of hauls | 268 | 250 |
| Depth (m) | 31.7 ± 11.9 | 32.2 ± 12.0 |
| No of hauls with cetacean bycatch | 15 | 0 |
| No cetaceans bycaught | 38 (9 dead) | 0 |
| No of hauls with cetacean presence during fishing operations | 47 | 34 |

Table 8 Effort by year and different monitoring method (at-sea observers-SO and vessel crew logbooks-VO); cetacean bycatch and mortality

| | Year | Monitoring scheme | Trips | Hauls | Hauls with capture | Cetaceans captured | Cetaceans dead | % Survival | Cetacean species |
|---|---|---|---|---|---|---|---|---|---|
| **Control** | **2020** | SO | 9 | 17 | 1 | 1 | 1 | 0 | *Delphinus delphis* |
| | | VO | 92 | 110 | 5 | 21 | 3 | 86 | |
| | **2021** | SO | 11 | 12 | 0 | 0 | 0 | | |
| | | VO | 116 | 129 | 9 | 16 | 5 | 73 | |
| **Acoustic device** | **2020** | SO | 7 | 11 | 0 | 0 | 0 | | |
| | | VO | 66 | 66 | 0 | 0 | 0 | | |
| | **2021** | SO | 2 | 3 | 0 | 0 | 0 | | |
| | | VO | 158 | 170 | 0 | 0 | 0 | | |
| **Control** | **2 yrs** | **All observation schemes** | **228** | **268** | **15** | **38** | **9** | **78** | |
| **Acoustic device** | | | **233** | **250** | **0** | **0** | **0** | | |

Table 9 presents the number of vessels per fishing port contributing to the trials, where it is once more noted the increased effort during CetAMBICion project, with a higher number of participating vessels.

Table 9 Number of vessels (purse seiners) per fishing port per project contributing for the trial with purse seine nets.

| **Port** | **N° vessels 2020 (iNOVPESCA)** | **N° vessels 2021 (CetAmBICion)** |
|---|---|---|
| Olhão | 1 | 4 |
| Portimão | 2 | 3 |
| Sagres | 2 | 2 |
| **Total** | **5** | **9** |

Monitoring effort (number of hauls with and without alarms) in the trials was uniform along the years, with a tendency to increase the use of the acoustic devices in the second year (Figure 15).

