Fisheries Research 278 (2024) 107100

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

# Evaluating dolphin interactions with bottom-set net fisheries off Southern Iberian Atlantic waters

Ana Marçalo *, Vighnesh Samel, Flávia Carvalho [1], Magda Frade, Karim Erzini, Jorge MS Gonçalves

*Centre of Marine Sciences (CCMAR), University of the Algarve, Campus de Gambelas, FCT Ed. 7, Faro 8005-139, Portugal*

ARTICLE INFO

Handled by: A.E. Punt

*Keywords:*
Bycatch
Bottom-set nets
Depredation
Dolphins
Fisheries interactions
Fisheries métiers

ABSTRACT

The present study, covering 2018–2022, evaluated the cetacean interactions with a bottom-set net fishery along the mainland Portuguese Southern coast (Algarve), estimating bycatch, depredation, gear damage and net length influence on Landing per Unit Effort (LPUE). The fishery employed various métiers (gillnets - mesh sizes: < 60, 60–75, 80 and 220 mm; trammel nets - 120 inner and 640 mm outer panels). Observations from 655 hauls revealed depredation by bottlenose dolphins in 17.7 % of hauls, while bycatch (isolated events of 4 bottlenose dolphins and one common dolphin) occurred in < 1 %. Depredation typically results in heavy damage to the net and occurs throughout the year, with elevated rates observed during the spring and winter months. Depredation rates varied among métiers, being higher in gears targeting red mullet and hake. The impact of depredation on LPUE varied based on net length and the targeted fish species. However, when comparing LPUE in hauls without depredation, there was no significant influence on the total and hake LPUE for nets shorter or longer than 6 km ($p > 0.05$). Interestingly, in hauls targeting red mullets without depredation, nets shorter than 6 km had a significantly higher LPUE ($p < 0.01$) compared to nets 6 km or longer, suggesting that longer nets increase fishing effort due to prolonged soaking times and a higher likelihood of depredation.

## 1. Introduction

Fisheries bycatch, defined as the accidental capture of non-target species, is considered the main threat to marine mammal populations globally, with several thousand cetaceans killed annually (Read et al., 2006; Schipper et al., 2008; Brownell et al., 2019). These encounters can be in the form of entanglement or entrapment in fishing gear resulting in major injuries and high pre/post release mortality (Read, 2008). The vulnerability of these populations to this threat is explained by their low potential population growth rates and late maturity (Wade et al., 2012; Peltier et al., 2016; Hall et al., 2017). All gears are responsible for cetacean bycatch but at different levels (Wade et al., 2021; Alexandre et al., 2022). Globally, gillnets (all types including drift, set, anchored and trammel) are responsible for a higher level of mortality (Wade et al., 2021). This threat primarily impacts coastal areas and species but can also impact other species living offshore. Moreover, these interactions, which have been occurring for centuries, have increased in frequency and intensity in recent decades in some regions (Peltier et al., 2016), and while bycatch occurs primarily in coastal fisheries (Cruz et al., 2018), bycatch in more near shore fisheries, which include small size vessels (<9 m), can be significant and should not be neglected as fleets of this segment make up a large part of each countrýs fleet (Lewison et al., 2014; Cruz et al., 2018; Alexandre et al., 2022).

Furthermore, the potential negative economic consequences of interactions with cetaceans in fisheries make depredation the interaction of greatest concern to the fishers (Reeves et al., 2013). Depredation has been defined by Bearzi and Reeves (2022) as the removal or damage of marketable organisms as well as bait from fishing gear. Also, in order to remove fish trapped in the net, the dolphins frequently tear large holes in the net (Goetz et al., 2014). They may also twist the net as they attempt to remove the prey and may become entangled in it (Brotons et al., 2008a; Bearzi et al., 2011; Goetz, 2015). Even if damaged, fishers will continue to use the nets, but their effectiveness may be reduced. These facts exacerbate the anger of fishers who may, in some situations, retaliate (Bearzi et al., 2008a). While bycatch represents a species conservation issue, in addition, depredation represents an economic

* Corresponding author.
*E-mail address:* amarcalo@ualg.pt (A. Marçalo).

[1] Present address - Sociedade Portuguesa para o Estudo das Aves (SPEA), Av. Almirante Gago Coutinho, 46ª, 1700–031 Lisboa, Portugal

https://doi.org/10.1016/j.fishres.2024.107100
Received 27 December 2023; Received in revised form 20 June 2024; Accepted 20 June 2024
Available online 24 June 2024

concern to fishers (Reeves et al., 2013; Lauriano et al., 2009), as well as an increased danger to the animal if it turns into a bycatch (Brotons et al., 2008a).

Depredation has been usually associated with bottlenose dolphins in coastal areas (Lauriano et al., 2004, 2009; Brotons et al., 2008a, 2008b; Reeves et al., 2013; Alexandre et al., 2022; Baez et al., 2023). This is not only due to their opportunistic feeding behaviours attributable to their high cognitive function, together with an advanced ability to solve problems associated with generating new foraging opportunities (Blanco et al., 2001; Lauriano et al., 2009) but also their coastal distribution (Lauriano et al., 2009, Baez et. al., 2023), which overlaps with artisanal fleet fishing areas (Goetz et al., 2014, 2015; Alexandre et al., 2022; Baez et al., 2023). Bottlenose dolphins are a species with high dietary diversity (Goetz et al., 2014; Giménez et al., 2017), although regionally and especially in Southern European Atlantic or Mediterranean waters, they have preferences for certain highly commercial species such as hake, *Merluccius* (Santos et al., 2007; Blanco et al., 2001; Giménez et al., 2017) and striped red mullet, *Mullus surmuletus* (Pardalou and Tsikliras, 2020), usually targeted by bottom-set net fisheries. Thus, individuals have learned that gillnet and trammel net catches represent an easier and readily available food resource for them (Pennino et al., 2014, Bearzi and Reeves, 2022).

Many species of cetaceans can be found in the waters of the Iberian Atlantic (Vingada and Eira, 2018). The most abundant coastal species are the short-beaked common dolphin *(Delphinus delphis)* and the bottlenose dolphin *(Tursiops truncatus)* (Goetz et al., 2014; Alexandre et al., 2022). Bottom-set nets (trammel and gill nets) are considered the gear most prone to cetacean interactions (bycatch and depredation) off the mainland Portuguese coast (Vingada and Eira, 2018; Alexandre et al., 2022). Along the southern coast, commonly referred to as the Algarve, while bottlenose dolphin density per square kilometer mirrors that of the western coast (Gilles et al., 2023), apprehensions regarding depredation in bottom set nets are heightened. This is attributed to the narrower continental platform in the southern region, consequently elevating the risk of dolphin habitat overlap with artisanal (local and coastal) fisheries (Alexandre et al., 2022).

The objective of this work was to study the extent of interaction between cetaceans and the bottom-set net fishery along the mainland Portuguese southern coast operated by local ($\leq$ 9 m) and coastal (> 9 m) vessels, from 2018 to 2022. Our work focused on characterising interaction (depredation or bycatch) level by month and season, by mesh size, the impact on Landings Per Unit Effort (LPUE), the level of gear damage, and the influence of net length on the LPUE.

## 2. Materials and methods

### 2.1. Study area

The study area included the waters off the mainland Portuguese southern coast (Fig. 1), also known as the Algarve, comprising a small area of the south-west coast (~50 km), from Odeceixe (37ο26’ N - 8ο47’ W) to Cape São Vicente (37ο1′ N - 8ο59′ W), and the Southern coast (~170 km extension), from Cape São Vicente to Vila Real de Santo António (37°11’ N - 7°25’ 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 (37°04’ N 8°06’ W) towards the west, and the leeward region from Quarteira to Vila Real de Santo António, towards the east.

### 2.2. Data collection and monitoring

The data were collected between November 2018 and November 2022. 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 fishers who voluntarily filled in paper logbooks designed specifically for the project, following instructions and training from SOs. For both methods, data obtained included: fishing gear and net characteristics (length and mesh size of the net), vessel activities during the

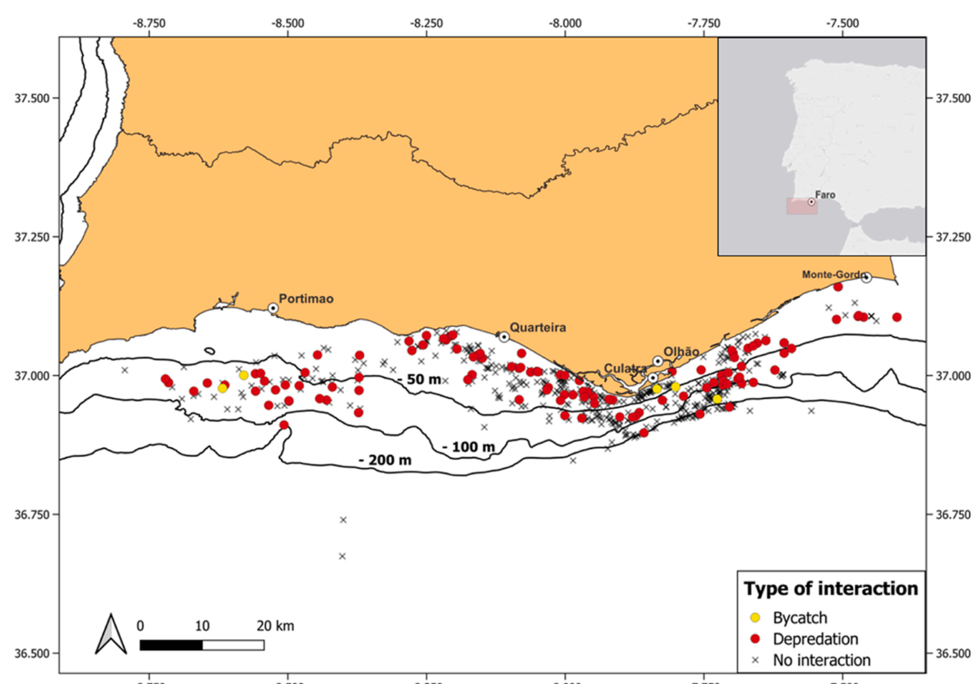


**Fig. 1.** Map of the study area with the sampled fishing harbours and hauls with or without interactions. No interactions (n = 534), depredation (n = 116), bycatch (n = 5).

