LIFE ilhas barreira

REPORT

Action D4 from Ilhas Barreira project

Best Practices to reduce bycatch including trials´ results and economic viability.

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COFINANCIAMENTO

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Best Practices to reduce bycatch including trials´ results and economic viability.

LIFE Ilhas Barreira Project.

UALG/CCMAR

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SUMMARY

This document summarizes the activities carried out in action D4 of the LIFE Ilhas Barreira project, which aims to assess mitigation measures to prevent the accidental capture of seabirds and their proximity to fishing vessels. As mentioned in previous reports, these measures were exclusively tested on fixed nets (gillnets and trammel nets) from 2021 to 2023, employing approaches that include visual and acoustic devices, along with the implementation of best practices onboard.

The tests with the megaphone did not show any effect on the behavior of the birds, on the contrary, when the device was used, the average number of birds per event was higher than observed in the control tests (without the megaphone). This result was consistent across all distance bands.

The tests using the 'scarybird' device to reduce bird bycatch, unfortunately, did not provide promising results as expected. In most distance bands, there was a higher abundance of birds in the experimental treatment compared to the control treatment. When the results were broken down by mesh size, it was observed that the 60mm mesh demonstrated better results, showing a lower occurrence of birds in the experimental events at shorter distances. Despite the overall lower bird abundance in the 60mm mesh treatment, the impact of the 'scarybird' device varied depending on the bird species and mesh size.

Among the various measures implemented, the adoption of best practices onboard and the subsequent behavioral changes resulted in the best outcomes, leading to a reduction in bird abundance. Upon analyzing different mesh sizes, the implementation of these measures had a significant impact on bird distancing, especially in the 220mm and 120mm mesh sizes. In these two mesh sizes, the best results were observed in terms of distancing both for *Larus* spp. and *Morus Bassanus*.

RESUMO

Este documento resume as atividades desenvolvidas na ação D4 do projeto LIFE Ilhas Barreira, que visa avaliar medidas de mitigação para prevenir a captura acidental de aves marinhas e sua aproximação às embarcações de pesca. Conforme mencionado em relatórios anteriores, essas medidas foram testadas exclusivamente em redes fixas (emalhar e tresmalho) no período de 2021 a 2023, utilizando abordagens que envolvem dispositivos visuais e acústicos, além da implementação de boas práticas a bordo.

Os testes com o megafone não demonstraram qualquer efeito no comportamento das aves; pelo contrário, quando o dispositivo foi utilizado, o número médio de aves por evento foi superior ao observado nos testes de controlo (sem megafone). Este resultado verificou-se em todas as bandas de distância.

Os testes com o papagaio afugentador não mostraram resultados promissores, observando-se maior abundância de aves no tratamento experimental em comparação com o tratamento controlo, na maioria das bandas de distância. Ao analisar individualmente as diferentes malhas utilizadas, observou-se que a malha de 60mm apresentou melhores resultados, com uma menor ocorrência de aves nos eventos experimentais nas primeiras faixas de distância. Quanto ao impacto do papagaio afugentador nas espécies *Larus* spp. e *Morus bassanus*, de modo geral, a utilização do dispositivo teve um efeito positivo no afastamento de ambas as espécies em relação à embarcação. Especificando para as malhas, a presença do dispositivo influenciou de forma positiva, ou seja, menor número de aves perto da embarcação, a malha de 60mm para a espécies *Larus* spp., a de 220mm para *Morus Bassanus*, e a de 120mm para ambas as espécies.

De todos as medidas implementadas, as boas práticas a bordo, com a correspondente alteração de comportamentos, foi a que mostrou melhores resultados, em que se verificou menor abundância de aves quando postas em prática. Analisando as diferentes malhagens, a aplicação desta medida teve um impacto significativo no afastamento das aves nas malhas de 220mm e 120mm. Foi nestas duas malhas que também se verificou melhores resultados no afastamento de *Larus* spp. e *Morus Bassanus*.

| INTRODUCTION

1.1 Fisheries in mainland Portugal

Portugal is a country where fishing is an activity with long tradition, cultural value and high economic importance. The importance of the fishing sector is related with the fact that Portugal holds and Exclusive Economic Zone of about 1.727.408 km^2, a large coastal area and a continental platform with high productivity, which are exceptional conditions to contribute to the maintenance of an important array of fisheries resources. Simultaneously, the Portuguese fishing fleet operating in the Atlantic area, shows a great diversity of vessels, fishing and technology practices, which developed regionally in a close adaptation to the exploration of the fish resources (Alexandre *et al.* 2022).

The bulk (> 80 %) of the Portuguese fleet is composed mainly by artisanal small local vessels (< 9 meters; DGRM, 2022), which are mostly multi-gear (operating fixed bottom set-net fishing gears like gill and trammel nets, longlines, pots and traps, bivalve dredges and less frequently purse seines). Vessels larger than 9 meters are classified as "coastal" and include mainly multi-gear vessels, larger purse seiners, demersal trawlers and offshore (operating in international waters) longliners or demersal trawlers.

The main species landed in mainland Portugal are small pelagics such as sardines (*Sardina pilchardus*), mackerels (*Scombrus scomber, Scomber colias* and *Trachurus* spp.) and anchovy (*Engraulis encrasicolus*) in coastal waters and mostly targeted by the purse seine fleet. From the demersal community and targeted by the multi-gear fleet, mainly using bottom set-nets are the hake (*Merluccius merluccius*), monkfish (*Lophius piscatorius*), red mullets (*Mullus* spp.), sparid fishes (e.g. *Diplodus* spp., *Pagellus* spp., *Pagrus* spp., *Sparus aurata*) flat fishes (e.g. *Solea* spp.) and cuttlefish (*Sepia officinalis*). There are other important commercial species which are very important in value such as the octopus (*Octopus vulgaris*) targeted by pots and traps, clams (e.g., *Donax* spp.) caught by dredges and crustaceans (*Parapenaeus longirostris* and *Nephrops norvegicus*) targeted by trawlers (DGRM, 2022).

1.1.1 Algarve

The Algarve area holds about 30 % of the national fleet, from which 80 % are local vessels. For the region, the fishing industry from 2020 to 2022 contributed in average 15.9 % in national landings and 26.2 % in national sales (DGRM, 2022). Therefore, we cannot underestimate the importance of the fishing sector in the area and its contribution for the national economy.

1.2 Seabirds and fisheries interactions

1.2.1 Worldwide

Fisheries can indirectly impact marine life as they cause changes in the levels of the food chain, through overfishing and/or increased food availability (Oliveira *et al*. 2022). Directly, fisheries, provide the occurrence of injuries or deaths caused by interactions with fishing gear or vessels. The frequency of interactions between groups of marine animals and fishing gear has been increasing, with marine birds being one of the most affected groups. Generally, marine birds feed in the most productive areas of the oceans, the same target areas used in commercial fisheries. This spatial and trophic overlap can trigger interactions between birds and vessels/fishing gear. These interactions can be both positive for fishers, who use marine bird aggregations to detect schools of fish, and for birds that obtain large amounts of food, easily and predictably, through discards of fish and viscera, during fishing operations.

The above-mentioned discards/rejects from fishing are defined as the portion of the catch that is not retained on board during fishing operations and is returned to the sea (Kelleher 2005). Usually, the rejected capture is dead or dying and may or may not be a target species (Oliveira *et al*. 2022). The seabirds take great advantage of these discards since they are easy to access and spend less time and energy foraging. This association can benefit the breeding season, allowing for greater breeding success, and the non-breeding season, enabling better physical condition and the highest survival, promoting the population increase (Oliveira *et al.* 2022).

On the other hand, there may be negative interactions in which marine birds can harm fisheries when, for example, they steal bait, damage fishing gear, or reduce the amount of capture (Oliveira *et al*. 2015). Conversely, fishing also has negative effects on birds involving competition for the same fishery resource and the occurrence of fishing-related injuries and mortality (Oliveira *et al*. 2015, 2020, 2022; Araújo *et al*. 2022).

Bycatch is considered one of the main threats to several seabird species. Most of the seabirds have low reproduction rates and delayed maturity, making populations of these groups very susceptible to the effects of interactions with fisheries (Dias *et al*. 2019; Oliveira *et al*. 2020). The incidental capture of birds is a worldwide problem and encompasses all fishing gear, especially in longline, set net, and trawling, however, it can occur in purse seine, traps, and recreational fishing (Oliveira *et al*. 2020, 2022). Globally, it is estimated that hundreds of thousands of marine birds die in longlines and static nets (Anderson *et al*. 2011; Zydelis *et al*. 2013), however, there are no estimates for the remaining fishing gear.

1.2.2. Portugal

The Portuguese mainland coast is used by several marine birds' populations to feed, as a resting place, or as a passage through various life stages such as reproduction, wintering, and migration (Meirinho *et al*. 2014). The marine birds' bycatch subject has only recently begun to be assessed in mainland Portugal, mostly as a result of some recent projects (e.g. Life Marpro, FAME, Life Berlengas; Oliveira *et al*. 2015, 2020; Vingada and Eira 2018, Araújo *et al*. 2022). These works relied on onboard observers, harbour questionnaires and log-books filled by vessel crew members, and allowed to detect bycatch mortality rates and calculate risk assessments for the fisheries and marine bird species of most concern.

The bycatch mortality rate is higher for the fixed gears (nets and longlines) in the polyvalent fleet and purse seining, and the species of most concern is the Northern Gannet (*Morus bassanus*) and the Balearic Shearwater (*Puffinus mauritanicus*) (Oliveira *et al*. 2015, 2020; Araújo *et al*. 2022). The bycatch risk for Balearic Shearwater was higher in nets and purse seines and the highest Northern Gannet bycatch risk was obtained for longline and net fisheries (Araújo *et al*. 2022).

A dedicated project for the Algarve region (Mar2020-iNOVPESCA) prior to LIFE Ilhas Barreira allowed to detect interaction levels of artisanal fisheries in the area and air-breathing megafauna (Marçalo *et al*. 2021; Alexandre *et al*. 2022), from which for marine birds, the fisheries with high bycatch rates in the leeward region (the area of operation of LIFE Ilhas Barreira), were purse seiners and nets.

1.3. Mitigation Measures

In order to mitigate bycatch, several measures have been tested, over the years, worldwide (Williams *et al*. 2012). These can be divided into operational (behavior changes during fishing operations) and technical measures (fishing gears modifications). Depending on the fishing gear, different mitigation measures can be applied, and can act in several ways:

Keep the birds away (e.g., scaring lines, visual or acoustics barriers);

Reduce bird attraction (e.g., night setting, dyed bait, net cleaning, fish remains and discards management)

Difficult access for bird (e.g., unfrozen bait, increase of the lines weight, increase of the nets depth, underwater setting, side setting, modified hooks)

All these measures are species, fishery and area dependent. Most research has been dedicated to longline and trawl fisheries with a mix of outcomes, but a lot of work is still missing in other fisheries such as nets (Almeida *et al*. 2023).

For gear types like bottom set nets, limited effective technical solutions have been identified for mitigating marine bird bycatch, as evidenced by studies (Melvin *et al*. 1999; Trippel *et al*. 2003; Mangel *et al*. 2018). The tested solutions have generally yielded unsatisfactory results (Almeida *et al*. 2018, 2023; Oliveira *et al*. 2021), primarily due to impracticalities in their onboard implementation, posing challenges to their adoption by fishers.

Consequently, efforts to identify and develop measures for gears like bottom set nets should consider local fleet characteristics, including technical specifications and prevalent seabird species subject to bycatch. A comprehensive understanding of these factors is essential to tailor effective mitigation measures and determine appropriate testing conditions.

The acceptance of modifications within the fishing community, particularly among artisanal fleets, is more likely if the proposed measures are characterized by simplicity, ease of operation, minimal disruption to fishing activities, economic viability, and no adverse impact on catch volumes (Avery *et al*. 2017). Therefore, beyond assessing the efficacy of bycatch reduction, testing mitigation measures should encompass economic considerations and an evaluation of their acceptability within the fishing industry, as advocated by Good *et al*. (2020).

Under Action A6 of this project, dedicated to assessing interactions (bycatch) between seabirds and problematic fisheries in the region, namely bottom set nets and purse seining, efforts were made to evaluate field outcomes. Under action C7, the objective was to implement mitigation trials aimed at reducing seabird bycatch on gears or métiers where most bycatch was observed. Trials followed under action D4 to monitor the implementation of mitigation measures, which were exclusively conducted in bottom set-nets due to operational constrains imposed by the purse seine fishery that operates mostly at night time.

1.4. Objectives

This report unveils the findings from mitigation trials involving the deployment of two technical devices (scary bird and megaphone) and one alteration in fisher behavior on vessels operating in the leeward region of the Algarve (Portugal). Anticipating a decline in bycatch or a decrease in the proximity of birds to fishing gear during critical operations such as net setting (gear deployment) and hauling (gear collection) — periods with heightened bycatch risk (Almeida *et al*. 2023). The impact of the measures on Landings Per Unit Effort (LPUE) was also assessed.

2 | METHODOLOGY

2.1 Study area

The work targeted the area off the Ria Formosa National Park (Figure 1) in the Leeward region of the Portuguese southern cost (Algarve, Figure 2). The Ria Formosa Natural Park ranges from the sandy peninsulas of Ancão (37° 1´54.818” N, 8° 2´18.272” W) and Manta Rota (37° 9 `33.149” N, 31´36.289” 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.