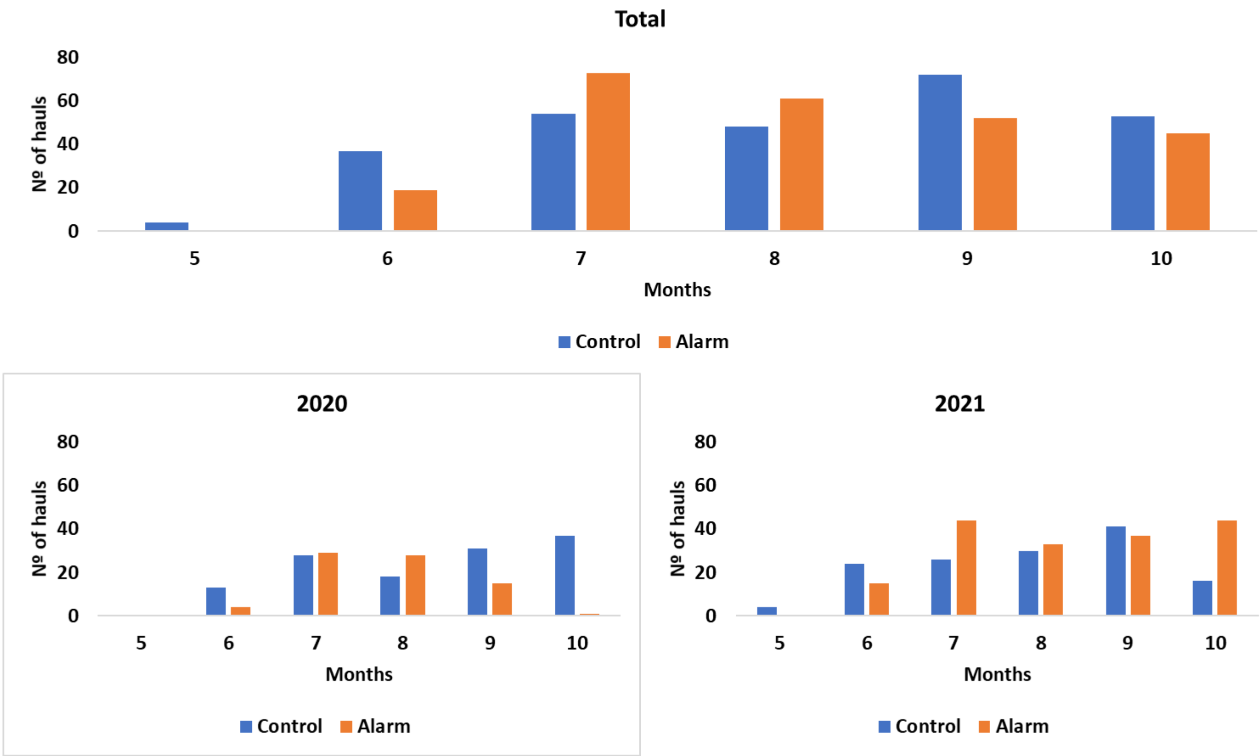



Figure 15 Distribution of monitoring effort in trials with (i.e., experimental treatment; in orange) and without treatment (i.e. control treatment; in blue) of acoustic devices in purse seine nets, per month for all years, both year joined (Total) and separately by year over the study duration.

### 3.2.2 Interaction rate

Bycatch rates were of 0.056 and 0 for the control and acoustic device treatments, respectively. Modelling and statistical tests on the data indicated for acoustic devices DDD in purse seine nets, that the presence of interactions in hauls with and without devices differs and is statistically significant (Table 10). **Hauls with acoustic devices had significantly lower occurrence of interaction between dolphins and purse seine nets.**

Table 10 Coefficients from GAMLSS Model for interaction of cetaceans with purse seine nets, in the trial with and without acoustic devices. Here the intercept represents the rate of interaction for the control treatment (without alarm). Significant terms are highlighted in bold.

| **Alarm Model** | DDD - Purse seining | | | |
|---|---|---|---|---|
| **Term** | Estimate | SE | Z | p |
| *Intercept* | -36,08 | 4430,97 | -0,008 | 6,00E-03 |
| Alarm-active | 8,77 | 738,5 | 0,012 | **0,009** |

### 3.2.3 Factors affecting the interaction.

It was not possible to apply the model to the purse seining dataset due to the limitations on the dataset (e.g., several parameters were not available as they were not noted down by the vessel crew observers).

### 3.2.4 Probability of interaction

The binomial analysis of the presence-absence of cetacean interaction in purse seine fishery, showed that hauls with acoustic devices had a significant lower rate of bycatch. For the DDD acoustic device model trial in purse seining, interactions occurred on average in about 0 % of hauls using the device and in 6% of hauls not using the device (controls) (Table 11).

Table 11 Results from binomial test testing probability of interaction of cetaceans with purse seine nets, in the trial with and without acoustic devices. In parenthesis are the 95 % Confidence intervals (CI)

| **Model** | With alarms | Without alarms |
|---|---|---|
| *Purse seining* | Average (95 % CI) | |
| Probability of interaction (%) | 0 (0 - 1.5) | 5.6 (3.2 - 9.1) |

### 3.2.5 Capture per Unit Effort of target species (Sardine) of purse seine fishery

Considering all purse seine net hauls monitored in the trial, CPUE of the target species of the métier purse seine, sardine *Sardina pilchardus*, did not differ significantly between hauls with (experimental treatment) and without acoustic devices (control treatment) (Figure 16 left panel). As for the subset of hauls monitored that had presence of cetaceans during fishing operations, CPUE of sardine is higher in treatment (with acoustic device) than in control, but this difference was also not significant (Figure 16 right panel).