fishing trip (timing of haul operations, namely net shooting, soaking, and hauling times), location of the haul (Latitude and Longitude), fish catch (weight in kg per species), cetacean presence within the field of observation during hauling, which takes place on the port side of the vessel, and type of interaction (bycatch with or without mortality and/or depredation). The number of hauls for each fishery was dependent on the fisheŕs choice in each vessel to use different mesh sizes to target specific species. The technical team maintained constant contact with the fishers to monitor the logbooks and the VO entries. Depredation from bottlenose dolphins was considered when fish catch or gear was damaged (usually, catches are either partially eaten and fish remains may present teeth marks left behind or when eaten as a whole, the net presents a hole, as the animals usually eat the entangled fish and rip the net completely; Revuelta et al., 2018).

### 2.3. Data analysis

The interaction rates for each type of mesh used were calculated separately for depredation and bycatch. Bycatch rate is the number of animals caught per haul obtained by the ratio of the number of animals observed bycaught per number of hauls observed. Depredation rate is the proportion of hauls depredated obtained by the ratio of number of hauls observed with depredation per total number of hauls observed. These rates were calculated for seasons, months, type of gear (gill or trammel), mesh used, and the target fish species. Seasons were described as winter (January to March), spring (April to June), summer (July to September) and autumn (October to December). Fishing métiers were identified based on the mesh sizes used by the skippers in the study area and the target fish species, as defined by national regulations of the Portuguese Directorate-General for Natural Resources, Safety and Maritime Services (www.dgrm.mm.gov.pt).

To determine the impact of depredation on the fishing gears, three gear damage levels were established based on the fisheŕs perception, balancing the number of holes and the intensity of net panel damage according to the net length, as low (few, dispersed, small holes; easy to mend), medium (25–50 % of the net unusable), and high (more than 50 % of the net is unusable), where the length of a net panel is 50 m. The rate of damage to the fishing gears by depredation events was calculated as the number of depredation events causing damage to nets for a given damage level divided by the total number of events where depredation was observed. LPUE was calculated as the weight of fish species landed (kg) divided by the total length of the net (km). Moreover, the LPUEs were calculated for total catch as well as separately for hake and red mullet since these were species of high commercial value among the targeted fish species and also a favoured depredation target. This was followed by a pairwise comparison of the LPUEs between hauls with and without depredation to infer the effects of depredation on LPUEs in different fishing métiers. Similar comparisons were also performed to determine the effects of net length ($<$ 6 Km and $\geq$ 6 Km) and depredation on the LPUE. The 6 Km threshold was chosen since it approximately coincided with the midpoint of the range of nets that were sampled, which ranged from 1 Km to 13 Km.

The LPUE data for each group were tested for normality and homoscedasticity using Shapiro-Wilk and Bartlett tests, respectively. Since the assumptions of normality were not satisfied, Wilcoxon-rank sum tests were applied to make statistical comparisons between groups. Likewise, Pearson's chi-square goodness of fit tests were used to compare the rates of interaction and damage between different groups. This was followed by post-hoc analyses consisting of pairwise comparisons between pairs of proportions, with Holm's adjustment. The alpha value was set at 0.05 and comparisons with $p < 0.05$ were deemed significant. All the analyses were performed using the software RStudio (R Core Team, 2023, version 4.3.0). The figures were created using the package "ggplot2" (Wickham, 2016). The maps were created using QGIS Desktop (version 3.30.0).

## 3. Results

Overall, 655 fishing hauls were registered in 11 vessels (35 % by SO and 65 % by VO; Table 1). The predominant form of interaction was depredation, which was observed in 17.7 % of the total observed hauls and occurred in all sampled métiers. Usually, depredation events included in most cases, both damaged catch (Fig. 2 **A-C**) and damaged gear (Fig. 2 **B-D**). The rate of depredation obtained from SÓs was 0.109, while that of VÓs was 0.215. Bycatch occurred in less than 1 % of the observed hauls and in three of the five sampled métiers (60 – 75 mm, 120 mm, and 220 mm nets). Three bycatch events were observed on the eastern side of the Algarve, and two in the western area (Fig. 1). All the bycatch events (n =5) were single animals. Out of the bycaught dolphins, four were bottlenose dolphins and one was a common dolphin. Three bycatch events were recorded by VÓs (all bottlenose dolphins) and two bycatch events by SÓs (one bottlenose dolphin and one common dolphin), corresponding respectively to a bycatch rate of 0.007 and 0.008 cetaceans per haul.

Despite the observation effort being higher off the coast of Olhão (Fig. 3**A**), depredation events occurred throughout the study area, were very coastal (within the 200 m isobath), and with two notable hotspots-one off the coast of Olhão within the 50–100 m isobaths and the other to the west of Quarteira in very shallow waters (<50 m) (Fig. 3**B**). Furthermore, higher number of depredation events were observed in the cold season (Fig. 3**C**) throughout the study area, while during the warmer season (Fig. 3**D**), depredation was more intense west of Quarteira.

### 3.1. Seasonal and spatial characteristics of the interactions

Seasonally, more hauls were observed in the summer (n = 235), followed by spring (n = 173), winter (n = 126), and autumn (n = 121). The depredation events were observed throughout the year. The rate of depredation was higher in winter (0.214), followed by spring (0.208), autumn (0.190), and summer (0.127); Table 2. However, no statistically significant differences were found between the seasons ($\chi^2 = 5.28$, df = 3, $p > 0.05$). The depredation events only occurred with bottlenose dolphins. Contrary to this, the bycatch events occurred with both bottlenose and common dolphins, resulting in 100 % mortality but were uncommon with respect to depredation rates and occurred only in the spring and summer with similar rates (0.011 and 0.013, respectively).

Fig. 4 shows the monthly rates of bycatch and depredation. Overall, a significant difference was found in the rate of depredation between months ($\chi^2 = 21.173$, df = 11, $p < 0.05$). March and November presented the highest depredation rates (0.352 and 0.293 per haul), while February, September, and July had the lowest depredation rates of 0.128, 0.121 and 0.093 per haul, respectively. The *post-hoc* pairwise comparison analysis revealed significant differences in the depredation rates between March and July ($p < 0.05$). The bycatch events only took place in May, June, August, and September.

### 3.2. Interaction rates by métier and target fish species

Higher rates of depredation were observed for the smaller mesh-size categories of < 60 mm gillnet (0.359 per haul), 80 mm gillnet (0.284 per haul), and 60 – 75 mm gillnet (0.231 per haul). In contrast, significantly lower depredation rates ($\chi^2 = 41.615$, df = 4, p = 0) were observed in the nets with larger mesh sizes of 120 mm trammel net (inner mesh size; 0.107 per haul), and 220 mm gillnet (0.009 per haul). This was also confirmed by the *post-hoc* pairwise comparisons, wherein the 120 mm trammel nets and the 220 mm gillnets had significant pairwise differences in depredation rates in all the pairwise comparisons ($p < 0.01$), while the smaller mesh sizes showed no such statistically significant differences among them.

Interaction rates between the dolphins and the fishing vessels were also calculated based on the species being targeted by those vessels to

**Table 1 –**
Summary table with sampling effort and interactions observed (depredation and bycatch) per gear (G – gill net; T – trammel net) and mesh type. N – total number of hauls sampled; DDE – *Delphinus delphis*; TTR – *Tursiops truncatus*.

| Mesh size (mm) | Gear type | Target species | Average soaking time in hours (± SE) | Hauls (N) | Depredation events | Depredation rate | Bycatch events | Bycatch rate | Species bycaught |
|---|---|---|---|---|---|---|---|---|---|
| < 60 | G | Multi-species | 5.83 (± 1.89) | 39 | 14 | 0.359 | 0 | 0 | 0 |
| 60–75 | G | Red mullet | 9.41 (± 0.53) | 216 | 50 | 0.231 | 2 | 0.009 | 2 TTR |
| 80 | G | Hake | 20.42 (± 0.61) | 116 | 33 | 0.284 | 0 | 0 | 0 |
| 120 | T | Soles, Cuttlefish | 36.17 (± 1.67) | 169 | 18 | 0.107 | 1 | 0.006 | 1 TTR |
| 220 | G | Monk fish | 88.16 (± 2.97) | 115 | 1 | 0.009 | 2 | 0.017 | 1 TTR + 1 DDE |
| **Total** | | | | **655** | **116** | | **5** | | **4 TTR + 1 DDE** |

**Fig. 2.** Evidences of depredation by bottlenose dolphins showing damaged catch (A, B, C) and gear (B, C, D) during hauling events.

deduce whether cetaceans have a preference for certain fish species (Fig. 5). Depredation was observed for all the mesh sizes and several targeted species, albeit with varied intensities. The highest rates of depredation were observed in métiers targeting red mullet, which use mesh sizes below 60 mm (0.25 per haul) and mesh size 60–75 mm (0.22 per haul), and in the métier targeting hake that uses 80 mm mesh-sized nets (0.25 per haul). The highest bycatch rate was observed in the 220 mm mesh size gillnets that targeted monkfish (*Lophius* spp.) (0.017 cetaceans per haul). Other than that, two bycatch events were noted for the mesh sizes between 60 – 75 mm targeting red mullet, and a single bycatch event in the case of the 120 mm trammel net that targeted soles **(Table1)**.