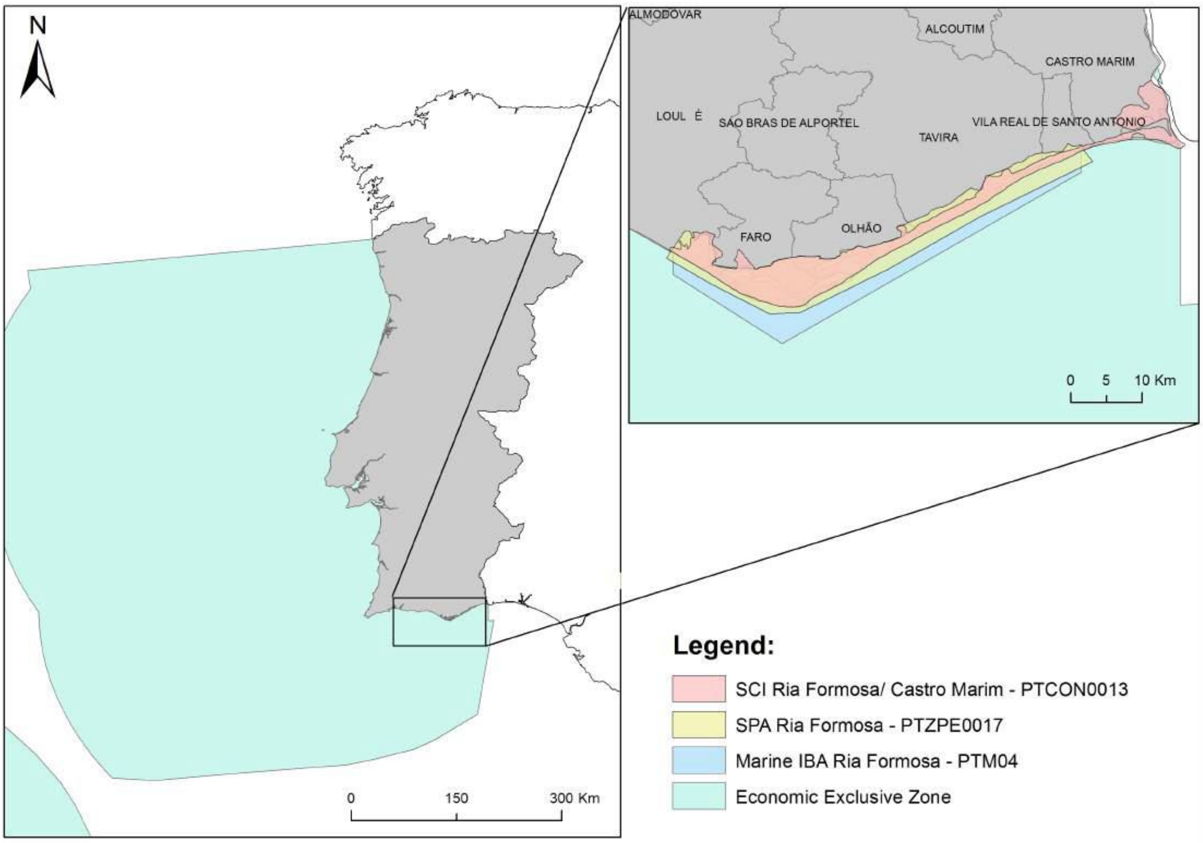


Figure 1 – Map of the designated area of the Ria Formosa Natural Park and marine IBA.

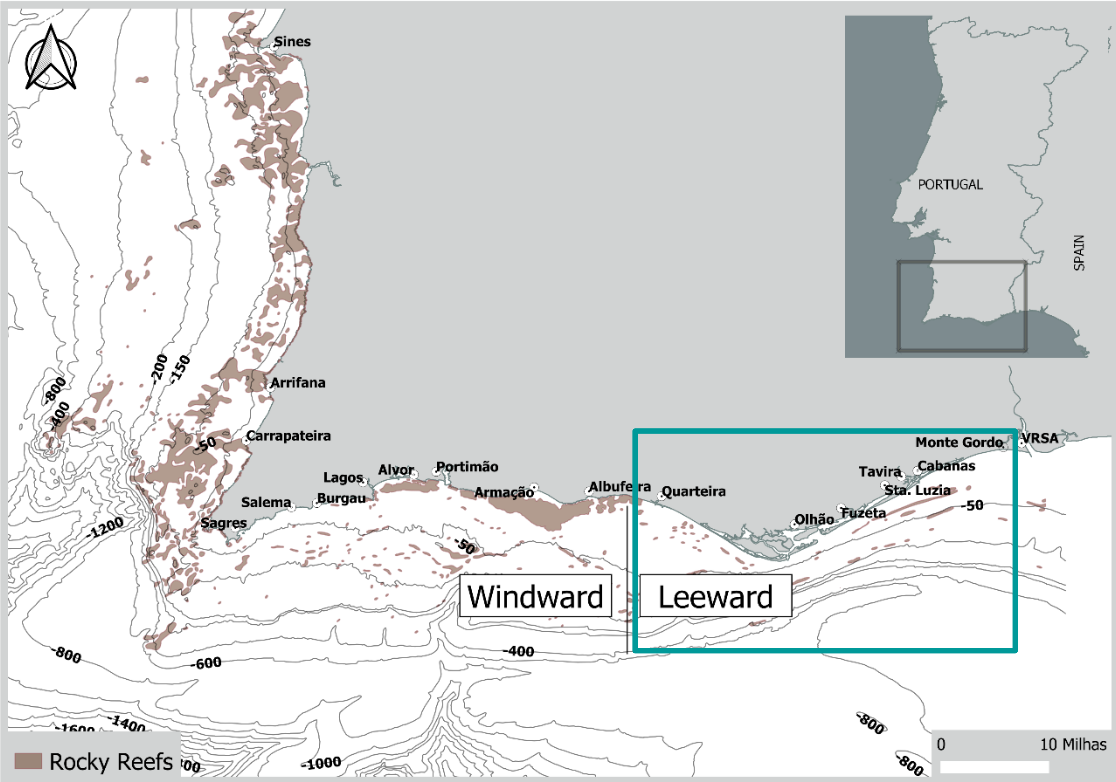


Figure 2 – Map with fishing ports in the Leeward region selected for the work performed within A6 (Quarteira, Olhão, Culatra, Fuzeta, Tavira, Cabanas, Monte Gordo).

In particular, the sea area in front of Barrier islands is home of a varied range of marine bird species, amongst which the Balearic Shearwater (an Annex I priority species, classified as Critically Endangered), the Northern Gannet, Little Tern (*Sternula albifrons*),Cory's shearwater (*Colonectris borealis*), Yellowlegged Gull (*Larus michahellis*). The project area holds significant concentrations of Balearic shearwaters during migration and wintering periods (Pereira *et al*. 2018) using the area as feeding and resting grounds. Also, as the Deserta island in the Ria Formosa Natural Park, holds the largest European colony of Audouin´s gulls (*Larus audouinnii*), it is legitime to infer that the species uses the offshore area as a foraging ground overlapping with fisheries operating in the area.

Ornithological importance

Based on the results obtained in the harbour questionnaire surveys conducted within the scope of A6, the species with the highest bycatch rate were the Northern Gannet, Great Cormorant (*Phalacrocorax carbo*), and seagulls, with incidental captures also occurring for shearwaters and auks. However, fishers showed difficulty in identifying shearwater and seagull species, namely the Balearic shearwater and Audouin's gull, which are the target species of the project. Therefore, mitigation trials focused on these species, in addition to those that recorded higher rates of accidental capture. The results of the mitigation measures' effects on the most observed species are detailed in the annex section.

2.2 Trialling the deterrent measures

Control and experimental fishing trips using the three mitigation tools (scary bird, megaphone, and behaviour alteration) were carried out using identical fishing vessels and crews as suggested in Almeida *et al*. (2023) (Figure 3). This approach ensured the replication of consistent conditions across both types of trips, encompassing similar fishing operations for control and experimental trips. This included uniform gear sinking times achieved using identical nets and fishing materials, as well as maintaining consistency in various day-to-day procedures involved in fishing operations.

Trials were conducted during fishing trips in commercial vessels from the ports of Olhão and Quarteira (Figure 3) employing various types of fishing gear, such as gillnets (GNS) and trammel nets (GTR). These trials were overseen by a trained on-board observer responsible for collecting comprehensive data on the fishing operation, including phases like navigation, gear deployment, and hauling. Additionally, the observer recorded the GPS location of fishing activities and interactions between seabirds and the fishery. Bird counts and species identification were performed every 15 minutes, with each bird's distance from the vessel categorized into bands (A = 0–20 m, B = 20–50 m, C = 50–100 m, D = 100–200 m, E = 200–300 m, F ≥ 300 m). Each bird's behavior was noted, whether it was in direct flight, circling around the vessel, or sitting on the water. The behavioral codes and distance bands utilized were in line with the European Seabirds At Sea (ESAS) methodology (Camphuysen and Garthe, 2004), with the addition of an extra distance band

(0–20 m) to gather additional information about bird numbers and behaviors near the vessel and fishing gear.

All data was recorded using a tablet (1 for each observer; Samsung Galaxy Tab A 8.0, 8", 2 GB ROM) in the Cyber tracker application, especially developed by SPEA and used in other projects when monitoring Portuguese fisheries interactions with marine birds.

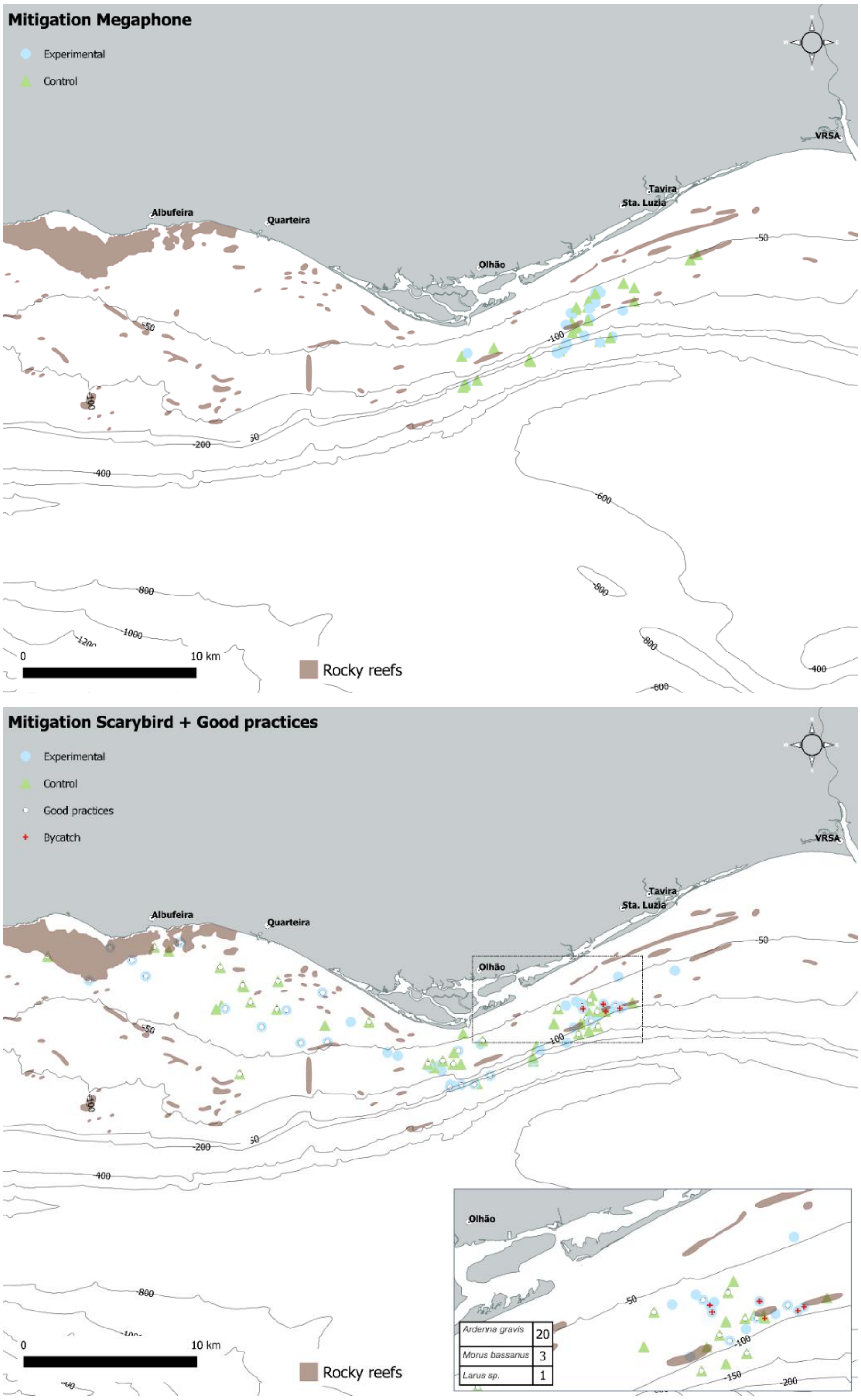


Figure 3 - Distribution of mitigation trials along the study area; top - Megaphone and bottom - Scarybird and good practices. Bycatch events are identified.

2.2.1 Acoustic device – Megaphone

The megaphone device acts as a distress caller with a built-in recording of distressed birds and is intended to scare away birds in the vicinity of the vessel. The megaphone model is the AH25, an ACTIVE WEATHERPROOF HORN SPEAKER, 25W, with the following dimensions: 295 x 265 x 25mm (~2kg). The system includes a power module connected to the vessel's power (12V), and two external inputs (USB and microSD) for audio file playback. The system was manually activated by the master using a switch located next to the vessel's throttle lever. The transmission speed is 51 kbps, with different time intervals to avoid habituation, and the maximum duration of vocalizations is 3 minutes and 15 seconds.