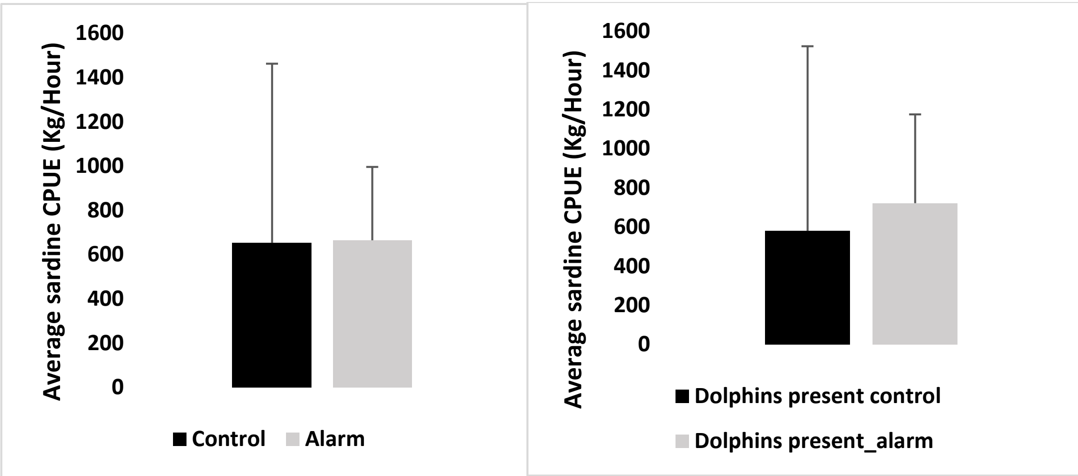



Figure 16 Catch per unit effort (mean and standard deviation) of target species (sardine *Sardina pilchardus*) of the purse seine fishery, grouped: considering all purse seine net hauls, per treatment (with or without acoustic device) (left panel); and considering only purse seine net hauls with presence of cetaceans during fishing operations, per treatment (with or without acoustic device) (right panel).

# 4 Conclusions and recommendations

The mitigation trials with the two models of acoustic deterrent devices in set nets (gill and trammel nets) and purse seine nets provided important information about the efficiency of these acoustic deterrent devices as mitigation tools. The use of these models of deterrents, at each specific fishery reduced the negative interactions between cetaceans and the fishing gear (i.e., depredation and bycatch in set nets, and bycatch in purse seine nets).

In set nets (gill and trammel nets), this long term (three year) study showed that bycatch rate (depredation or bycatch with mortality) was significantly lower in hauls with acoustic devices than in hauls without. Moreover, for the 3 years for set nets (gill and trammel nets), for both models tested (DiD or DDD), the interaction rate (i.e., depredation or bycatch) was about 50 % lower with the use of the alarms for all metiers tested. Also, a gradual but slow habituation of the bottlenose dolphins to the equipment was observed throughout the study period.

In purse seine nets, the study covered two consecutive years, during the period with increased fishing effort targeting sardine, known as the favourite prey of the common dolphin (Silva, 1999; Marçalo et al., 2018) and the season where most common dolphin incidental captures occur (Marçalo et al., 2015; Dias et al., 2022). In this fishery, incidental did not occur in any of the hauls using the acoustic device.

Despite this effect, for both fisheries, cetaceans were observed in the vicinity of the vessels during fishing operations, in hauls for both treatments (control, i.e. not using acoustic device; and experimental, i.e. using acoustic device), but the present study did not collect and record that type of data in a systematic manner as vessel crew observers are working fishers and when busy may focus only on the negative interaction (bycatch or depredation). Furthermore, we must take into consideration that these are pilot studies conducted in a small number of vessels.

Fishery-cetacean interactions worldwide are specific and depend on several variables such as the cetacean species, fishery operation, area, and sea conditions. Therefore, mitigation measures that are successful in some areas may not be necessarily appropriate for others, which makes mitigation of these conflicts a continuous challenge. Mitigation experiments frequently lack funding to be continued in time to provide more robust conclusions regarding habituation of the animals to the devices or insights of their effects on the well-being of the animals (e.g., indirect interactions such as habitat exclusion; or unintended harmful effects of the sound produced by the acoustic devices that could be detrimental to the protected species). In this respect, the CetAMBICion project allowed the extension of testing in time, so the conclusions are thus more robust. However, the explained variance for the models in all fishing gears and devices tested was rather low, which reiterates the need to extend these mitigation trials.