### 3.3. *Effect of depredation on landings per unit effort (LPUE) and net length*

Concerning the impact of depredation on the LPUE (Fig. 6), the depredation only affected significantly the LPUE of the 60 – 75 mm mesh size gillnets category that targets red mullet, for which the LPUE in trips with depredation had a significantly lower LPUE as compared to the trips without depredation (Wilcoxon- rank sum test, $W = 1381.5$, $p = 0$). The pairwise comparisons between trips with and without depredation for all the other métiers were found to be non-significant ($p > 0.05$).

Comparisons of LPUE in hauls without depredation made between nets longer and shorter than 6 km showed that the net length did not influence the overall LPUE ($p > 0.05$; Fig. 7**A**). The same was true in the case of the 80 mm mesh-sized gillnets that targeted hake. However, the LPUE in hauls without depredation for red mullets targeted by the nets with mesh sizes ranging between 60 – 75 mm, was significantly higher in the nets below 6 km as compared to those greater than or equal to 6 km ($W = 6661$, $p < 0.01$).

Also, depredation significantly reduced the LPUEs for both length categories (< 6 km: $W = 17764$, $p < 0.05$; ≥ 6 km: $W = 12388$, $p = 0$; Fig. 7**A**). In the case of the métier targeting hake, a slight decrease of LPUE of hake due to depredation was observed in nets < 6 km in length and the opposite in nets ≥ 6 km, but these differences were not statistically significant ($p > 0.05$; Fig. 7**B**). On the other hand, a reduction in the LPUE of red mullets (Fig. 7**C**) due to depredation was significant in the nets that were shorter than 6 km ($W = 965$, $p < 0.01$), but not in those that exceeded 6 km in length ($p > 0.05$).

Data on net damage due to depredation were available for a total of 61 hauls, where bottlenose dolphins were conspicuously observed in the vicinity of the vessel in 36 hauls and were not observed in 25 hauls (Fig. 8). The dolphins were observed during all three damage categories. The rate of damage differed significantly between the three categories ($\chi^2 = 12.426$, df = 2, $p < 0.01$), with the rate of damage due to depredation being significantly higher in the 'medium damage' ($p < 0.01$) and 'high damage' ($p < 0.01$) categories than the 'low damage' category. Within the 'high damage' category, the proportion of hauls with depredation with observations of bottlenose dolphins significantly exceeded the ones that did not ($\chi2 = 6.533$, df = 1, $p < 0.05$). However, such observations were not evident for the 'medium' and the 'low' damage categories ($p > 0.05$).

## 4. Discussion

### 4.1. *Distribution of depredation and bycatch events in time and space*

This study presents for the first time a direct characterisation using onboard observations of the level of cetacean interactions (bycatch or depredation), with nets of different mesh sizes used in a bottom-set net fishery operating in a Portuguese mainland coast area, namely in the southern coast-Algarve. The two cetacean species observed to interact with bottom-set net fishing vessels were bottlenose dolphins and common dolphins.

All the depredation events ($n = 116$) involved bottlenose dolphins and were observed throughout the whole Algarve region. This validates the results of a previous study using harbour inquiries to fishers in the area, that reported a high association of bottlenose dolphins with vessels

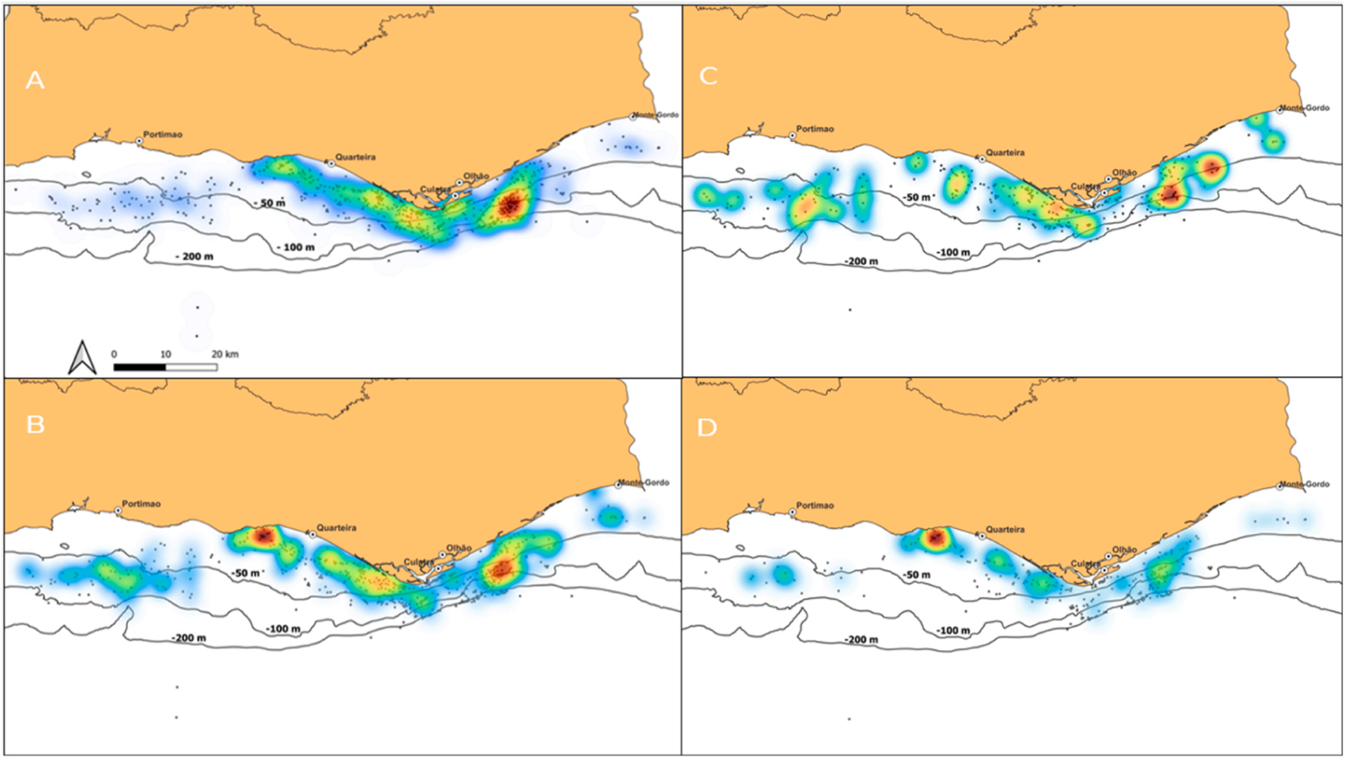


**Fig. 3.** Intensity of observations effort and interaction (depredation and bycatch) level; A – Heatmap of all the observed hauls; B – Heatmap of hauls with interactions; C – Heatmap of hauls with interactions in winter and spring (colder season); D - Heatmap of hauls with interactions in summer and fall (warmer season). Color gradient shows intensity of interaction (hot colors – higher interaction; cold colors – lower interaction; Black dots show the locations of the monitored hauls).

**Table 2**
Summary table of interaction (depredation and bycatch) rate by season. N – total number of hauls sampled.

| Season | Hauls (N) | Depredation events | Depredation rate | Bycatch events | Bycatch rate |
|---|---|---|---|---|---|
| Summer | 235 | 30 | 0.127 | 3 | 0.013 |
| Autumn | 121 | 23 | 0.19 | 0 | 0 |
| Winter | 126 | 27 | 0.214 | 0 | 0 |
| Spring | 173 | 36 | 0.208 | 2 | 0.011 |

operating bottom-set nets, with more depredation declared on the leeward (eastern) side of the Algarve (Alexandre et al., 2022). Moreover, the results of the studies conducted in nearby regions off Iberia and the Mediterranean (Báez et al., 2023; Alexandre et al., 2022; Goetz et al., 2014; Bearzi et al., 2011; Brotons et al., 2008a, 2008b) have also shown that bottlenose dolphins are known to be strongly associated with depredation events. Indeed, in response to declining fish stocks, individuals of this species have learnt that fish targeted in gillnets or trammel nets represent a more accessible meal for them (Bearzi et al., 2006; Pennino et al., 2014). A possible explanation for the lack of depredation by common dolphins in our study is that the fish targeted by the fishing boats studied using bottom-set nets are not the most preferred by this species. Common dolphins along the Portuguese mainland coast prefer small pelagic fish, having sardines as their favoured prey (Silva, 1999; Marçalo et al., 2018). Moreover, common dolphins are the species most commonly associated with purse seine fisheries operating in Portuguese mainland waters (Marcalo et al., 2015; Dias et al., 2022).