It was installed at the highest point of the vessel and was activated during the net deployment (Figure 4). The experimental trials (both using the megaphone and controls) took place between April and October 2021. The device was set up in April 2021 in one vessel and in June 2021 in the second vessel, both in Olhão fishing port.

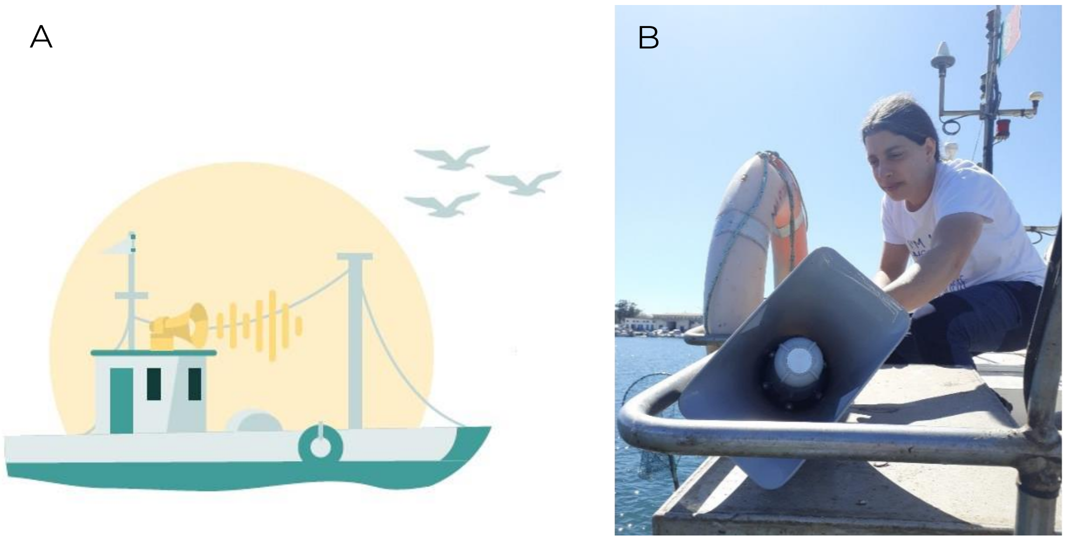


Figure 4 – (A) Megaphone illustration and (B) implementation in a vessel @Ana Marçalo.

2.2.2 Visual device – Scarybird kite

The scarybird device, designed in the shape of a bird of prey, incorporates a retractable system that keeps it in constant motion with even a slight breeze (2 km/h), effectively mimicking the flight pattern of a bird of prey hovering above the fishing area. Its dimensions, measuring 155 × 56 cm, emulate the wingspan and body length of a medium-sized bird of prey, falling between the size range of a large peregrine falcon and a red kite. Positioned at the highest point of the fishing vessel, the scarybird is mounted on a 4 m long pole and a 0.65 m craft line to maintain its stability. Upon deployment, the scarybird reaches a maximum height of 7 m above sea level. Careful consideration was given to its placement, ensuring it was set at a safe distance from vessel structures and fishing equipment, while being as close as possible to the location where nets were deployed and retrieved (refer to Figure 5.). The device was installed and removed at the start and end of each fishing trip, a process taking approximately 15 minutes by the observers. The scarybird was operated in both control and experimental events between October 2021 and January 2023. The trials started in October 2021 in two vessels in Olhão fishing port, and in April 2022 in two vessels in Quarteira fishing port.

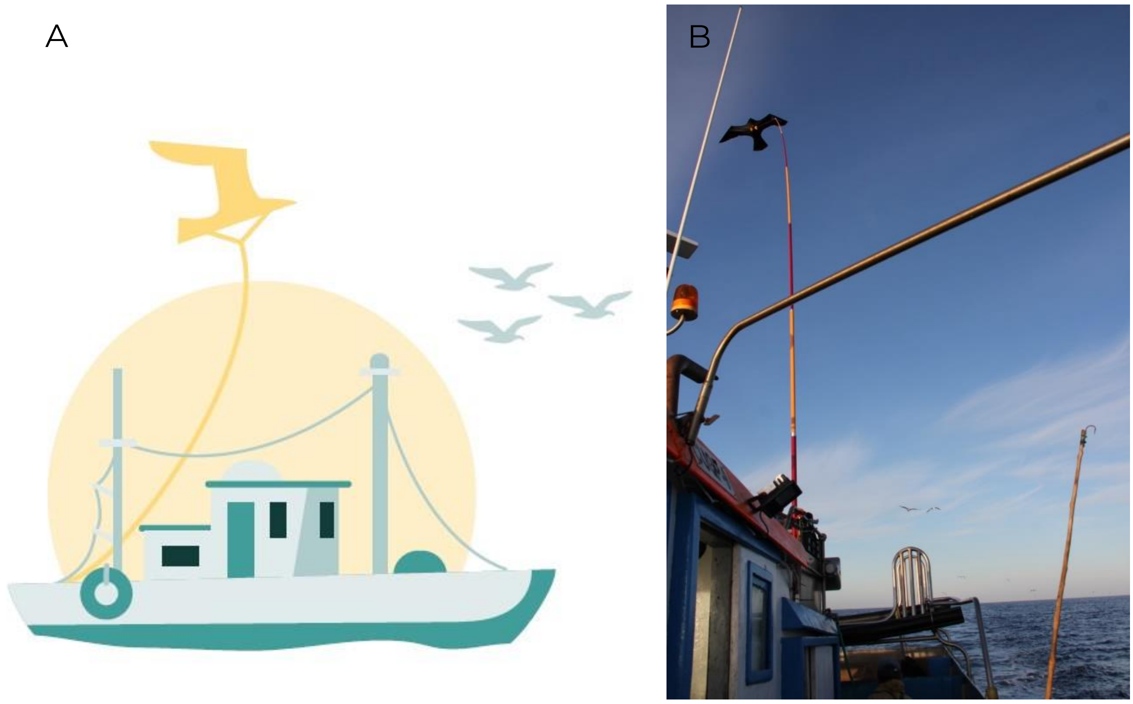


Figure 5 – (A) Scarybird in bird of prey shape illustration and (B) implemented in a vessel @Magda Frade.

2.2.3 Good practices onboard – Discards control

Besides these devices (megaphone or scarybird), on-board observations during A6, allowed to detect fisher behaviors during fishing operations as the main cause for attracting birds to the boat. Therefore, the team gradually suggested some change to fishers' behavior in order to: a) improve cleaning of the net after hauling and before deployment. This way the net when deployed would reduce the attraction of seabirds and number of dives, reducing the chances of entanglement; b) avoid evisceration of fish and any fish discards during fishing operations (net hauling and deployment) to also reduce the attraction of birds. Keeping viscera or any fish to be discarded in a container and getting rid of it during navigation would result in less attraction of the marine birds to the vicinity of the operating vessel (Figure 6), thus also reducing the chances of entanglement and bycatch risk.

So, from May 2022 until January 2023, the control and experimental events using the scary bird were performed with or without containers so we could test and evaluate the differences.

Figure 6 - Containers strategically placed next to the fishermen, during net hauling and deployment. @Flávia Carvalho

2.3 Impact of the deterrent measure on fish catch

In addition to assessing the effectiveness of mitigation measures in reducing accidental captures, the socio-economic impact of these measures on fishing was evaluated. Three aspects were analysed for this purpose: the expenses and costs associated with the implementation of the measures, the impact of the measures on fishing catches, and the acceptability of the measures among fishers. All data was collected by the observers except for the weight of the catches and their respective selling prices, which were obtained from the sales sheets provided by the skipper.

During the project's concluding stage, semi-structured interviews were carried out with the skippers of the vessels participating in the tests. The goal was to evaluate their acceptance of the mitigation measures. The interviews covered a range of topics, including challenges encountered in implementing these measures and the fishers´ tendency to continue using them post-project completion.

2.4 Data analysis

The fishing operations' locations, georeferenced for every fishing trip, were utilized to depict the fishing areas for both control and experimental trips (refer to Fig. 3). Bird counts for the trials occurred during specific moments of the most problematic operations, namely hauling and net deployment. Owing to challenges in accurately distinguishing between immature yellow-legged gulls and lesser black-backed gulls, especially in the presence of high gull numbers, all ages and both species were consolidated into a single group (referred to hereinafter as "gulls") for all analyses.

The effectiveness of mitigation measures was based on comparing the number of birds in the vicinity of the vessel during treatments (control sets vs experimental mitigation sets) with t-tests. When the assumptions of normality (Shapiro–Wilk test) and homoscedasticity (Equal Variance Test) were not fulfilled, a non-parametric Mann-Whitney Rank Sum Test was used to compare the number of birds in the nearest distance band to the vessel (<20m) with the number of birds in the other distance bands for control and experimental treatments. Also, to understand if the use of mitigation measures had an impact on LPUE, the same tests were used. Statistical significance was inferred when $p < 0.05$.

3 | RESULTS

3.1 Megaphone

The métiers tested targeted species such as hake, monkfish and sole. The monitored vessels operated the nets at an average depth between 75m and 150m and spent an average of 19 to 96 hours soaked in the water (Table 1).

Table 1. Characteristics of the sampled trips and hauls per vessel in the métiers where the megaphone was tested.

Vessel	Fishing gear	Mesh size	Trips	Events	Target specie	Average depth (m)	Average soaking time (h)
A +B	Gillnet	80mm	36	19	Hake	114,6 ± 64,7	18,6 ± 4,5
		220mm		17	Monkfish	145,1 ± 50,3	95,8 ± 41,4
A	Trammel net	120mm	10	10	Sole	78,6 ± 7,5	49,4 ± 10,7

To test the effect of the device as a bird deterrent measure, a total of 42 fishing trips and 46 fishing events were monitored in one year (2021). The megaphone was operated in 20 fishing trips (21 experimental fishing events), while 22 fishing trips with no megaphone device (25 control fishing events) were also monitored.

The trials involving the megaphone showed no significant impact ($p > 0.05$, Mann-Whitney test) on deterring birds from the vessel during fishing operations across all tested métiers. Conversely, when the device was employed, the average number of birds per event exceeded that observed in control trials (without the megaphone). This outcome was consistent across all band ranges, but was particularly pronounced in the first two bands, specifically within the <20m and 20-50m proximity from the vessel (Figure 7).

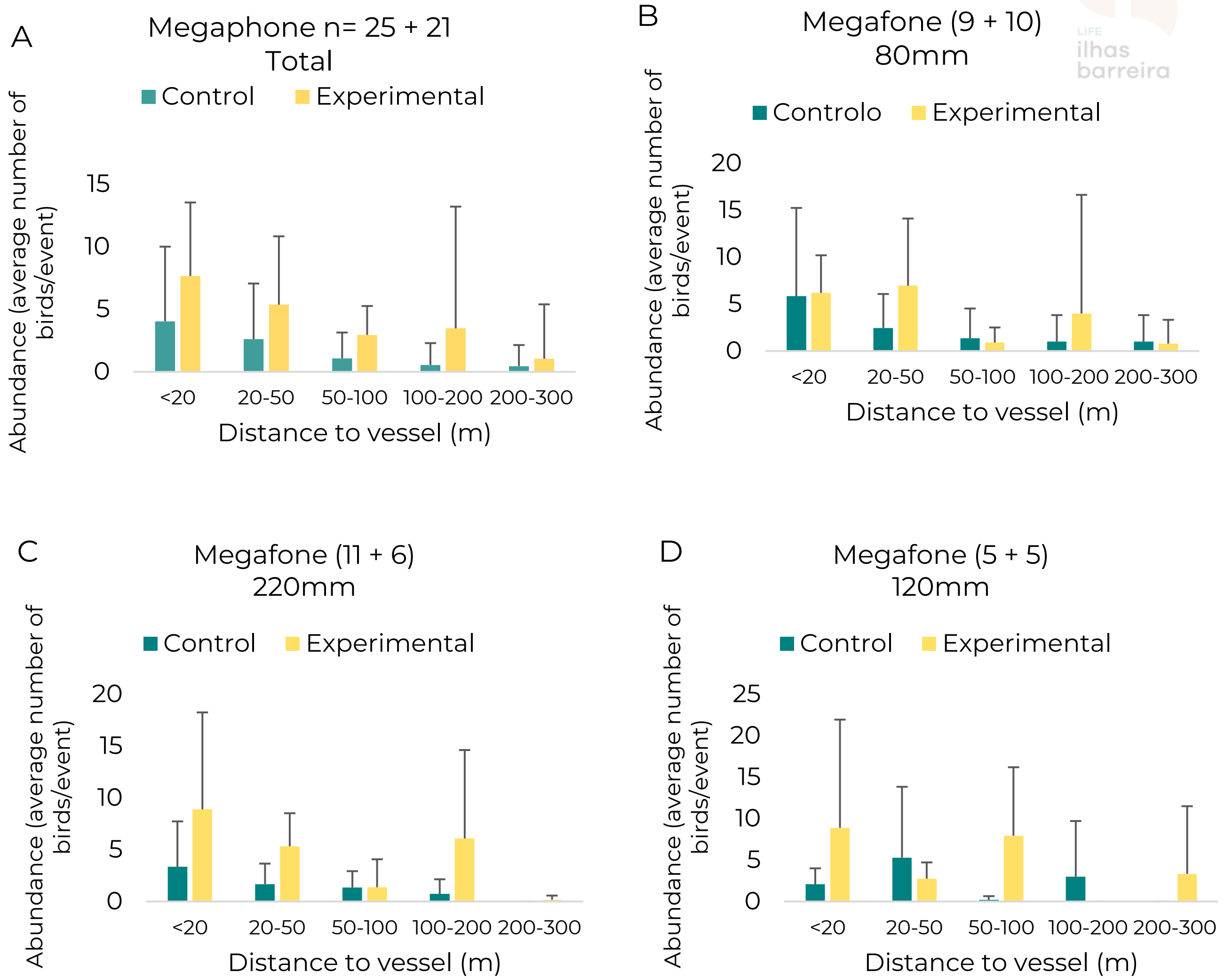


Figure 7 - Abundance of seabirds (average number of birds per event and standard deviation) in different range bands from the fishing vessel, operating both gillnets and trammel nets (A), gillnets (métier 80mm (B), 220mm (C)) and trammel net (120mm, D), during the observations on board, testing the megaphone device (experimental or control).