Furthermore, mitigation with deterrent devices should always be considered with caution and not as the unique solution, since it may be financially challenging to be applied in small scale fisheries vessels, and also because the large-scale use of acoustic devices can contribute to added noise to the environment. The use of DiD seems to be a good solution as they emit the sound only when dolphins approach the fishing gear, thus limiting noise pollution or increased habituation of the animals.

There is not a simple way to mitigate conflicts between fisheries and cetaceans. And there seems to be some agreement that mitigation should be an inclusive process involving all stakeholders (scientists, fishers, governmental entities, and NGO ´ s) to discuss strategies. These strategies should rely on changes of behaviours when managing the ocean, e.g., from reduced fishing effort to increased control. Similarly, adoption of good practices by fishers should be voluntary as governmental impositions are not necessarily so well accepted. For instance, some operational or mitigation measures to reduce negative interactions with cetaceans must be practical and must not consume time and/or affect the regular fishing operation so that fishers can easily adopt them.

Along CetAMBICion, several workshops with stakeholders took place, where the results of the mitigation trials were presented, and fishers' knowledge and experience added to the discussions. Exercises during these meetings provided a list of suggestions to the fishing sector to reduce conflicts between fisheries and cetaceans.

The following table contains mitigation suggestions, other than the use of acoustic deterrent devices, to reduce interactions of cetaceans with set nets (gill and trammel nets) and purse seine net fisheries. This was the product of the several workshops that took place within the scope of the iNOVPESCA and CetAMBICion projects, with the attendance of several stakeholders and a special input from the fishing community (fishers and fishing associations´ representatives).

| Fishery | Mitigation measures | |
|---|---|---|
| | **Operation measures** | **Non-operational measures** |
| **Purse seine nets** | **At sea communication**<br>**Before net shooting**<br>The skippers must communicate with other skippers the presence of cetaceans in the fishing grounds and avoid hauling the net in those areas.<br>In daytime net hauls, crew members must alert the skipper to the presence of cetaceans. Net haul should be aborted if cetaceans are in the vicinity.<br>**After net shooting**<br>In case of cetaceans incidentally captured, the skipper must be informed by crew members and actions taken to prioritize the release of the animal.<br>**Releasing a cetacean from the net**<br>Avoid putting a rope around the peduncle lifting the animal with the crane, as this maneuver causes physical damage and may lead to a slow and painful dead. Use a stretcher or other technique that is favorable to the removal of the animal without injury. | **Use of DDD**<br>Results show that the use of DDDs in purse seine reduce the incidental capture of cetaceans. It is suggested that 1 DDD goes into the water at the beginning of net setting and kept submerged up until the rings are lifted. |
| **Set nets** | **At sea comunication**<br>**Before net shooting**<br>The skippers must communicate with other skippers the presence of cetaceans in the fishing grounds and avoid haulting the net in those areas.<br>**After net shooting**<br>In case a cetacean is observed bycaught and still alive, the hauling device must stop, and the animal released with care.<br>**Avoiding interaction increase**<br>Follow legislation considering net dimensions and soaking times for each metier. | Results show that the use of DDD and DiD in set nets (gill and trammel nets) reduce interaction rate (i.e., depredation rate). However, it is suggested, that fishers should avoid long (overnight) soaking times of nets with deterrent devices to reduce probability of cetacean habituation and noise pollution.<br>**Important: The use of acoustic devices is not an absolute solution to eliminate interactions between fisheries and cetaceans.** |