From a seasonal point of view, depredation occurred throughout the year. Although the rate of depredation peaked in winter and spring, the seasonal differences were not statistically significant, which is in line with other studies (Pardalou and Tsikliras, 2020). These results also suggest that bottlenose dolphins are present in the Algarve region

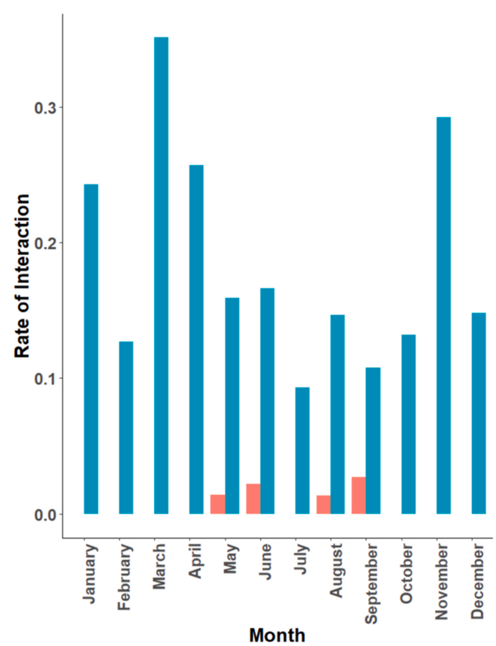


**Fig. 4.** Interaction rates (per haul) between cetacean and fishing gear by month. (Red columns: Represent the rate of bycatch; Turquoise columns: Represent the rate of depredation); Sample size (n): January = 41, February = 47, March = 54, April = 35, May = 69, June = 90, July = 86, August = 75, September = 37, October = 53, November = 41, December = 27).

throughout the year. Moreover, refining the temporal resolution by studying the variations of depredation on a monthly scale, we observed small monthly variations in line with a study in the Balearic Islands-Mediterranean by Brotons et al. (2008a), also indicating a decrease in

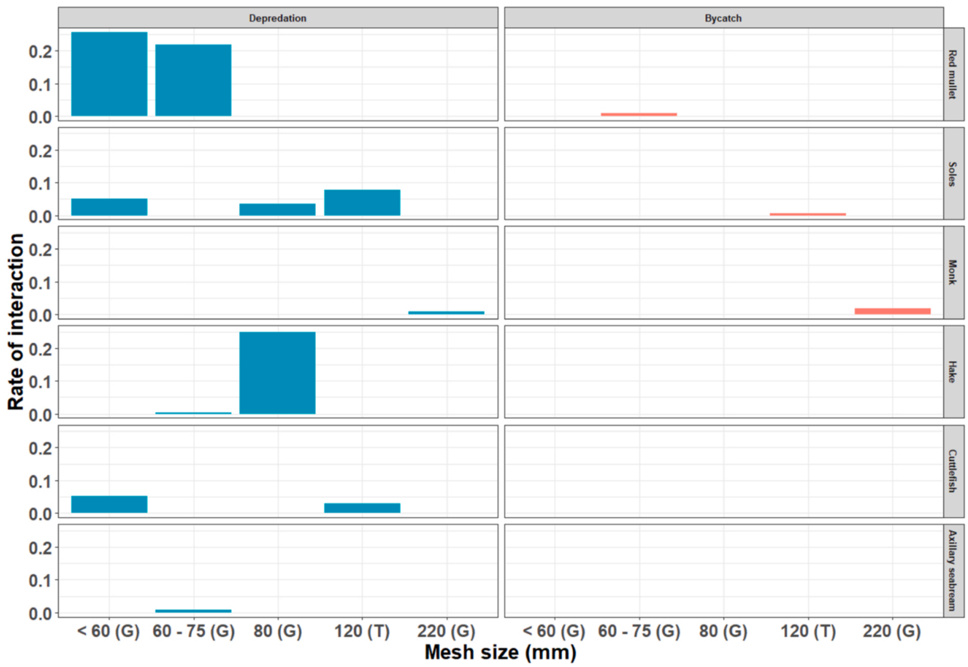


**Fig. 5.** Interaction rate per haul by mesh size for the different target species in each métier. (Red columns: Represent the rate of bycatch; Turquoise columns: Represent the rate of depredation, G- Gill nets; T – Trammel nets, inner mesh size); Sample size (n): < 60 mm = 39, 60 – 75 mm = 216, 80 mm = 116, 120 mm = 169, 220 mm = 115).

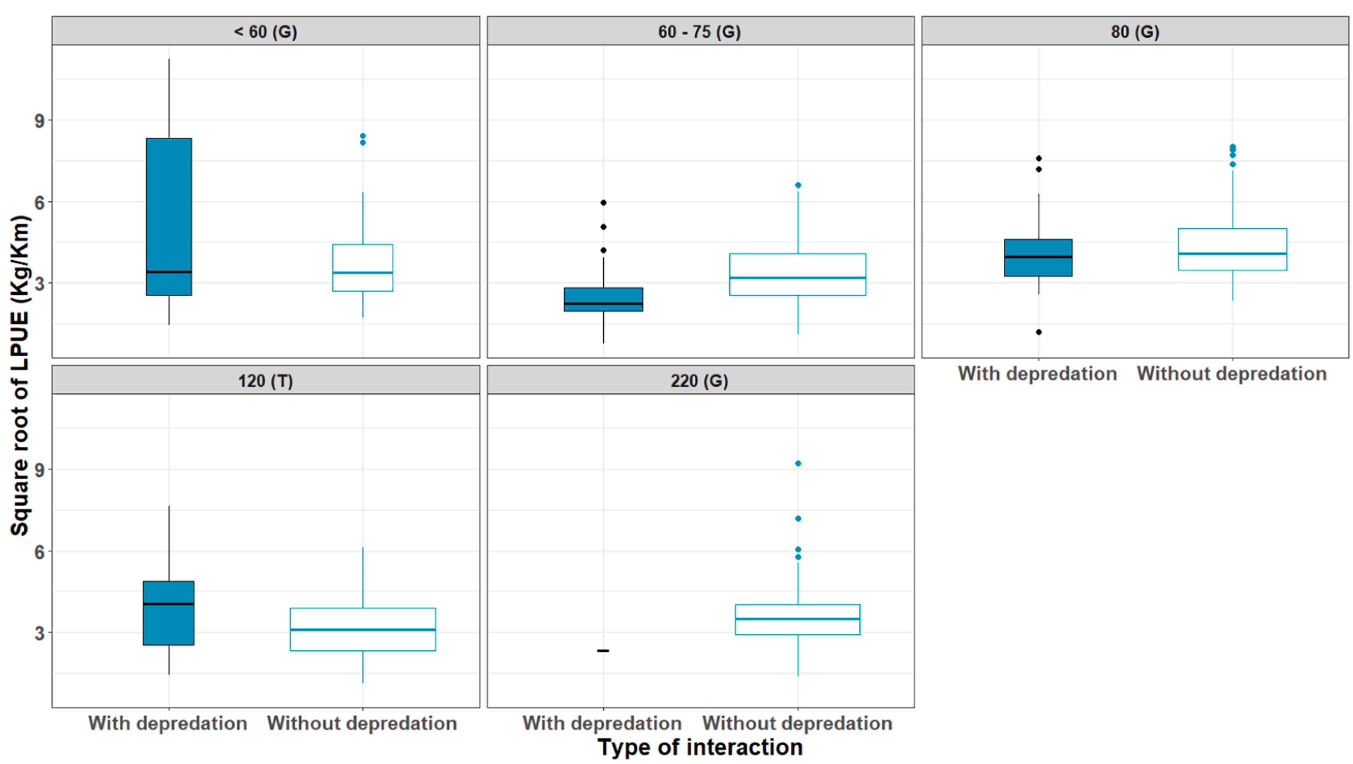


**Fig. 6.** Boxplots showing the variation in the landing per unit effort observed from hauls with different mesh sizes and the impact of depredation. Horizontal line: Median, first and third quartile, range of observed values and outliers for each category are shown. G- Gill nets; T – Trammel nets, 120 mm inner mesh size); Sample size (n): < 60 mm = 39, 60 – 75 mm = 216, 80 mm = 116, 120 mm = 169, 220 mm = 115).

depredation in the summer months. They attributed these variations to the local oceanographic conditions prevailing in that area, which directly influence the abundance and distribution of prey species. Similar seasonal fluctuations in depredation rates have been observed in other parts of the Mediterranean (Bearzi et al., 2011; Feliu-Tena et al., 2023)

Of the total number of cetacean bycatch events that occurred during the data collection period (n = 5), 4 were bottlenose dolphins and 1 was a common dolphin. As all the dolphins involved in depredation events were bottlenose dolphins, they were most likely accidently entangled in

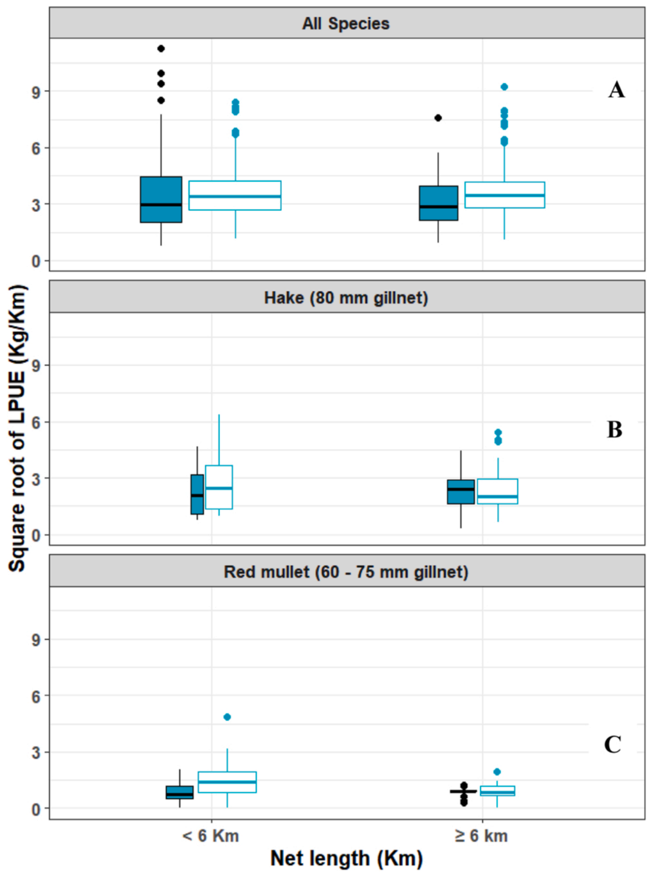


**Fig. 7.** Boxplots showing the influence of net length on LPUEs with and without depredation. Horizontal line: Median, first and third quartile, range of observed values and outliers for each category are shown). Turquoise -hauls with depredation; White columns - hauls without depredation; Sample sizes (n): A) All species = 655, B) Hake (80 mm gillnet) = 116, Red mullet (60 – 75 mm gillnet) = 216).