In the 42 fishing trips monitored, gulls (considering both the Yellow-Legged Gull and Lesser Black-Backed gull) were the most abundant species around the fishing vessel, occurring in all fishing trips, followed by Audouin's Gull and Northern Gannets (Table 2). From all other species recorded during on-board monitoring, two other species occurred in 50 % or more of the fishing trips: Cory's shearwater and Balearic shearwater.

Table 2 - Bird occurrence (N and %) and bycatch (N) of the seabird species recorded in the study area (0–300 m distance band from the vessel) during the fishing sets of 42 fishing trips monitored using the megaphone (22 control and 20 experimental fishing trips) in 2020–2022.

	Control						Experimental					
Species	Fishing trips occurrence %	N	Fishing sets occurrence %	N	Sum birds	By-catch	Fishing trips occurrence %	N	Fishing sets occurrence %	N	Sum birds	By-catch
Larus michahellis/fuscus	100	22	88	22	471	0	100	20	100	21	643	0
Larus audouinii	91	20	12	3	11	0	70	14	29	6	20	0
Morus bassanus	86	19	24	6	19	0	90	18	19	4	15	0
Calonectris borealis	55	12	12	3	19	0	55	11	19	4	39	0
Puffinus mauretanicus	45	10	8	2	2	0	65	13	24	5	12	0
Hydrobates pelagicus	18	4	4	1	8	0	15	3	5	1	2	0
Catharacta skua	14	3	4	1	1	0	15	3	5	1	1	0
Ardenna gravis	5	1	0	0	2	0	10	2	0	0	4	0
Larus melanocephalus	5	1	0	0	1	0	5	1	0	0	2	0
Puffinus spp.	5	1	4	1	1	0	5	1	5	1	1	0
Stena hirundo	5	1	0	0	8	0	5	1	0	0	2	0
Thalasseus sandvicensis	5	1	4	1	6	0	0	0	0	0	0	0
Melanitta nigra	0	0	0	0	0	0	5	1	0	0	8	0

The number of birds recorded (of the more abundant five species or groups) varied across distance bands, being higher in the closest distance band to the vessel for gulls and the opposite for Northern Gannets, Cory's shearwater and Balearic shearwater.

Table 3 – Number of birds per species (average ± standard deviation) according to the distance band to the fishing vessel (0–20 m, 20–300 m) during fishing sets of control and experimental fishing trips (Ncon = 22, Nexp = 21).

	0-20m		20-300m	
	Control	Experimental	Control	Experimental
Larus michahellis/fuscus	14.52 ± 23.82	13.48 ± 11.14	4.44 ± 8.58	17.14 ± 18.08
Larus audouinii	0.40 ± 1.15	1.24 ± 2.36	0.04 ±0.20	0.00 ± 0.00
Morus bassanus	0.12 ± 0.60	0.14 ± 0.65	0.64 ± 1.89	0.57 ± 1.54
Calonectris borealis	0.00 ±0.00	0.05 ± 0.22	0.76 ±1.48	1.76 ± 6.76
Puffinus mauretanicus	0.04 ± 0.20	0.14 ± 0.48	0.08 ± 0.28	0.00 ±0.00
Hydrobates pelagicus	0.00 ± 0.00	0.00 ± 0.00	0.32 ± 1.60	0.10 ± 0.44

Economic impact

The only cost associated with the implementation of this mitigation measure was the acquisition and installation cost of the deterrent device (megaphone) (492€ per megaphone) and technical travel expenses for installation (2-3 trips; 100€ each).

Regarding the impact of the megaphone on the target catches of the fishing activity, no significant differences were observed (p> 0.05, Mann-Whitney) within treatments, for all mesh sizes, in both the volume of catches and the revenue generated at the fish auction, the revenue when using the megaphone was higher.

Table 4 – Average landings in weight and value of landings in euros per trip, per mesh size (target species).

LPUE (kg/km)

	Control	Experimental
Gillnets 80mm (Hake)	19.9 ± 7.2	22.7 ± 21.0
Gillnets 220mm (Monkfish)	12.0 ± 7.4	14.1 ± 7.4
Trammel nets120mm (Sole)	8.4 ± 4.0	12.0 ± 3.0
Average ± SD	14.4 ± 8.1	17.5 ± 15.1

Value of landings (€)

	Control	Experimental
Gillnets 80mm (Hake)	740.7 ± 523.0	788.9 ± 565.9
Gillnets 220mm (Monkfish)	769.9 ± 571.9	904.4 ± 426.80
Trammel nets120mm (Sole)	618.1 ± 124.6	844.6 ± 284.7
Average ± SD	727.9 ± 480.8	840.5 ± 456.0

Acceptance of mitigation measure by fishers

Concerning the acceptability of the implemented measure by the involved skippers, the megaphone gathered significant approval. Its acceptance was strengthened by the fact that the project covered its installation costs, ensuring it did not disrupt fishing operations and had no adverse effects on fish catches. Despite this positive reception, fishers expressed the belief that the megaphone did not influence the quantity of birds present during its use, what is proven by the results obtained for all the tested mesh sizes used. Consequently, its effectiveness as a mitigation tool was deemed unsatisfactory, and there was reluctance within the fishing community to adopt it due to its perceived high cost and results. The utilization of the device did not yield a significant impact on landings nor on revenue.

3.2 Scarybird kite

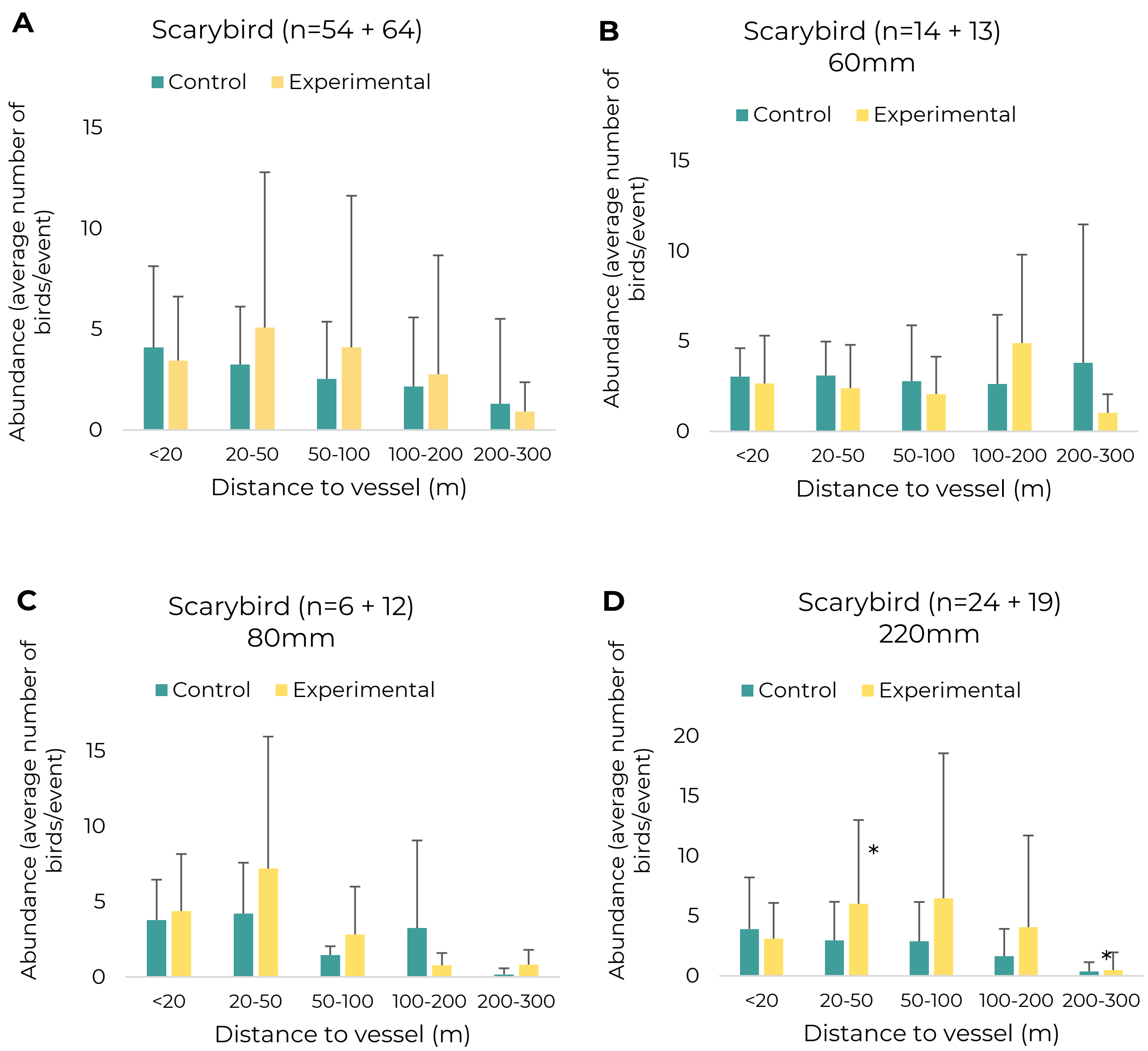
The métiers tested targeted species such as hake, monkfish, sole and red mullet. The monitored vessels operated the nets at an average depth between 27m and 116m and spent an average of 1 to 110 hours soaked in the water (Table 5).

Table 5. Characteristics of the sampled trips and hauls per vessel in the métiers where the scarybird was tested.

Vessel	Fishing gear	Mesh size	Trips	Events	Target specie	Average depth (m)	Average soaking time (h)
A +B	Gillnet	80mm	48	17	Hake	75,2 ± 20,7	16,1 ± 5.5
		220mm		44	Monkfish	115,3 ± 40,8	108,4 ± 38,5
A	Trammel net	120mm		30	Sole	88,7 ± 9,2	68,8 ± 19,1
C+D	Gillnet	60mm	27	27	Red mullet	27,9 ± 11,9	1,85 ± 0,3

To test the effect of the device as a bird deterrent measure, a total of 75 fishing trips and 118 events (net hauling and deployment) were monitored in two years (2021–2023). The scarybird was operated in 40 fishing trips (64 experimental fishing events – net hauling or deployment), while 35 fishing trips with no scarybird device (54 control fishing events) were also monitored.

The scarybird trials, for the first and last range band, <20m and 200-300m, showed a higher abundance of birds in the control treatment compared to the experimental treatment (with scarybird). However, for the rest of the range bands, 20-50m, 50-100m, 100-200, there was a higher abundance of birds in the experimental treatment compared to the control treatment (Figure 8 A). Nonetheless, none of the treatments showed significant differences (p > 0.05, Mann-Whitney Rank Sum Test). When analysing each métier individually, for the métier 220mm and trammel net (120mm) (Figure 8 D and 8 E), none of the treatments showed statistically significant differences (p > 0.05, Mann-Whitney Rank Sum Test), except when significant differences were observed in the métier 220mmm for the distance band 20-50m (p=0,032, Mann-Whitney Rank Sum Test) and 200-300m (P=0,035, Mann-Whitney Rank Sum Test) with a higher number of birds in the experimental events compared to the control. In the 60mm métier (Figure 8 B), higher bird abundances were observed in the control events, except for the distance band of 100-200m. Conversely, in the métier 80mm (Figure 8 C), the abundance of birds was higher when using the scarybird in all bands except in the distance 100-200 m. All these differences were not significant (P> 0.05, Mann-Whitney Rank Sum Test).



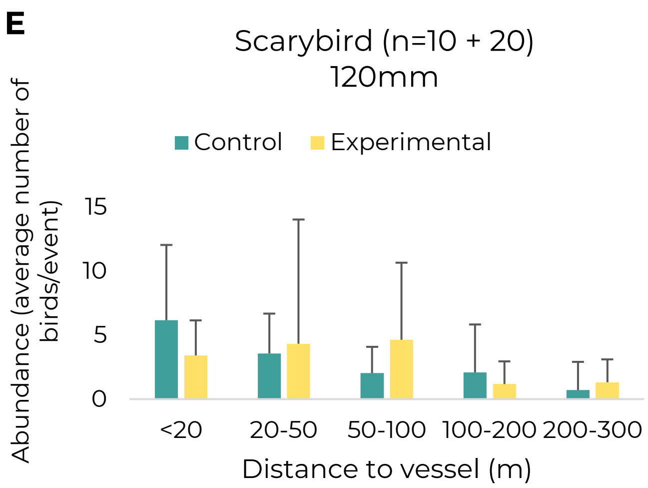


Figure 8 – Abundance of seabirds (average number of birds per event and standard deviation) in different range bands from the fishing vessel, operating both gillnets and trammel nets (A), gillnets (métier 60mm (B) 80mm (C), 220mm (D)) and trammel net (120mm, E), during the observations on board, testing the scarybird device (experimental or control). * Significant differences (p≤ 0.05).