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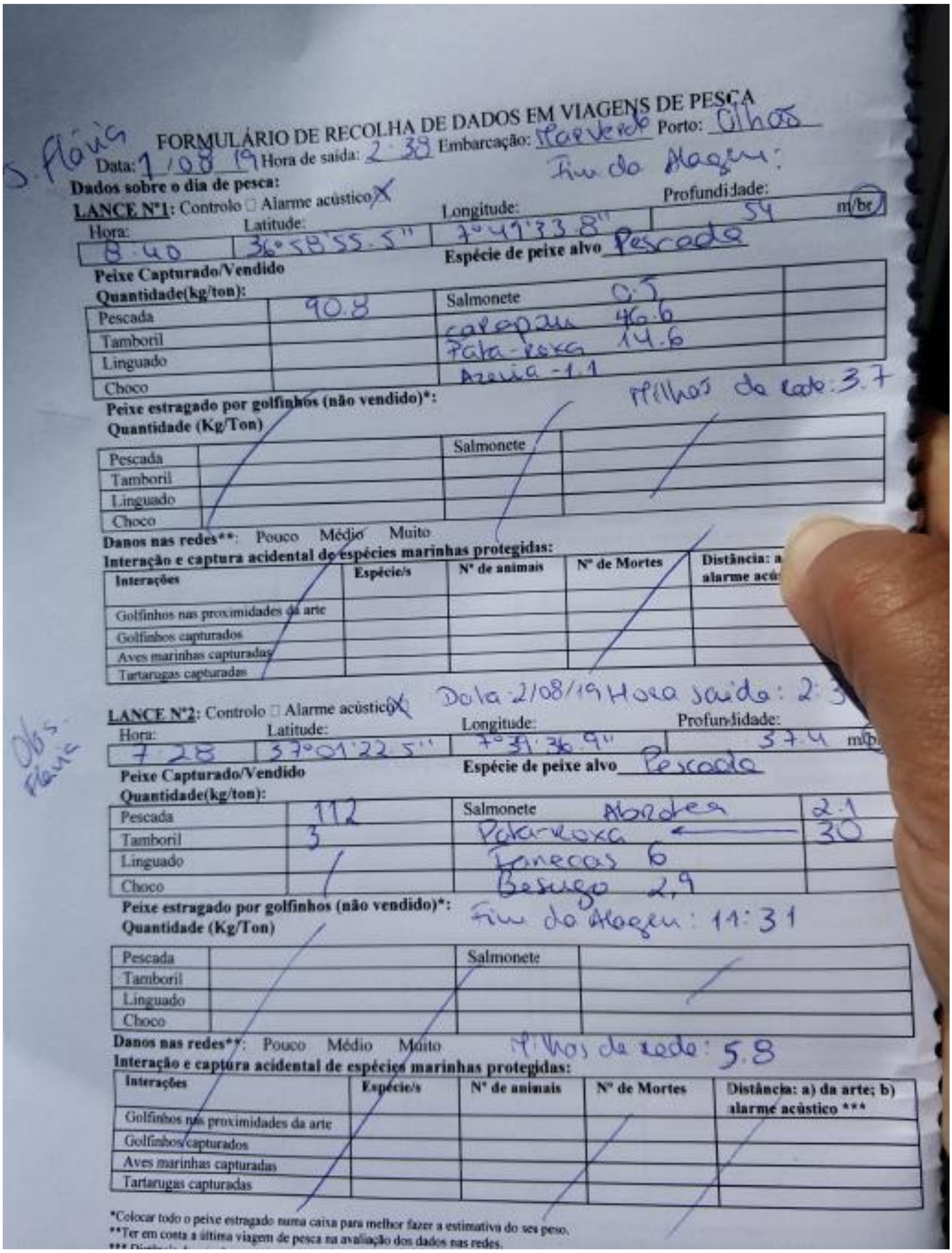
# 6 Annexes

Annex 1 – Example of logbook page



FORMULÁRIO DE RECOLHA DE DADOS EM VIAGENS DE PESCA

S. Flávia

Data: 1/08/19 Hora de saída: 2:38 Embarcação: Mar Verde Porto: Olhão

Fim do Alagem:

**Dados sobre o dia de pesca:**

**LANCE Nº1:** Controlo ☐ Alarme acústico X

| Hora: | Latitude: | Longitude: | Profundidade: |
|---|---|---|---|
| 8:40 | 36°58'55.5" | 7°47'33.8" | 54 m/br |