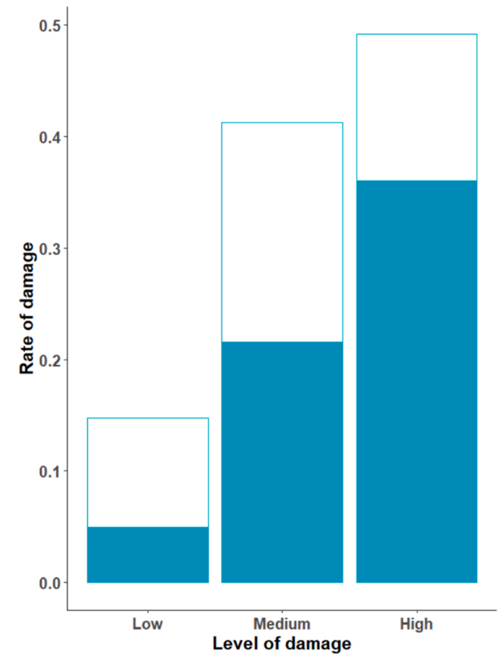


**Fig. 8.** Level of net damage per haul (Low, Medium, High) as a result of depredation events. Turquoise columns: Represent the rate of damage when bottlenose dolphins were observed; White columns: Represent the rate of damage when bottlenose dolphins were not observed); Sample size (n): Low = 9, medium = 23, high = 30).

fishing nets while feeding close to or from the net (Terranova et al., 2022). During navigation, cetaceans can detect fishing gear using visual and acoustic systems (Kastelein et al., 2000). However, Dolman and Moore (2017) explain that echolocation may be reduced as a result of distraction, such as fleeing from predators, playing with other cetaceans, curiosity, or imprudence, which leads to bycatch. Furthermore, Pennino et al. (2014) explained that high dolphin depredation implies an increased risk of bycatch. As for the common dolphin found dead, this species does not usually feed on the target species from bottom-set nets, this bycatch and subsequent death is most likely associated with distraction. This is particularly notable given the large number of fixed nets used in the area, where common dolphins, the most abundant small cetacean species in western Iberia, are frequently reported to be bycaught (Vingada and Eira, 2018; ICES, 2023). Furthermore, it is likely that the bycaught individuals could be young/immature, which may be inexperienced and hence, more prone to getting entangled (Byrd and Hohn, 2017).

The bycatch in this study was low for the four years of study, only observed in spring and summer at similar rates and evenly distributed between 4 months of the year: May, June, August and September. While it is evident that these months are close to each other, it would be far too ambitious to deduce a relation between the occurrence of these events and their temporality, given the small number of individuals. Nonetheless, we can further discuss these numbers as mortality in gillnets are by far the most serious threat to the survival of coastal dolphin populations (Read et al., 2006; Wade et al., 2021). In our study, if we extend the bycatch findings from the 11 examined fishing boats to the entire fleet of approximately 360 fishing vessels operating bottom-set nets in the Algarve region (EC, Fleet Register, 1.1.0.0), the potential impact on the bottlenose population, for instance, could be substantial. As the latest coastal bottlenose dolphin population density estimate for the Algarve coast is approximately 1431 individuals (CI: 28–5043 individuals; Gilles et al., 2023), the estimated yearly bycatch of bottlenose dolphins for the entire fleet is 2.3 % (about 33 bottlenoses per year) of the local population size and in line with values presented in the work of Alexandre et al. (2022) (2.4 % for bottom-set nets) in the area. Nevertheless, it is crucial to approach the provided extrapolated values cautiously. This caution stems from the dependence on various unaccounted variables, including the seasonal fishing efforts across all gear types and the distribution of different cetacean species in the region. It is worth noting that these species are highly mobile, as highlighted by Vingada and Eira in 2018.

### *4.2. Nets and mesh size that are the most problematic for dolphins and their selectivity for fishing*

Our analyses showed that the small mesh-sized net categories, i.e. < 60 (G), 60–75 (G), and 80 (G) suffered a considerably higher rate of depredation compared to the big mesh-size categories, 120 (T) and 220 (G), respectively. This result is in agreement with the findings of Pardalou et al. (2022), who noted lower net damage due to depredation in larger mesh-sized nets. They attributed this to the fact that larger mesh sizes tend to be more species selective in their catch, and when targeting less favoured prey, are less likely to be depredated by bottlenose dolphins. Taking into account that bottlenose dolphins feed opportunistically and target multiple species, we attempted to calculate the depredation rates individually for gear type targeting a specific species to determine the gear and target species most prone to depredation in the Algarve. It was found that red mullet (*Mullus surmuletus*) was the most depredated species, with high depredation rates (0.25 and 0.21) in the two smallest mesh-size categories, respectively < 60 (G) and 60 – 75 (G). Such high rates of depredation in the < 60 (G) category are because although this category is only supposed to target small soles, fishers tend to use these nets to also target red mullets (A. Marçalo pers. Obs.), which are more profitable. This was not unexpected since several studies in the past have indicated red mullets to be a preferred prey item for bottlenose dolphins and that nets targeting red mullets are frequently depredated in the Mediterranean (Gazo et al., 2008; Rocklin et al., 2009; Pardalou and Tsikliras, 2018, 2020).

Likewise, hake is also known to be an important component in the diet of bottlenose dolphins (Blanco et al., 2001; Giménez et al., 2017, Ana Marçalo pers. comm.). This was also reflected in our analysis with the 80 (G) net category targeting hake also having a high rate of depredation (0.25). The trammel nets sampled in our study (120 (T) usually targeted cuttlefish and sole. Even though they were depredated upon, the rate of depredation was comparatively lower than those of the small-meshed gillnets. This is in corroboration with other studies suggesting the importance of those species as secondary prey items for bottlenose dolphins (dos Santos et al., 2007; Blasi et al., 2015; Giménez et al., 2017). The category least prone to depredation was 220 (G). This large-meshed gillnet is highly selective in targeting monkfish. This indicates that the monkfish are not a preferred prey species for the dolphins. However, this métier had the longest average soaking time, which increases the probability of accidental bycatch. Also, the net twine from the monkfish nets is made of stronger (thicker in diameter) monofilament compared to nets of smaller mesh sizes, making it more difficult to break away. This could explain the two bycatch events recorded from the 220 (G) nets.

### 4.3. Catch and gear damage caused by interactions with cetaceans

Depredation events, involving damage to fishing gear, direct removal of catch, and rendering the remaining catch unmarketable, can significantly impact a fishing vessel's profitability (Alexandre et al., 2022; Garagouni et al., 2022). This study investigates the influence of depredation on the Landings Per Unit Effort (LPUEs) of various bottom-set net métiers in the Algarve. Contrary to our expectations, depredation did not result in reduced LPUEs across all métiers, except those employing mesh sizes between 60 and 75 mm, specifically targeting red mullet. The substantial loss of red mullets to depredation underscores their significance as prey for bottlenose dolphins.

Despite a prevailing belief among the Algarve fishers that longer nets lead to increased fish landings (Ana Marçalo pers. Obs.), our examination found no significant LPUE increase with longer nets for all landed fish. Actually, in vessels targeting red mullet, longer nets were associated with significantly lower LPUEs. Therefore, although fishers can occasionally achieve higher catches using longer nets, it amplifies depredation risks due to extended soaking and hauling durations.