In the 75 fishing trips monitored, gulls (considering both the yellow-legged gull and lesser black-backed gull) were the more abundant species around the fishing vessel, occurring in all fishing trips, followed by northern gannets, Cory's shearwater and Audouin's Gulls (Table 6). From all other species recorded during on-board monitoring, two other species occurred in 50 % or more of the fishing trips: Audouin's Gull and European Storm-petrel (*Hydrobates pelagicus*).

Table 6 – Birds occurrence (N and %) an bycatch (N) of the seabird species recorded in the study area (0–300 m distance band from the vessel) during the fishing sets of 75 fishing trips monitored using the scarybird (35 control and 40 experimental fishing trips) in 2020–2023.

Species	Control						Experimental					
	Fishing trips occurrence %	N	Fishing sets occurrence %	N	Sum birds	By-catch	Fishing trips occurrence %	N	Fishing sets occurrence %	N	Sum birds	By-catch
Larus michahellis/fuscus	100	35	100	54	4651	0	100	40	98	63	6007	1
Morus bassanus	74	26	69	37	392	0	78	31	61	39	258	0
Calonectris borealis	60	21	35	19	65	0	55	22	34	22	105	0

Larus audouinii	60	21	30	16	86	0	58	23	27	17	95	0
Hydrobates pelagicus	40	14	13	7	61	0	45	18	19	12	51	0
Puffinus mauretanicus	29	10	13	7	27	0	38	15	14	9	20	0
Ardenna gravis	26	9	17	9	191	13	45	18	33	21	160	0
Puffinus spp.	17	6	9	5	9	0	15	6	6	4	5	0
Catharacta skua	14	5	11	6	9	0	30	12	14	9	13	0
Hydrobates spp.	14	5	17	9	36	0	8	3	30	19	82	0
Thalasseus sandvicensis	11	4	0	0	0	0	10	4	3	2	6	0
Ardenna grisea	9	3	6	3	3	0	3	1	5	3	3	0
Alca torda	6	2	4	2	2	0	3	1	0	0	1	0
Larus melanocephalus	6	2	2	1	10	0	10	4	0	0	3	0
Stena hirundo	6	2	2	1	2	0	3	1	3	2	2	0
Sternula albifrons	3	1	2	1	1	0	3	1	0	0	2	0
Melanitta nigra	3	1	0	0	0	0	3	1	0	0	0	0
Thalasseus spp.	0	0	0	0	0	0	5	2	0	0	7	0
Xema sabini	0	0	0	0	0	0	3	1	0	0	0	0

The number of birds recorded (of the more abundant five species or groups) varied across distance bands, being higher in the closest distance band to the vessel for gulls, Audouin's gulls, Balearic shearwater and Great Shearwater (*Ardenna gravis*). The opposite happened for the other species.

Table 7 -Number of birds per species (average ± standard deviation) according to the distance band to the fishing vessel (0–20 m, 20–300 m) during fishing sets of control and experimental fishing trips (Ncon = 54, Nexp = 64).

	0-20m		20-300m	
	Control	Experimental	Control	Experimental
Larus michahellis/fuscus	47.70 ± 78.37	37.8 ± 62.1	38.65 ± 55.32	56.1 ± 85.4
Morus bassanus	0.74 ± 2.29	0.7 ± 3.4	3.74 ± 7.01	3.4 ± 5.5
Larus audouinii	0.85 ± 2.24	0.7 ± 2.2	0.61 ± 1.75	0.8 ± 3.5
Calonectris borealis	0.24 ± 0.93	0.1 ± 0.8	1.02 ± 2.05	1.5 ± 4.4
Puffinus mauretanicus	0.26 ± 1.92	0.1 ± 0.2	0.24 ± 0.76	0.3 ± 0.8
Ardenna gravis	1.96 ± 9.11	1.0 ± 3.3	1.57 ± 8.61	1.4 ± 4.4

Economic impact

The implementation of the visual device scarybird had a cost of 80€ with no additional costs due to replacements or repairs.

Regarding the impact of the scarybird on the catch volume and value of the landings, significant differences were identified between the control and the experimental group in total and using the mesh size of 220mm.

Table 8 – Average landings in weight and value of landings in euros per trip, per mesh size (target specie). * significant differences ($p \leq 0.05$)

LPUE (kg/km)

	Control	Experimental
Gillnets 60mm (Red mullet)	13.5 ± 13.3	17.8 ± 10.5
Gillnets 80mm (Hake)	11.8 ± 6.7	19.9 ± 10.2
Gillnets 220mm (Monkfish)*	9.0± 5.0	22.8± 14.4
Trammel nets120mm (Sole)	15.9± 2.5	11.5± 6.8
Average ± SD*	11.9.1 ± 9.7	17.5± 11.0

Value of landings (€)

	Control	Experimental
Gillnets 60mm (Red mullet)	429.1 ± 212.0	592.1 ± 260.8
Gillnets 80mm (Hake)	739.2 ± 315.8	891.0 ± 312.4
Gillnets 220mm (Monkfish)	587.9 ± 311.5	1423.7 ± 765.8
Trammel nets120mm (Sole)	1047.7 ± 278.2	794.0 ± 370.0
Average ± SD*	599.4 ± 331.3	887.0 ± 542.6

3.3 Good practices onboard – Discard control

To test the effect of the scarybird device and behaviour change, as a bird deterrent measure, both methods were operated along 118 events (net hauling and deployment) which were monitored in two years (2021–2023). For this trial, four different treatments were put into practice: 1. Control (as previously defined with not mitigation measure in place); 2. Experimental (scarybird only), 3. Control with container; 4. Experimental with container.

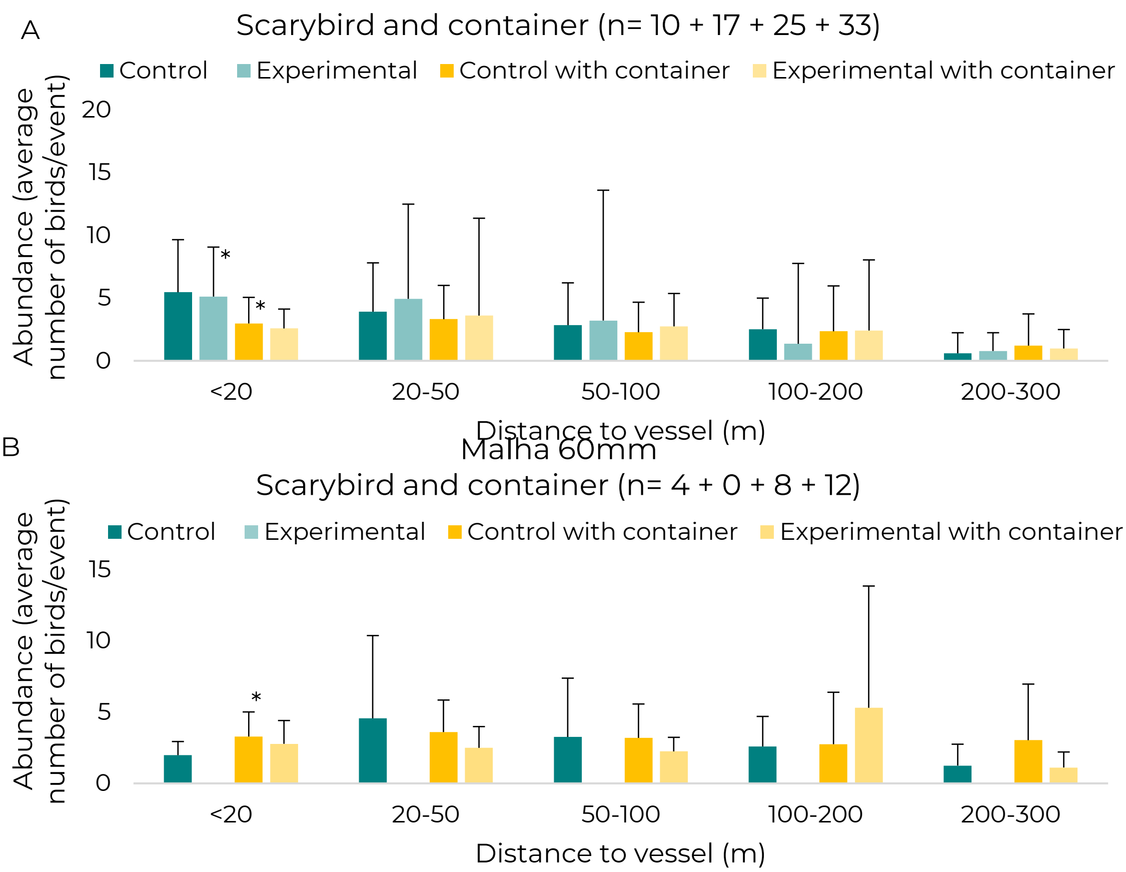
We observed in the three closest distance bands (nearest to the vessel), a lower abundance of birds in events (either control or experimental) with a container compared to events without a container (Figure 9 A). Comparing the control and experimental events, the abundance of birds did not show significant variation among the treatments ($p > 0.05$, Mann-Whitney Rank Sum Test).
In the occurrence of events involving the use of a container, a variation in the number of birds along distance ranges was observed, with significant differences for the first distance band ($p = 0.05$, Mann-Whitney Rank Sum Test). When comparing control events (with and without a container), no notable variations were found. However, when comparing experimental events (with and without a container), significant differences were noticed, particularly in the distance nearest to the vessel, < 20m ($p = 0.006$, Mann-Whitney Rank Sum Test).

In terms of the influence of the scarybird on the 60mm métier (Figure 9 B), the presence of birds varied among different treatments, with a higher quantity of birds noted in events involving the use of a container, except within the distance range of 20-50m. Significant differences were observed only between control and experimental events, both with container, when the distance was less than 20m ($p = 0.036$, Mann-Whitney Rank Sum Test).

In the 80mm métier (Figure 9 C), overall, the occurrence of events when the container was used compared to events where it was not used was similar However, significant differences were identified, in the distance range of 50 to 100 meters, between control and experimental events (both with container) ($p = 0.029$, Mann-Whitney Rank Sum Test) and between experimental events and experimental events with container ($p = 0.048$, Mann-Whitney Rank Sum Test)

Regarding the impact of scarybird on the 220mm métier (Figure 9 D), a reduction in bird abundance was observed in events where the container was employed for the first two distance ranges. Significant differences were noted between experimental events with and without the container, particularly in the distance range below 20 meters ($p = 0.029$, T-Test). Regarding events without the container, significant differences were also identified between those with and without the use of scarybird (experimental and control, respectively) for the range 20-50m (p=0.003, T- Test).

In the trammel net (mesh size 120mm) (Figure 9 E), a lower number of birds was observed in events with a container in almost all distance bands. Significant differences were observed between control and experimental events (both with a container) in the distance band <20m (p=0.018 Mann-Whitney Rank Sum Test), with higher abundance in control events with a container. Comparatively, experimental events and experimental events with a container showed significant differences in the distance bands <20m (p=0.021, Mann-Whitney Rank Sum Test) with a higher number of birds in events without a container, and 20-50m (p=0.048, Mann-Whitney Rank Sum Test) with a higher record of birds in events with a container.