**Espécie de peixe alvo** Pescada

**Peixe Capturado/Vendido**
**Quantidade(kg/ton):**

| | | | | |
|---|---|---|---|---|
| Pescada | 90.8 | Salmonete | 0.5 | |
| Tamboril | | Carapau | 46.6 | |
| Linguado | | Pata-roxa | 14.6 | |
| Choco | | Azevia - 1.1 | | |

Milhos de rede: 3.7

**Peixe estragado por golfinhos (não vendido)*:**
**Quantidade (Kg/Ton)**

| | | | |
|---|---|---|---|
| Pescada | | Salmonete | |
| Tamboril | | | |
| Linguado | | | |
| Choco | | | |

**Danos nas redes**:** Pouco Médio Muito

**Interação e captura acidental de espécies marinhas protegidas:**

| Interações | Espécie/s | Nº de animais | Nº de Mortes | Distância: a) alarme acú |
|---|---|---|---|---|
| Golfinhos nas proximidades da arte | | | | |
| Golfinhos capturados | | | | |
| Aves marinhas capturadas | | | | |
| Tartarugas capturadas | | | | |

Data 2/08/19 Hora saída: 2:3

**LANCE Nº2:** Controlo ☐ Alarme acústico X

Obs. Flávia

| Hora: | Latitude: | Longitude: | Profundidade: |
|---|---|---|---|
| 7:28 | 37°01'22.5" | 7°39'36.9" | 37.4 m/br |

**Espécie de peixe alvo** Pescada

**Peixe Capturado/Vendido**
**Quantidade(kg/ton):**

| | | | |
|---|---|---|---|
| Pescada | 112 | Salmonete Abrótea | 2.1 |
| Tamboril | 3 | Pata-roxa ← | 30 |
| Linguado | | Fanecas 6 | |
| Choco | | Besugo 2.9 | |

**Peixe estragado por golfinhos (não vendido)*:** Fim do Alagem: 11:31
**Quantidade (Kg/Ton)**

| | | | |
|---|---|---|---|
| Pescada | | Salmonete | |
| Tamboril | | | |
| Linguado | | | |
| Choco | | | |

**Danos nas redes**:** Pouco Médio Muito Milhos de rede: 5.8

**Interação e captura acidental de espécies marinhas protegidas:**

| Interações | Espécie/s | Nº de animais | Nº de Mortes | Distância: a) da arte; b) alarme acústico *** |
|---|---|---|---|---|
| Golfinhos nas proximidades da arte | | | | |
| Golfinhos capturados | | | | |
| Aves marinhas capturadas | | | | |
| Tartarugas capturadas | | | | |

*Colocar todo o peixe estragado numa caixa para melhor fazer a estimativa do seu peso.
**Ter em conta a última viagem de pesca na avaliação dos dados nas redes.

Annex 2

**stm**
INDUSTRIAL ELECTRONICS

37135 VERONA – Italy – Via Morgagni 14
Tel. +39 045 585700 – Fax +39 045 585730
E-mail : info@stm-products.com

To whom it concern

## STATEMENT/DECLARATION

"We, **STM Products s.r.l.** Via Morgagni, 14 – 37135 Verona, ITALY, declare that our Dolphin Dissuasive Devices, models DDD 03X and DiD 01 do not harm to dolphins, since the models are authorized by the same organizations that protect the marine environment. Dolphins use "clicks" up to 200 dB to locate their prey, while the maximum power of our pingers reaches 155-165 dB, which means about 5,000 times less powerful than the signals emitted by dolphins. Furthermore the fish isn't affected by ultrasonic emissions"

In faith,

**STM PRODUCTS**

(Luca Tommasoli)

ITALY VIA MORGAGNI, 14, 37135 VERONA STM PRODUCTS

VERONA, 17th of March, 2020

Capitale sociale L. 99.000.000 - Reg. Soc. VR 28830 - Fac 34022 - C.C.I.A.A. VR 219251 - P. IVA IT 02137800237

Annex 3