Comparisons were also made to determine how net length influences depredation first, for all the species caught by all vessels combined and then separately for those targeting economically important species – hake and red mullet. There was an overall reduction of LPUE in both nets shorter and longer than 6 km when depredated. Similar results were obtained by Massaoud and Nakhla (2023), who noted 38 % and 37.7 % reductions in the LPUEs due to depredation by bottlenose dolphins on gillnets and trammel nets, respectively in fisheries along the coast of Teboulba, Tunisia (Western Mediterranean). Pennino et al. (2014) observed a significant reduction of CPUEs in trammel net operations with bottlenose dolphin interactions in the Archipelago de La Maddalena, Italy (Western Mediterranean). In our studies, vessels targeting red mullets with nets less than 6 km in length also witnessed a considerable reduction of LPUE in trips with dolphin depredation. However, depredation did not result in a significant loss of LPUE in the vessels targeting hake for both the net length categories. Brotons et al. (2008a) estimated an annual loss of 3.4 % by weight of the total catch due to dolphin interactions in artisanal fisheries around the Balearic Islands. Furthermore, the dolphins were observed to be selective towards a few species including red mullet, which led to a reduction in the CPUEs of those species. A study conducted in Sardinia showed that bottlenose dolphin interactions occurred primarily with vessels targeting red mullets and that a significant loss of catch took place only during the red mullet fishing season (Lauriano et al., 2004). Such preferential targeting of red mullets by the bottlenose dolphins could explain the large reduction in LPUE observed in the present study. However, it is evident, given the high rate of depredation in the 80 mm gillnets targeting hake, that the dolphins might also be targeting hake and hence, the absence of reduction in the LPUE is surprising. The probability of depredation has been shown to be correlated to the CPUE. That is, the higher the catch volume, the higher the chances of depredation (Rechimont et al., 2018). Hence, it could be possible in our case, that bottlenose dolphins preferably target net sets that had a high catch of hake over the ones that had a comparatively lower catch. This might have led to the reduction of LPUE in the sets with a higher hake catch and hence, there was no significant difference in trips with and without depredation. In general, assumptions on the reduction of catch due to depredation must be made prudently. That is because the CPUE depends on a variety of other factors besides depredation, including resource availability and catchability, expertise of the crew, changes in the fishing area, as well as temporal changes in the weather and the local oceanographic conditions (Chávez-Martínez et al., 2022).

### 4.4. Level of net damage from depredation

Of all the sets that were assessed for net damage, a high percentage (49.2 %) belonged to the category of high damage, while 41.1 % had medium damage. The frequency of high net damage rose considerably when bottlenose dolphins were observed during the set, but that was not observed in the case of sets with medium and low damages. This implies that a substantial degree of net damage is attributable to depredation and that depredation events usually cause heavy damage to the net. This result is in line with several studies conducted in this region as well as in the adjoining regions of the Mediterranean Sea. Brotons et al. (2008a), in their study along the Balearic Islands observed that the number of large holes in the net increased sharply whenever there was a depredation event. An interview-based survey of fishers in the Algarve estimated heavy losses ranging from 7 % to 21 % of the total revenue in bottom-set net fisheries as a result of catch and gear loss due to depredation, with 80 % of the fishers affected (Alexandre et al., 2022). In South Sicily, net damage was shown to be the major negative impact of dolphin interactions with fisheries, since 36 % of all depredation events led to net damage (Geraci et al., 2019). Net damage, as a result of depredation, was almost unanimously reported by the small-scale fishers in the Gulf of Ambracia and the Inner Ionian Sea Archipelago, wherein 86 % of the respondents reported damaged gear due to dolphin depredation (Gonzalvo et al., 2015). Garagouni et al. (2022) reported an average of 0.59 % of the net's surface area per set damaged due to depredation in Greece, while the damage was as high as 3.7 % per set in the waters along the coast of Cyprus, when dolphins were observed (Eastern Mediterranean; Snape et al., 2018). Likewise, a detailed study on interactions with trammel net fisheries off the coast of Valencia revealed that a single interaction event damaged between 0.39–1345 $m^2$ of the net (Feliu-Tena et al., 2023). Such gear damage invariable results in economic losses of varied degrees for the fishers (Brotons et al., 2008a; Bearzi et al., 2011; Gönener and Özdemir, 2012), as they are compelled to purchase new fishing gear to replace the damaged one, get it repaired, or repair it themselves in which case the cost incurred is in the form of time. This has created a negative perception of dolphins amongst the fishing communities (Revuelta et al., 2018; Li Veli et al., 2023).

### 4.5. Study limitations and recommendations

An important aspect of studying cetaceans and fisheries interactions also involves looking into the age and sex-class of the interacting individuals to gain insights into which age group and sex class is more likely to depredate and be caught in the fisheries. In bottlenose dolphins, the presence of calves is a driving factor for depredation on trammel net fisheries (Pennino et al., 2013). Several studies have indicated a prevalence of males in interactions with fisheries (Morales-Rincon et al., 2019; Powell and Wells, 2011), a trend also supported by the regional stranding network operating in the area (Fialho et al., 2023). Given that our data were collected by onboard observers combined with the log-book recordings from vessel-crew observers, it was not possible to ascertain the demographic parameters of the interacting groups, which remains a major limitation of our study. Furthermore, visual surveys of marine mammals have their limitations, in that, there is a high probability of missing a cetacean when it is present (Evans and Hammond, 2004). The detection probability of bottlenose dolphins has been shown to increase with a Passive Acoustic Monitoring (PAM) device attached to the net when compared to the conventional visual observations (La Manna et al., 2022). In future studies, we propose the combination of acoustic techniques with visual observations in the Algarve to ameliorate the threat of missing dolphin interactions when they are present.

Taking into consideration the findings of Alexandre et al. (2022), the interactions of bottlenose dolphins with bottom-set net fisheries can be extremely detrimental for both parties. On the one side, the fishers suffer heavy losses with severe socio-economic implications. While on the other, such interactions can alter the social dynamics of the dolphins (Pennino et al., 2013), while regular bycatch could imperil their population.

We emphasize the need to engage in ongoing dialogue with fishers for testing and promoting measures that reduce interactions with cetaceans. While some measures, such as acoustic deterrent devices, have been implemented in successful pilot trials in the area (Marçalo et al., 2021; ICES, 2023) or other nearby regions (Brotons et al., 2008b; Gazo et al., 2008; Gönener and Özdemir, 2012; Dawson et al., 2013; ICES, 2023), scaling up the use of acoustic deterrents faces economic challenges, potentially raising conservation concerns like habitat exclusion. We propose expanding sampling efforts by collaborating with more vessels and ports and employing species distribution models (Guisan and Zimmermann, 2000; Araújo et al., 2019; Carlucci et al., 2021) to offer comprehensive recommendations for minimizing dolphin-fishery overlap on a spatiotemporal scale. This approach enhances precision in our analysis and interpretation. Despite limitations, this study establishes a crucial baseline for future conservation and fisheries management studies, revealing the extent of cetacean interactions with artisanal fisheries using bottom-set nets.

## CRediT authorship contribution statement

**Flávia Carvalho:** Methodology, Investigation, Data curation. **Vighnesh Samel:** Writing – original draft, Visualization, Formal analysis, Data curation. **Ana Marçalo:** Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Jorge MS Gonçalves:** Writing – review & editing, Project administration. **Karim Erzini:** Writing – review & editing. **Magda Frade:** Methodology, Investigation, Data curation.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data Availability

Data will be made available on request.

## Acknowledgements

We thank all skippers and crews that allowed the onboard observation and voluntarily filled the logbooks. A special thank you to the intern Karolina Abosaleh for partially organizing the data and Rúben Gregório for some onboard observations. This work was supported by projects Mar2020- iNOVPESCA (DGRM/MM, MAR2020: MAR-01.03.01-FEAMP-0020), CetAMBICion (EU, DG-ENV/MSFD 2020) and LIFE Ilhas Barreira (LIFE18/NAT/PT/000927). Additionally, this study was supported by the Portuguese Science and Technology Foundation (FCT) through projects UIDB/04326/2020, UIDP/04326/2020 and LA/P/0101/2020 to CCMAR. A special thank goes to three unknown reviewers whose comments contributed substantially to the improvement of the manuscript.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.fishres.2024.107100.

## References

Alexandre, S., Marçalo, A., Marques, T.A., Pires, A., Rangel, M., Ressurreição, A., Monteiro, P., Erzini, K., Gonçalves, J.M.S., 2022. Interactions between air-breathing marine megafauna and artisanal fisheries in Southern Iberian Atlantic waters: Results from an interview survey to fishers. Fish. Res. 254, 1–14. https://doi.org/10.1016/j.fishres.2022.106430.

Araújo, M.B., Anderson, R.P., Barbosa, A.M., Beale, C.M., Dormann, C.F., Early, R., Garcia, R.A., Guisan, A., Maiorano, L., Naimi, B., O'Hara, R.B., Zimmermann, N.E., Rahbek, C., 2019. Standards for distribution models in biodiversity assessments. Sci. Adv. 5 (1), 1–12. https://doi.org/10.1126/sciadv.aat4858.

Báez, J.C., Camiñas, J.A., Aguilera, R., Castro-Gutiérrez, J., Real, R., 2023. When non-target wildlife species and alien species both affect negatively to an artisanal fishery: the case of trammel net in the Alboran Sea. Rev. Fish. Bio. Fish. 33 (3), 785–799. https://doi.org/10.1007/s11160-023-09759-6.

Bearzi, G., Reeves, R.R., 2022. Marine mammals foraging around fishing gear or preying upon fishing catch and bait: it may not be "depredation. ICES J. Mar. Sci. *79* (8), 2178–2183. https://doi.org/10.1093/icesjms/fsac173.

Bearzi, G., Politi, E., Agazzi, S., Azzellino, A., 2006. Prey depletion caused by overfishing and the decline of marine megafauna in eastern Ionian Sea coastal waters (central Mediterranean). Biol. Conserv. 127 (4), 373–382. https://doi.org/10.1016/j.biocon.2005.08.017.

Bearzi, G.Ã., Bonizzoni, S., Gonzalvo, J., 2011. Dolphins and coastal fisheries within a marine protected area: mismatch between dolphin occurrence and reported depredation. Aqua. Conserv.: Mar. Fresh. Eco. 267, 261–267. https://doi.org/10.1002/aqc.1179.