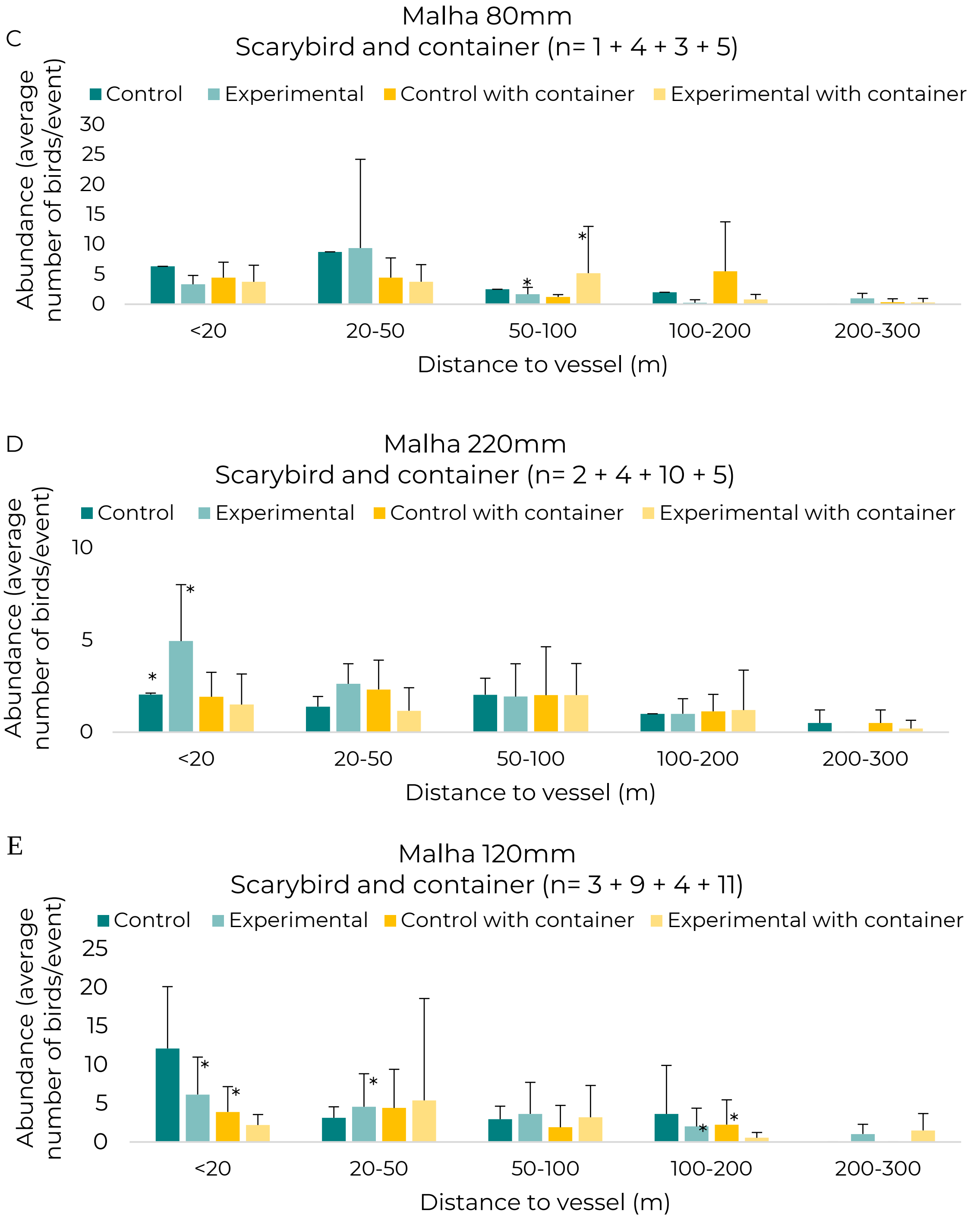


Figure 8 – Abundance of seabirds (average number of birds per event and standard deviation) in different range bands from the fishing vessel, operating both gillnets and trammel nets (A), gillnets (métier 60mm (B) 80mm (C), 220mm (D)) and trammel net (120mm, E), during the observations on board, testing the scarybird device (experimental or control) and behaviour change (with or without bucket).

In the 85 fishing events monitored, gulls (considering both the Yellow-Legged Gull and lesser Black-Backed Gull) were the most abundant species around the fishing vessel, occurring in all fishing events, followed by Northern Gannets (Table 9). From all other species recorded during on-board monitoring, two other species occurred in 50 % or more of the fishing events: Great Shearwater and Cory's Shearwater. A lower percentage of gulls and Northern Gannets was observed in the experimental events, with and without the use of the container.

Table 9 – Birds occurrence (% and N) and number of bycatch (BYC) of the seabird species recorded in the study area (0–300 m distance band from the vessel) during the fishing sets of 118 fishing sets monitored in the study (10 control – no container, 25 control – container, 17 experimental – no container and 33 experimental – container) in 2020–2023.

	Control							Experimental						
	No container			Container			Sum birds	No container			Container			Sum birds
Species	Fishing sets occurrence %	N	BYC	Fishing sets occurrence %	N	BYC		Fishing sets occurrence %	N	BYC	Fishing sets occurrence %	N	BYC	
Larus michahellis/fuscus	100	10	0	100	25	0	3415	94	16	1*	100	33	0	4336
Morus bassanus	90	9	0	56	14	0	119	76	13	0	55	18	1	156
Ardenna gravis	50	5	13*	16	4	0	191	71	12	0	24	8	7	159
Calonectris borealis	40	4	0	40	10	0	57	35	6	0	45	15	0	103
Ardenna grisea	30	3	0	0	0	0	3	6	1	0	3	1	0	2
Larus audouinii	30	3	0	32	8	0	74	18	3	0	39	13	0	63
Catharacta skua	20	2	0	8	2	0	4	29	5	0	6	2	0	9
Hidrobates spp.	20	2	0	28	7	0	33	47	8	0	27	9	0	80
Hydrobates pelagicus	20	2	0	28	7	0	61	47	8	0	12	4	0	49
Puffinus mauretanicus	10	1	0	24	6	0	27	12	2	0	18	6	0	20
Puffinus sp.	10	1	0	12	3	0	8	6	1	0	3	1	0	4
Alca torda	0	0	0	8	2	0	2	0	0	0	0	0	0	0
Larus melanocephalus	0	0	0	4	1	0	10	0	0	0	6	2	0	3
Sterna hirundo	0	0	0	4	1	0	2	0	0	0	0	0	0	0
Sterna sp.	0	0	0	0	0	0	0	6	1	0	3	1	0	3
Sternula albifrons	0	0	0	4	1	0	1	0	0	0	0	0	0	0
Thalasseus sandvicensis	0	0	0	0	0	0	0	0	0	0	3	1	0	2

*bycaught animals also present on table 6

The number of recorded birds, specifically the more abundant five species or groups, displayed variations across different distance bands, influenced by the treatment applied (Table 10). In the 0-20m distance band, higher gull abundance was noted in both control and experimental treatments when no container was used compared to instances with the container. As for the other species, the average number of birds showed variability. Moving to the 20-300m distance band, lower bird abundance was observed in events involving a container (in both control and experimental groups) for gulls, Northern Gannets, and Great Shearwater. Audouin's gull, particularly in experimental events, exhibited lower abundance, especially when the container was utilized.

Table 10 – Number of birds per species (average ± standard deviation) according to the distance band to the fishing vessel (0–20 m, 20–300 m) during fishing sets of control and experimental fishing events (10 control – no container, 25 control – container, 17 experimental – no container and 33 experimental – container).

	0-20m				20-300m			
	Control		Experimental		Control		Experimental	
Species	No container	Container	No container	Container	No container	Container	No container	Container
Larus michahellis/fuscus	7.19 ± 12.10	4.71 ± 6.44	6.67 ± 11.40	3.46 ± 4.38	6.66 ± 8.81	4.95 ± 7.13	8.19 ± 26.61	5.04 ± 12.24
Morus bassanus	1.25 ± 0.66	1.83 ± 0.99	11.00 ± 0.40	1.25 ± 0.43	1.23 ± 0.50	1.85 ± 2.70	1.36 ± 0.71	1.49 ± 1.00
Ardenna gravis	3.48 ± 3.50	0.00 ± 0.00	2.07 ± 1.22	1.83 ± 1.46	3.04 ± 2.14	1.80 ± 1.60	2.59 ± 2.35	1.54 ± 0.75
Calonectris borealis	1.00 ± 0.00	1.80 ± 0.75	0.00 ± 0.00	1.75 ± 1.3	1.19 ± 0.39	1.59 ± 1.03	1.80 ± 1.78	1.73 ± 1.84
Ardenna grisea	1.00 ± 0.00	1.00 ± 0.00	0.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	0.00 ± 0.00	1.00 ± 0.00	0.00 ± 0.00

Acceptance of mitigation measures by fishers

Regarding the acceptance of the implemented measures, both the scarybird and the behaviour changes on board, including the use of the container by fishermen, were well received. As for the scarybird, fishermen faced no costs or responsibilities with its installation, which facilitated its acceptance. On the other hand, the behaviour changes across the crew posed a challenge, given that altering mindsets and practices is always a difficult task. However, fishers overcame this obstacle, and the measure was widely accepted. This occurred because fishers could directly observe that reducing discards at sea, especially during the most problematic fishing operations (net hauling and deployment), resulted in fewer birds being attracted. Additionally, they realized that the practice of storing unwanted fish and viscera in a container during net hauling and deployment, boat cleaning, and discarding them only when navigate back to land, was a simple and effective solution. Therefore, fishers believe that it is not the "scarybird" itself that influences the presence of birds around the vessel, but rather the change in behaviour adopted by the entire crew.

The use of this measure had a significant impact on catches (Table 8), as when the scarybird was employed, the quantity of captured fish was significantly higher for the

220mm mesh and overall, compared to when the device was not used. However, it is important to note that this device is aimed at influencing bird behaviour, not affecting the fishing gear's behaviour and its respective catches. In economic terms, the average value of catches when the scarybird was used was significantly higher for the 220mm mesh compared to control fisheries (without the device). However, it's crucial to emphasize that the economic consequences are not considered problematic. The value is contingent upon market demands and is unrelated to the magnitude of the catch.

4 | CONCLUSIONS

Our investigation underscores the complexity and challenges associated with implementing effective mitigation measures aimed at deterring marine birds from areas surrounding fishing vessels, particularly during critical operations such as hauling and deployment. Mainly, two categories of mitigation deterrents have been employed to minimize bird interactions with fixed net fisheries—some involving visual measures underwater (Lucas and Berggren 2023) or above the water surface (Field *et al*. 2019; Almeida *et al*. 2023). In our study, we focused on above-water deterrents, specifically employing an acoustic device (megaphone), a visual device (scarybird), and a behavioral modification in fisher practices (adherence to best practices in retaining fish discards or viscera onboard during hauling and net deployment).

The megaphone exhibited suboptimal results across all métiers tested, revealing a higher number of observed seabirds in the treatment group using the device compared to controls (no megaphone) for most distance bands from the fishing vessel. Furthermore, the considerable cost associated with implementing such equipment onboard renders it impractical for our artisanal fisheries.

Similarly, the use of the scarybird yielded less promising outcomes, with observations indicating either an increase or non-significant differences in the number of birds in most distance bands across various métiers. This contradicts findings by Almeida *et al*. (2023) along the Portuguese western mainland coast, where the scarybird demonstrated significant efficacy in deterring gulls and northern gannets. The divergent results in the Algarve region compared to the western coast underscore the context-specific nature of mitigation measures, influenced by geographical location, bird species, and fishing practices.

Contrastingly, the implementation of good practices onboard, specifically the use of a container to retain viscera and discards during fishing operations, emerged as the most effective strategy. This approach not only consistently demonstrated favourable overall outcomes, exhibiting evidence of reduced bird presence at various distance bands, but it also proved to be a cost-effective and practical measure. As highlighted by Suuronen (2022), fishers often exhibit reluctance toward adopting bycatch reduction technologies due to a lack of comprehensive evidence demonstrating efficacy across diverse conditions. Therefore, our results suggest that, instead of relying on technical solutions like the megaphone or the scarybird, a simple behavioral modification among fishers could yield the most immediate and impactful results in mitigating seabird interactions with Algarve leeward fisheries.

Nevertheless, it is important to highlight that instances of bycatch were infrequently observed, with such events occurring sporadically during periods of extreme conditions. One notable occurrence was a two-week period in October 2022, coinciding with the implementation of good practices trials, which led to the observation of over 92% of the total bycatch recorded throughout the entire study. Consequently, it is currently premature to draw definitive conclusions about the efficacy of the implemented mitigation measures concerning bycatch.

Achieving successful implementation of measures to mitigate seabird bycatch depends on vigilance, adherence, and a strong partnership with the fishing community. While ensuring compliance can involve both enforcement and incentives, it is crucial to develop a profound understanding of fishermen's viewpoints to authentically shape their attitudes and commitment (Cox *et al*., 2007, Suuronen, 2022). To continue and enhance this work, it is essential to maintain these collaborations in a way that they become strong and reliable partnerships.

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ANEXO 1

1. Effects of the scarybird on *Larus* spp. and *Morus bassanus*

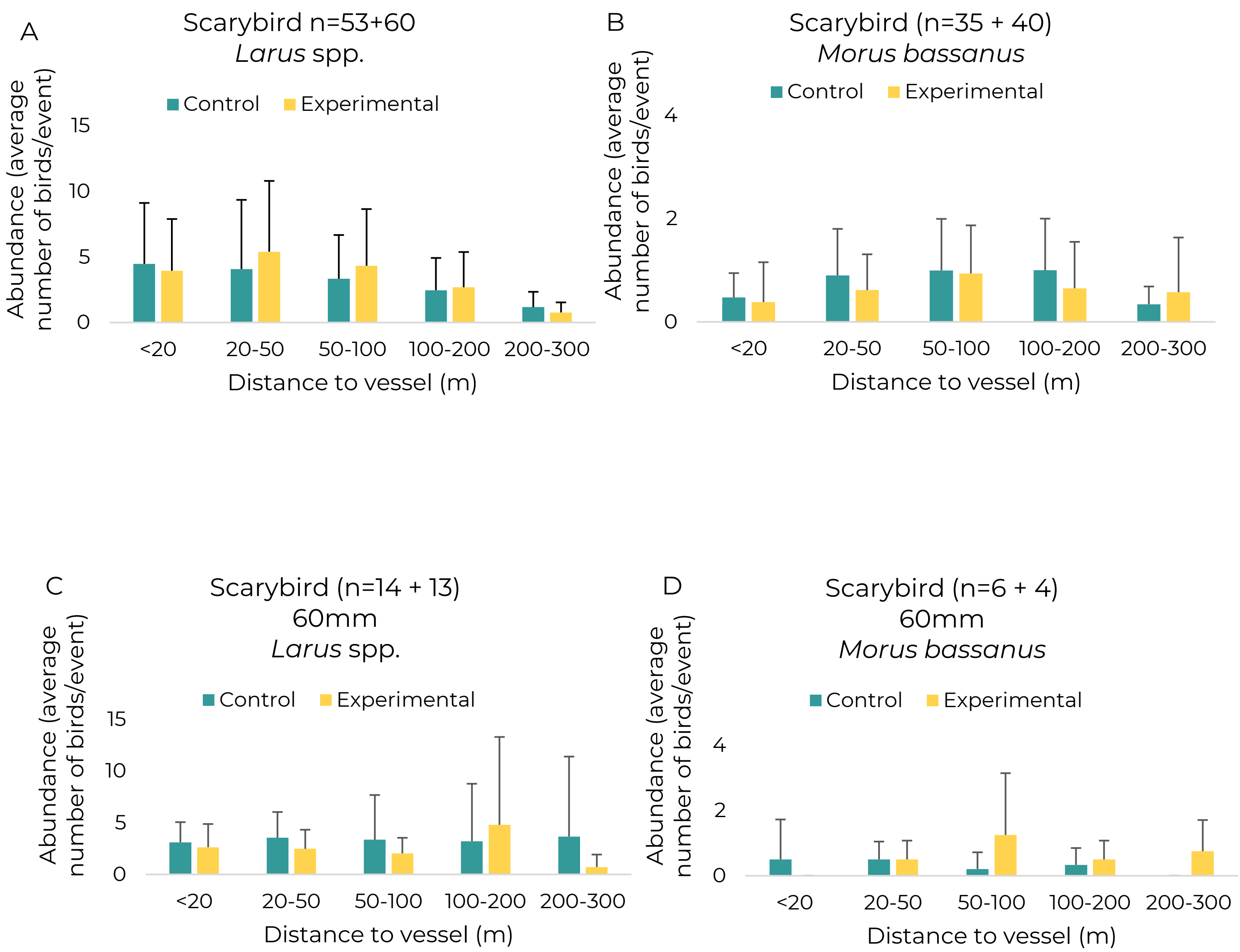
The impact of the scarybird varied among species, proving more effective for the *Morus bassanus*. In the case of *Larus* spp.. (Figure 9 A), a higher number of birds was observed in the experimental events compared to the control events, except for the last distance band where the opposite was observed. No significant differences were found in any of the treatments ($p > 0.05$, Mann-Whitney Rank Sum Test). For *Morus bassanus* (Figure 9 B), a higher abundance was observed in the control events across all distance bands, except for the last one. However, no significant differences were found between the treatments ($p > 0.05$, Mann-Whitney Rank Sum Test).