Bettencourt, A., Bricker, S.B., Ferreira, J.G., Franco, A., Marques, J.C., Melo, J.J., Nobre, A., Ramos, L., Reis, C.S., Salas, F., Silva, M.C., Simas, T., Wolff, W.J., 2004. Typology and reference conditions for Portuguese Transitional and Coastal Waters Development of guidelines for the application of the European Union Water Framework Directive. Instituto da Agua (INAG) - Institute of Marine Science (IMAR), Lisbon, Portugal, p. 119.

Blanco, C., Salomón, O., Raga, J.A., 2001. Diet of the bottlenose dolphin (Tursiops truncatus) in the western Mediterranean Sea. J. Mar. Biol. Ass. U. K. 81 (6), 1053–1058. https://doi.org/10.1017/S0025315401005057.

Blasi, M.F., Giuliani, A., Boitani, L., 2015. Influence of trammel nets on the behaviour and spatial distribution of bottlenose dolphins (*Tursiops truncatus*) in the Aeolian Archipelago, Southern Italy. Aqua. Mam. 41 (3), 295. https://doi.org/10.1578/AM.41.3.2015.295.

Brotons, J.M., Munilla, Z., Grau, A.M., Rendell, L., 2008b. Do pingers reduce interactions between bottlenose dolphins and nets around the Balearic Islands. Endang. Species Res. 5, 301–308. https://doi.org/10.3354/esr00104.

Brotons, J.M., Grau, A.M., Rendell, L., 2008a. Estimating the impact of interactions between bottlenose dolphins and artisanal fisheries around the Balearic Islands. Mar. Mammal. Sci. 24, 112–127. https://doi.org/10.1111/j.1748-7692.2007.00164.x.

Brownell Jr, R.L., Reeves, R.R., Read, A.J., Smith, B.D., Thomas, P.O., Ralls, K., Amano, M., et al., 2019. Bycatch in gillnet fisheries threatens critically endangered small cetaceans and other aquatic megafauna. Endang. Species Res. 40, 285–296. https://doi.org/10.3354/esr00994.

Byrd, B.L., Hohn, A.A., 2017. Differential risk of bottlenose dophin (Tursiops truncatus) bycatch in North Carolina, USA. Aqua. Mam. 43 (5), 558–569. https://doi.org/10.1578/AM.43.5.2017.558.

Carlucci, R., Manea, E., Ricci, P., Cipriano, G., Fanizza, C., Maglietta, R., Gissi, E., 2021. Managing multiple pressures for cetaceans' conservation with an Ecosystem-Based Marine Spatial Planning approach. J. Envir. Man. 287, 112240 https://doi.org/10.1016/j.jenvman.2021.112240.

Chávez-Martínez, K., Morteo, E., Hernández-Candelario, I., Herzka, S.Z., Delfín-Alfonso, C.A., 2022. Opportunistic gillnet depredation by common bottlenose dolphins in the southwestern Gulf of Mexico: Testing the relationship with ecological, trophic, and nutritional characteristics of their prey, 870012 Front. Mar. Sci. 9, 1–17. https://doi.org/10.3389/fmars.2022.870012.

Cruz, M.J., Machete, M., Menezes, G., Rogan, E., Silva, M.A., 2018. Estimating common dolphin bycatch in the pole-and-line tuna fishery in the Azores. PeerJ 6, e4285. https://doi.org/10.7717/peerj.4285.

Cunha, M.E., 2001. Physical control of biological processes in a coastal upwelling system: Comparison of the effects of coastal topography, river run-off and physical oceanography in the northern and southern parts of western Portuguese coastal waters (PhD thesis). Faculty of Sciences, University of Lisbon, p. 293 (PhD thesis).

Dawson, S.M., Northridge, S., Waples, D., Read, A.J., 2013. To ping or not to ping: the use of active acoustic devices in mitigating interactions between small cetaceans and gillnet fisheries. Endang. Species Res. 19, 201–221.

Dias, I.C., Marçalo, A., Feijó, D., Domingos, I., Silva, A., 2022. Interactions between the common dolphin, *Delphinus delphis*, and the Portuguese purse seine fishery over a period of 15 years (2003 – 2018. Aquat. Conserv. https://doi.org/10.1002/aqc.3828.

Dolman, S.J., and Moore, M.J. 2017. Welfare Implications of Cetacean Bycatch and Entanglements. In Marine Mammal Welfare, Animal Welfare (pp. 41–65). https://doi.org/10.1007/978-3-319-46994-2.

Evans, P.G.H., Hammond, P.S., 2004. Monitoring cetaceans in European waters. Mammal. Rev. 34 (1), 131–156.

Feliu-Tena, B., Rodilla, M., Pastor, J., Abalo-Morla, S., Bou-Cabo, M., Belda, E.J., 2023. Evaluating dolphin damage in trammel net fisheries in the Valencia region: Insights to improve management. Reg. Stud. Mar. Sci. 65, 103075 https://doi.org/10.1016/j.rsma.2023.103075.

Fialho, A., Hofman, J., Nicolau, L., Pontes, J., Marçalo, A., 2023. First insights on differential bycatch risk of bottlenose doplhins (*Tursiops truncatus*) off the southern Iberain coast. Books of abstracts. 34th Eur. Cetacea Soc.

Garagouni, M., Avgerinou, G., Mouchlianitis, F., Minos, G., Ganias, K., 2022. Questionnaire and experimental surveys show that dolphins cause substantial losses to a gillnet fishery in the eastern Mediterranean Sea. ICES J. Mar. Sci. 79, 2552–2561. https://doi.org/10.1093/icesjms/fsac196.

Gazo, M., Gonzalvo, J., Aguilar, A., 2008. Pingers as deterrents of bottlenose dolphins interacting with trammel nets. Fish. Res. 92, 70–75. https://doi.org/10.1016/j.fishres.2007.12.016.

Geraci, M., Falsone, F., Scannella, D., Sardo, G., Vitale, S., 2019. Dolphin-Fisheries Interactions: An Increasing Problem for Mediterranean Small-Scale Fisheries. Exam. Mar. Bio. Ocean. *3* (1). EIMBO.000552.2019.

Gilles, A., Authier, M., Ramirez-Martinez, N.C., Araújo, H., Blanchard, A., Carlström, J., Eira, C., Dorémus, G., Fernández-Maldonado, C., Geelhoed, S.C.V., Kyhn, L., Laran, S., Nachtsheim, D., Panigada, S., Pigeault, R., Sequeira, M., Sveegaard, S., Taylor, N. L., Owen, K., Saavedra, C., Vázquez-Bonales, J.A., Unger, B., Hammond, P.S. (2023). Estimates of cetacean abundance in European Atlantic waters in summer 2022 from the SCANS-IV aerial and shipboard surveys. Final report published 29 September 2023. 64 pp. https://tinyurl.com/3ynt6swa.

Giménez, J., Marçalo, A., Ramírez, F., Verborgh, P., Gauffier, P., Esteban, R., Nicolau, L., et al., 2017. Diet of bottlenose dolphins (*Tursiops truncatus*) from the Gulf of Cadiz: Insights from stomach content and stable isotope analyses. PLOS ONE 12 (9), 1–14.

Goetz, S., Read, F.L., Santos, M.B., Pita, C., Pierce, G.J., 2014. Cetacean–fishery interactions in Galicia (NW Spain): results and management implications of a face-to-face interview survey of local fishers. ICES J. Mar. Sci. 71 (3), 604–617. https://doi.org/10.1093/icesjms/fst149.

Goetz, S., Read, F.L., Ferreira, M., Portela, J.M., Santos, M.B., Vingada, J., Siebert, U., et al., 2015. Cetacean occurrence, habitat preferences and potential for cetacean-fishery interactions in Iberian Atlantic waters: Results from cooperative research involving local stakeholders. Aqua. Conserv. 25 (1), 138–154. https://doi.org/10.1002/aqc.2481.

Gönener, S., Özdemir, S., 2012. Investigation of the Interaction Between Bottom Gillnet Fishery (Sinop, Black Sea) and Bottlenose Dolphins (*Tursiops truncatus*) in Terms of Economy. Turk. J. Fish. Aqua. Sci. 12, 115–126. https://doi.org/10.4194/1303-2712-v12.

Gonzalvo, J., Giovos, I., Moutopoulos, D.K., 2015. Fishermen's perception on the sustainability of small-scale fisheries and dolphin-fisheries interactions in two increasingly fragile coastal ecosystems in western Greece. Aquat. Conserv. 25 (1), 91–106. https://doi.org/10.1002/aqc.2444.

Guisan, A., Zimmermann, N.E., 2000. Predictive habitat distribution models in ecology. Ecol. Model. 1*35*, 147–186.

Hall, M., Gilman, E., Minami, H., Mituhasi, T., Carruthers, E., 2017. Mitigating bycatch in tuna fisheries. Rev. Fish. Bio. Fish. 27, 881–908.

ICES, 2023. Working Group of Bycatch of Protected Species (WGBYC). ICES Sci. Rep. 5 (111), 334. https://doi.org/10.17895/ices.pub.24659484.

Kastelein, R.A., Au, W.W.L., de Haan, D., 2000. Detection distances of bottom-set gillnets by harbour porpoises (*Phocoena phocoena*) and bottlenose dolphins (*Tursiops truncatus*). Mar. Environ. Res. 49, 359–375.

La Manna, G., Ceccherelli, G., Campisi, S.S., Manghi, M., Fois, N., 2022. Acoustic detection of bottlenose dolphin depredation on nets and implications for conservation. Aqua. Conserv. 33, 179–190. https://doi.org/10.1002/aqc.3907.

Lauriano, G., Fortuna, C., Moltedo, G., Notarbartolo di Sciara, G., 2004. Interactions between common bottlenose dolphins (*Tursiops truncatus*) and the artisanal fishery in Asinara Island National Park (Sardinia): assessment of catch damage and economic loss. J. Cet. Res. Manag. 6 (2), 165–173.

Lauriano, G., Caramanna, L., Scarnò, M., Andaloro, F., 2009. An overview of dolphin depredation in Italian artisanal fisheries. J. Mar. Bio. Ass. U. K. 89 (5), 921–929. https://doi.org/10.1017/S0025315409000393.

Lewison, R.L., Crowder, L.B., Wallace, B.P., Moore, J.E., Cox, T., Zydelis, R., McDonald, S., et al., 2014. Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots. Proceed. Natl. Acad. Sci. 111 (14), 5271–5276. https://doi.org/10.1073/pnas.1318960111.

Li Veli, D., Petetta, A., Barone, G., Ceciarini, I., Franchi, E., Marsili, L., Pietroluongo, G., 2023. Fishers' Perception on the Interaction between Dolphins and Fishing Activities in Italian and Croatian Waters (ett al). Diversity 15 (2), 1–16. https://doi.org/10.3390/d15020133.

Marçalo, A., Katara, I., Feijo, D., Araújo, H., Oliveira, I., Santos, J., Katara, I., et al., 2015. Quantification of interactions between the Portuguese sardine purse-seine fishery and cetaceans. ICES J. Mar. Sci. 72 (8), 2438–2449.

Marçalo, A., Nicolau, L., Giménez, J., Ferreira, M., Santos, J., Araújo, H., Silva, A., et al., 2018. Feeding ecology of the common dolphin (*Delphinus delphis*) in Western Iberian waters: has the decline in sardine (*Sardina pilchardus*) affected dolphin diet? Mar. Biol. 165, 44. https://doi.org/10.1007/s00227-018-3285-3.

Marçalo, A., Carvalho, F., Frade, M., Pires, A., Alexandre, S., Bentes, L., Soares, C., Zabel, F., Rangel, M. Oliveira, F., Monteiro, P., Ressurreição, A., Erzini, K., Gonçalves, J.M. S., 2021. Redução de capturas acidentais de espécies marinhas protegidas em pescarias costeiras algarvias: inovação de procedimentos e técnicas de mitigação. iNOVPESCA Technical Report, MAR2020 Program, MAR-16–01-03-FMP-0020. CCMAR, University of the Algarve. Faro. 66p.

Massaoud, B., Nakhla, B., 2023. Overview of Bottlenose dolphin depredation in Teboulba region (East of Tunisia). Overview of Bottlenose dolphin depredation in Teboulba region (East of Tunisia). INSTM Bull. Mar. Fresh. Sci. 48, 23–26.

Morales-Rincon, N., Morteo, E., Delfín-Alfonso, C.A., 2019. Influence of artisanal fisheries on the behaviour and social structure of *Tursiops truncatus* in the South-western Gulf of Mexico. J. Mar. Bio. Ass. U. K. 99 (8), 1841–1849. https://doi.org/10.1017/S002531541900078X.

Pardalou, A., Tsikliras, A.C., 2018. Anecdotal information on dolphin-fisheries interactions based on empirical knowledge of fishers in the northeastern Mediterranean Sea. Ethics Sci. Env. Polit. 18 (1), 1–8. https://doi.org/10.3354/esep00179.

Pardalou, A., Tsikliras, A.C., 2020. Factors influencing dolphin depredation in coastal fisheries of the northern Aegean Sea: Implications on defining mitigation measures. Mar. Mammal. Sci. 36 (4), 1126–1149. https://doi.org/10.1111/mms.12702.

Pardalou, A., Adamidou, A., Tsikliras, A.C., 2022. Dolphin depredation and damage accumulation on different set nets in the northeastern Mediterranean Sea. Estuar., Coast. Shelf Sci. 271, 107866 https://doi.org/10.1016/j.ecss.2022.107866.

Peltier, H., Authier, M., Deaville, R., Dabin, W., Jepson, P.D., van Canneyt, O., Daniel, P., Ridoux, V., 2016. Small cetacean bycatch as estimated from stranding schemes: the common dolphin case in the northeast Atlantic. Env. Sci. Pol. 63, 7–18. https://doi.org/10.1016/j.envsci.2016.05.004.

Pennino, M.G., Mendoza, M., Pira, A., Floris, A., Rotta, A., 2013. Assessing foraging tradition in wild bottlenose dolphins (*Tursiops truncatus*). Aqua. Mamm. 39 (3), 282–289. https://doi.org/10.1578/AM.39.3.2013.282.

Pennino, M.G., Rotta, A., Pierce, G.J., Bellido, J.M., 2014. Interaction between bottlenose dolphin (*Tursiops truncatus*) and trammel nets in the Archipelago de La Maddalena, Italy. Hydrobio 747 (1), 69–82. https://doi.org/10.1007/s10750-014-2127-7.

Powell, J.R., Wells, R.S., 2011. Recreational fishing depredation and associated behaviors involving common bottlenose dolphins (*Tursiops truncatus)* in Sarasota Bay, Florida. Mar. Mammal. Sci. 27 (1), 111–129. https://doi.org/10.1111/j.1748-7692.2010.00401.x.

R Core Team, 2023. R: A languade and Environmental for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria (https://www.R-project.org/).

Read, A.J., 2008. The looming crisis: interactions between marine mammals and fisheries. J. Mamm. 89 (3), 541–548.

Read, A.J., Drinker, P., Northridge, S., 2006. Bycatch of marine Mammals in the U.S. and global fisheries. Conserv. Bio. 20 (1), 163–169. https://doi.org/10.1111/j.1523-1739.2006.00338.x.

Rechimont, M.E., Lara-domínguez, A.L., Morteo, E., Martínez-serrano, I., Equihua, M., 2018. Depredation by Coastal Bottlenose Dolphins (*Tursiops truncatus*) in the Southwestern Gulf of Mexico in Relation to Fishing Techniques. Aquat. Mamm. 44 (5), 469–481. https://doi.org/10.1578/AM.44.5.2018.469.

Reeves, R.R., McClellan, K., Werner, T.B., 2013. Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011. Endang. Species Res. 20 (1), 71–97. https://doi.org/10.3354/esr00481.

Revuelta, O., Domènech, F., Fraija-Fernández, N., Gozalbes, P., Novillo, O., Penadés-Suay, J., Tomás, J., 2018. Interaction between bottlenose dolphins (*Tursiops truncatus*) and artisanal fisheries in the Valencia region (Spanish Mediterranean Sea). Ocean Coast. Man. 165, 117–125. https://doi.org/10.1016/j.ocecoaman.2018.08.001.

Rocklin, D., Santoni, M.C., Culioli, J.M., Tomasini, J.A., Pelletier, D., Mouillot, D., 2009. Changes in the catch composition of artisanal fisheries attributable to dolphin depredation in a Mediterranean marine reserve. ICES J. Mar. Sci. 66 (4), 699–707. https://doi.org/10.1093/icesjms/fsp036.

Santos, M.B., Fernandéz, R., López, A., Martínez, J.A., Pierce, G.J., 2007. variability in the diet of bottlenose dolphin, *Tursiops truncatus*, in Galician waters, north-wester Spain, 1990-2005. J. Mar. Bio. Ass. U. K. 87, 231–241.

dos Santos, M.E., Coniglione, C., Louro, S., 2007. Feeding behaviour of the bottlenose dolphin, Tursiops truncatus (Montagu, 1821) in the Sado estuary, Portugal, and a review if its prey species. Zoociências 9 (1), 31–39.

Schipper, J., Chanson, J.S., Chiozza, F., Cox, N.A., Hoffmann, M., Katariya, V., Lamoreux, J., et al., 2008. The status of the world's land and marine mammals: diversity, threat, and knowledge. Science 322 (5899), 225–230. https://doi.org/10.1126/science.1165115.

Silva, M., 1999. Diet of common dolphins, *Delphinus delphis*, off the Portuguese continental coast. J. Mar. Bio. Ass. U. K. 79, 531–554.

Snape, R.T.E., Broderick, A.C., Çiçek, B.A., Fuller, W.J., Tregenza, N., Witt, M.J., 2018. Conflict between Dolphins and a Data-Scarce Fishery of the European Union (Godley, et al). Hum. Eco 46, 423–433.

Terranova, F., Raffa, A., Floridia, S., 2022. Vocal Behaviour of a Bottlenose Dolphin Pod during a Deadly Bycatch Event in the Gulf of Catania, Ionian Sea. J. Mar. Sci. Eng. 10 (616), 1–10.
Vingada, J.V., Eira, C. 2018. Conservação de Cetáceos e Aves Marinhas em Portugal Continental. O projeto LIFE+ MarPro. LIFE. Rainho & Neves, Lda., Santa maria da Feira.
Wade, P.R., Reeves, R.R., Mesnick, S.L., 2012. Social and behavioural factors in cetacean responses to overexploitation: are odontocetes less "resilient" than mysticetes? J. Mar. Bio. Vol. 2012, 567276 https://doi.org/10.1155/2012/567276.
Wade, P.R., Long, K.J., Francis, T.B., Punt, A.E., Hammond, P.S., Heinemann, D., Moore, J.E., et al., 2021. Best practices for assessing and managing bycatch of marine mammals. Front. Mar. Sci. 8, 757330 https://doi.org/10.3389/fmars.2021.757330.
Wickham, H., 2016. ggplot2: Elegant Graphics for data Analysis. Springer-Verlag, New York.