In the 60mm métier, the impact of the scarybird bird was more favorable for *Larus* spp. (Figure 9 C), with a lower number of birds observed in the proximity of the vessel during events with the scarybird compared to events without its use in the first three distance bands. The opposite was observed for the remaining distance bands. In the case of *Morus bassanus* (Figure 9 D), the use of the scarybird did not show promising results. For both species, no significant differences were observed between the treatments ($p > 0.05$, Mann-Whitney Rank Sum Test).

For the 80mm métier, in both species (Figure 9 E and 9 F), a higher abundance of birds was observed in the experimental events compared to the control, except for the distance band of 100-200m in the case of *Morus bassanus*, results that do not align with the main goal, scare away the birds. No significant differences were found between the treatments ($p= >0.05$, Mann-Whitney Rank Sum Test) for both species.

In the 220mm mesh size, it was observed that the sacrybird exhibited higher performance on *Morus bassanus* (Figure 9 G) compared to *Larus* spp. (Figure 9 H). This was evidenced by the lower abundance of birds in the experimental events, unlike the case with *Larus* spp., where a higher number of birds was recorded in events involving the sacrybird. However, it is important to note that the differences between treatments did not reach statistical significance (p= >0.05, Mann-Whitney Rank Sum Test).

In trammel net (mesh size 120mm), the effect of the scarybird on *Larus* spp. (Figure 9 I) was positive for the first distance band (<20m), the closest to the vessel, where significant differences were observed between control and experimental events, with higher bird abundance in control events (p= 0.027, Mann-Whitney Rank Sum Test). For the remaining bands, the opposite was observed, with higher abundance in experimental events, and no significant differences (p= >0.05, Mann-Whitney Rank Sum Test). Regarding *Morus bassanus* (Figure 9 J), the scarybird had a positive effect, with a higher number of birds in control events in all distance bands (except for the 100-200m band), however, no significant differences between treatments were observed (p= >0.05, Mann-Whitney Rank Sum Test).



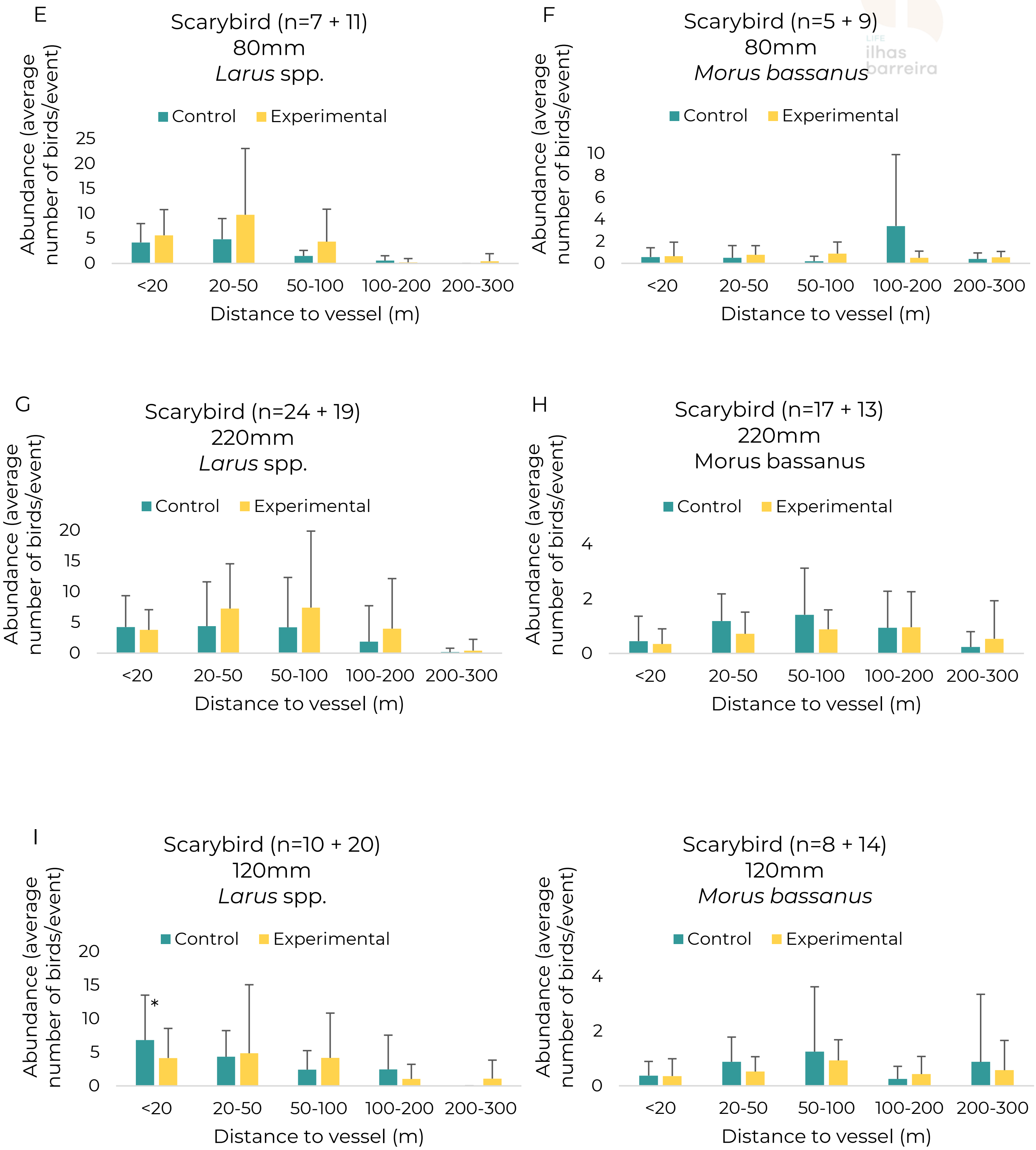


Figure 9 - Abundance of *Larus* spp. and *Morus bassanus* (average number of birds per event and standard deviation) in different range bands from the fishing vessel, operating both gillnets and trammel nets (A and B), gillnets (métier 60mm (C and D) 80mm (E and F), 220mm (G and H)) and trammel net (120mm, I and J), during the observations on board, testing the scarybird device (experimental or control).

2. Effects of the scarybird and good practices on *Larus* spp. and *Morus bassanus*

In general, for both species, the adoption of good onboard practices (events involving the use of the container) resulted in a lower number of birds at all distance ranges compared to events where these good practice measures were not applied. Regarding the effect of these measures on *Larus* spp. (Figure 10 A), significant differences were observed when comparing experimental events and experimental events with a container, for distance bands <20m ($p=0.009$, Mann-Whitney Rank Sum Test). In the case of *Morus bassanus* (Figure 10 B), no significant differences were observed in any distance bands ($p > 0.05$, Mann-Whitney Rank Sum Test).

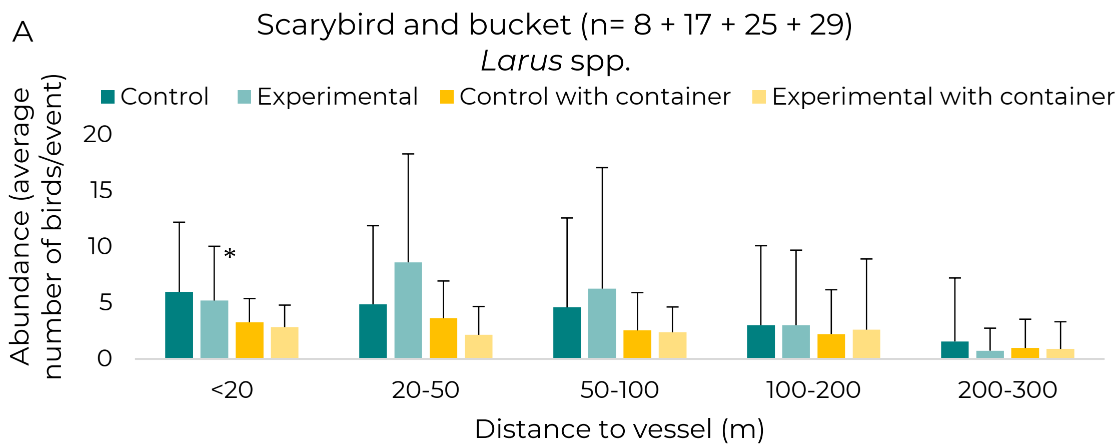
When analysing the effect of the use of both measures on the 60mm métiers, for *Larus* spp. (Figure 10 C), we observed a lower abundance of birds in events using the container, with significant differences only between control and experimental events (both with a container) in <20m distance band ($p=0.032$, Mann-Whitney Rank Sum Test). No significant differences were observed in the other distance bands ($p <0.05$, Mann-Whitney Rank Sum Test). For *Morus bassanus* (Figures 10 D), the effect varied across distance bands without any significant differences observed ($p <0.05$, Mann-Whitney Rank Sum Test).

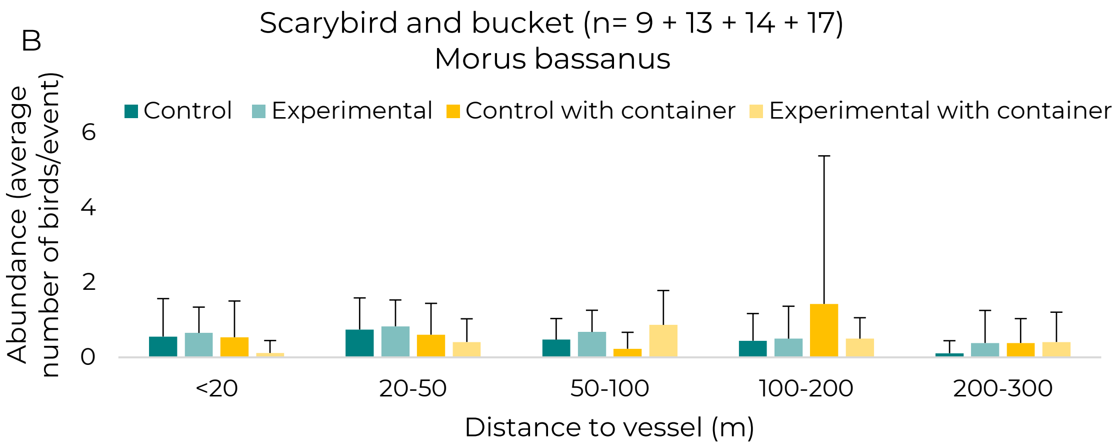
Regarding the effect of the scarybird and the use of the container on the approach of *Larus* spp. to the vessel (Figure 10 E), in the 80mm métier, it is possible to observe a lower abundance of birds in events using the container for the first two distance bands (the ones closest to the vessel). In the remaining distance bands, the number of birds varied. No significant differences were observed between treatments in any of the distance bands ($p > 0.050$, Mann-Whitney Rank Sum Test). As for the impact of the scarybird on *Morus bassanus* (Figure 10 F), no significant differences were observed between treatments.

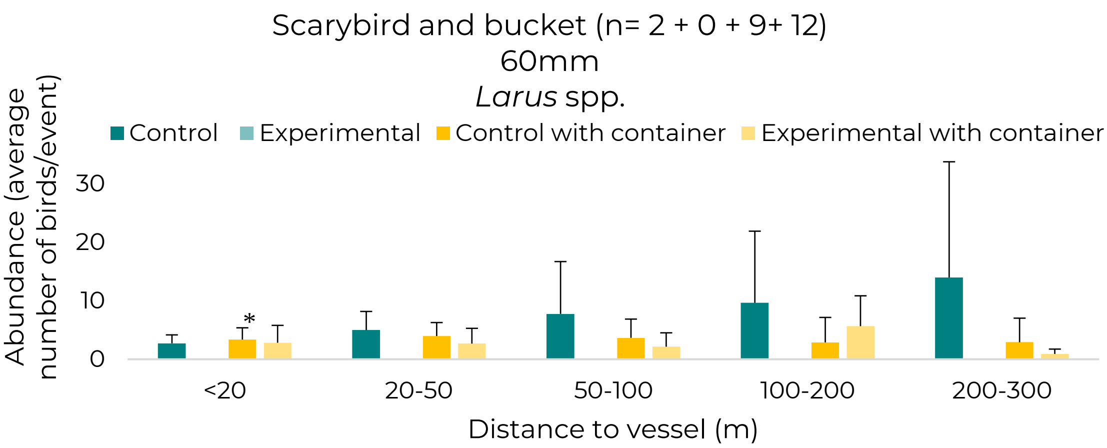
When using the 220mm métier, both for *Larus* spp. (Figure 10 G) and *Morus bassanus* (Figure H), a higher number of birds was observed in events without the container compared to events with it. In the case of *Larus* spp., significant differences were observed, for the <20m distance band, between control and experimental events (both without a container) (p=0,034, T Test) and between experimental events and experimental events with a container (p=0.006, T Test). For *Morus bassanus*, no significant differences were noted between any of the treatments.

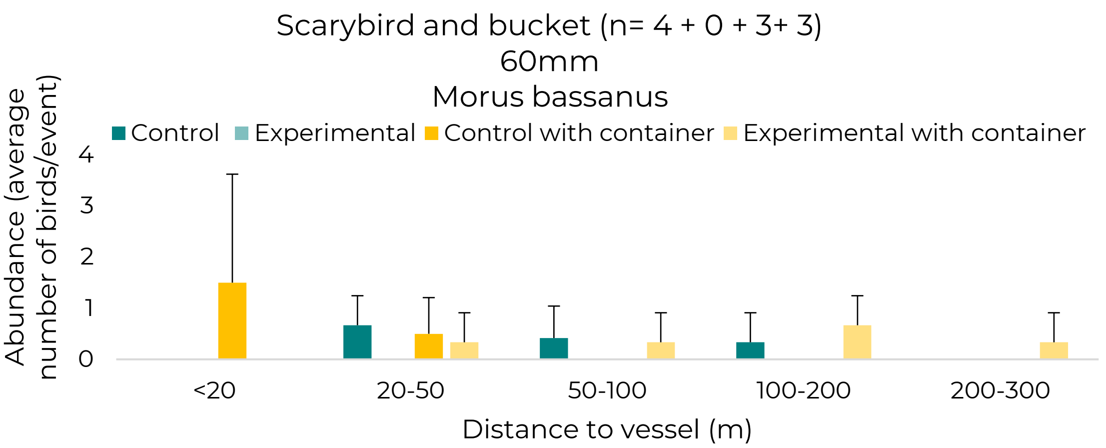
In the 120mm gear (trammel net), the impact of using good practices on *Larus* spp. (Figure 10 I) revealed significant differences between treatments, mainly in the <20m distance band. These differences were observed between control and experimental events (both with a container) (p=0.014, Mann-Whitney Rank Sum Test), and between experimental and experimental with a container events (p=0.026, Mann-Whitney Rank Sum Test).

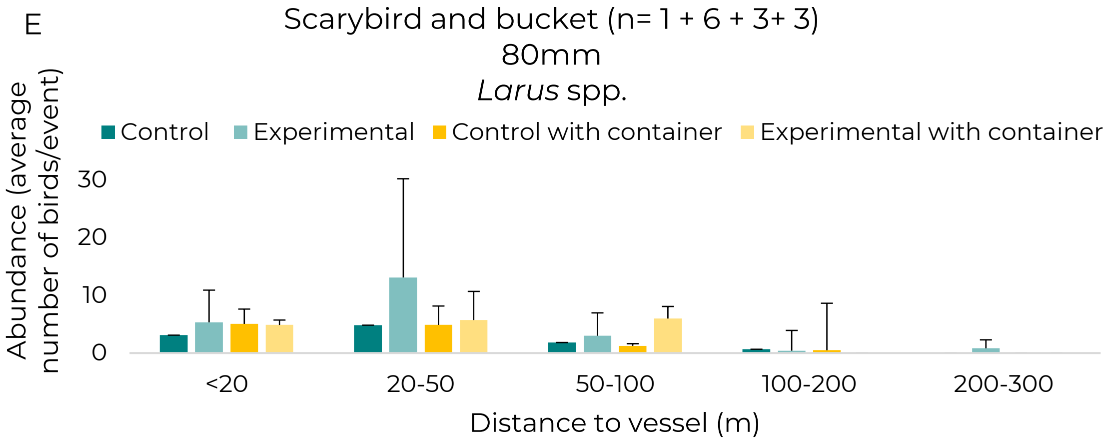
For *Morus bassanus* (Figure 10 J), a lower abundance was observed in events with the use of containers for the 20-50m and 100-200m distance bands. However, the observed differences were not significant (p=<0,05, Mann-Whitney Rank Sum Test).

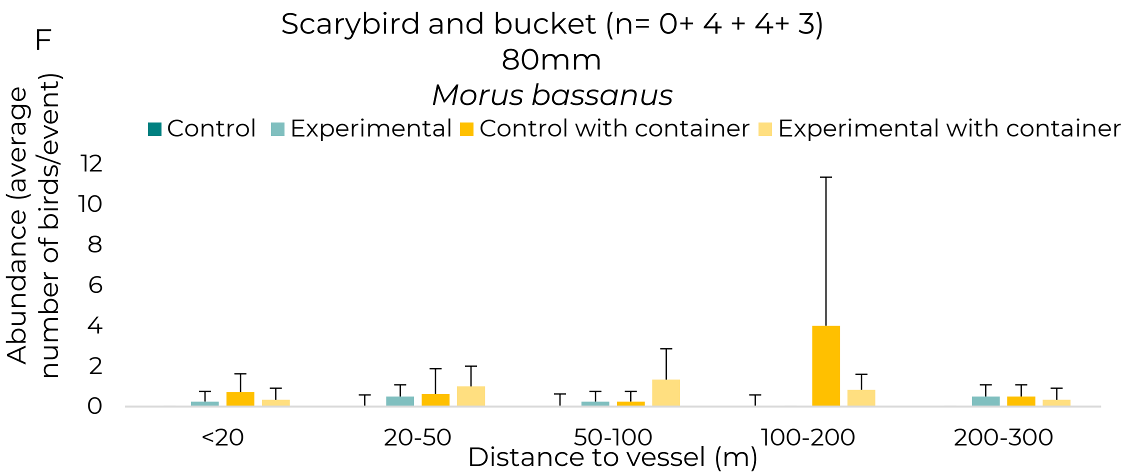


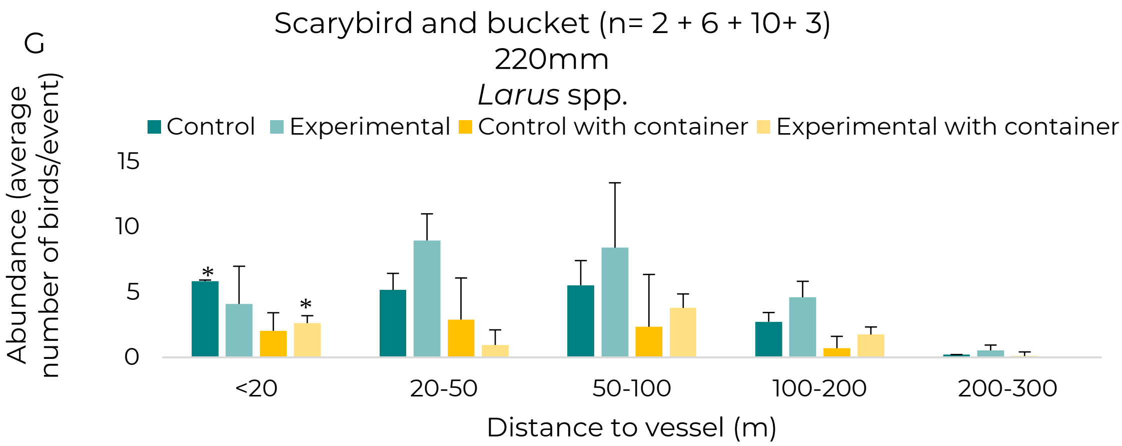

B
Scarybird and bucket (n= 9 + 13 + 14 + 17)
Morus bassanus
Control
Experimental
Control with container
Experimental with container
Abundance (average number of birds/event)
0
2
4
6
<20
20-50
50-100
100-200
200-300
Distance to vessel (m)

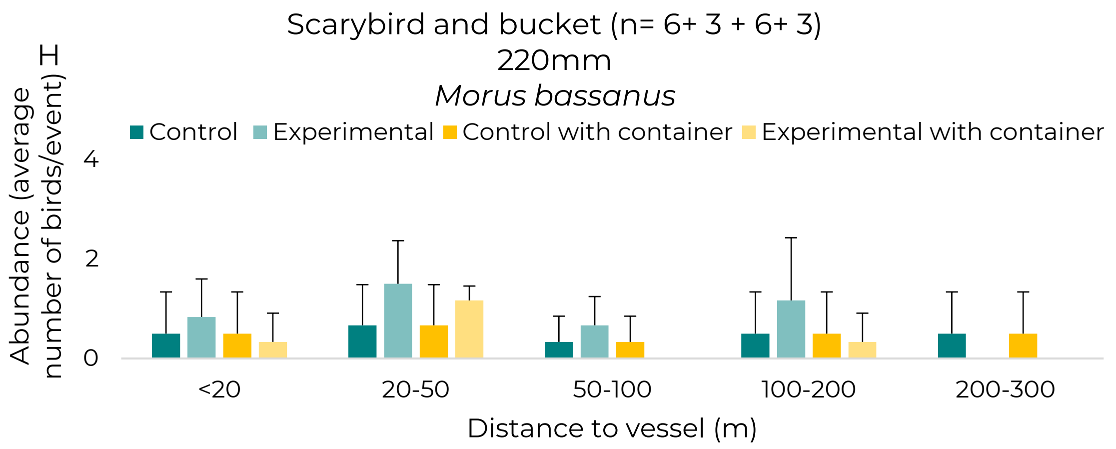

Scarybird and bucket (n= 2 + 0 + 9+ 12)
60mm
Larus spp.
Control
Experimental
Control with container
Experimental with container
Abundance (average number of birds/event)
0
10
20
30
*
<20
20-50
50-100
100-200
200-300
Distance to vessel (m)

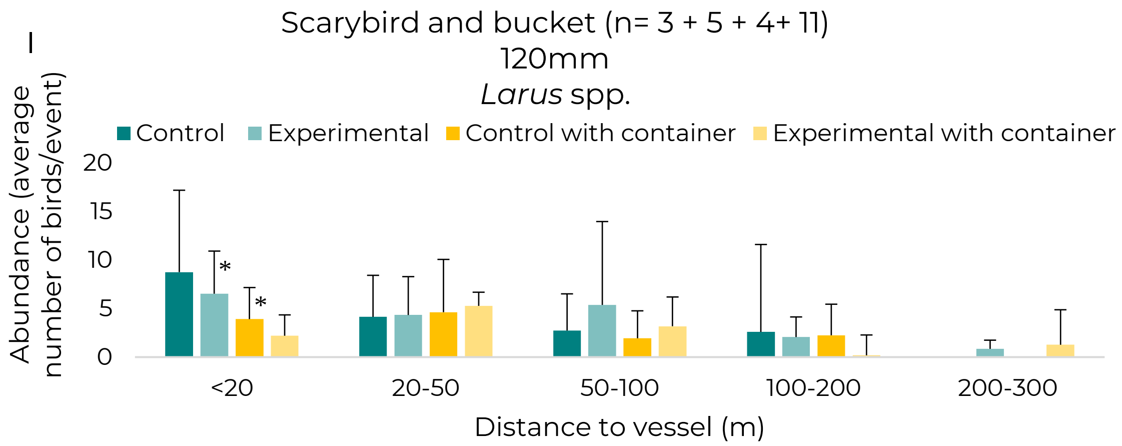

Scarybird and bucket (n= 4 + 0 + 3+ 3)
60mm
Morus bassanus
Control
Experimental
Control with container
Experimental with container
Abundance (average number of birds/event)
0
1
2
3
4
<20
20-50
50-100
100-200
200-300
Distance to vessel (m)


E
Scarybird and bucket (n= 1 + 6 + 3+ 3)
80mm
Larus spp.
Control
Experimental
Control with container
Experimental with container
Abundance (average number of birds/event)
30
20
10
0
<20
20-50
50-100
100-200
200-300
Distance to vessel (m)


F
Scarybird and bucket (n= 0+ 4 + 4+ 3)
80mm
Morus bassanus
Control
Experimental
Control with container
Experimental with container
Abundance (average number of birds/event)
12
10
8
6
4
2
0
<20
20-50
50-100
100-200
200-300
Distance to vessel (m)


G
Scarybird and bucket (n= 2 + 6 + 10+ 3)
220mm
Larus spp.
Control
Experimental
Control with container
Experimental with container
Abundance (average number of birds/event)
15
10
5
0
*
*
<20
20-50
50-100
100-200
200-300
Distance to vessel (m)





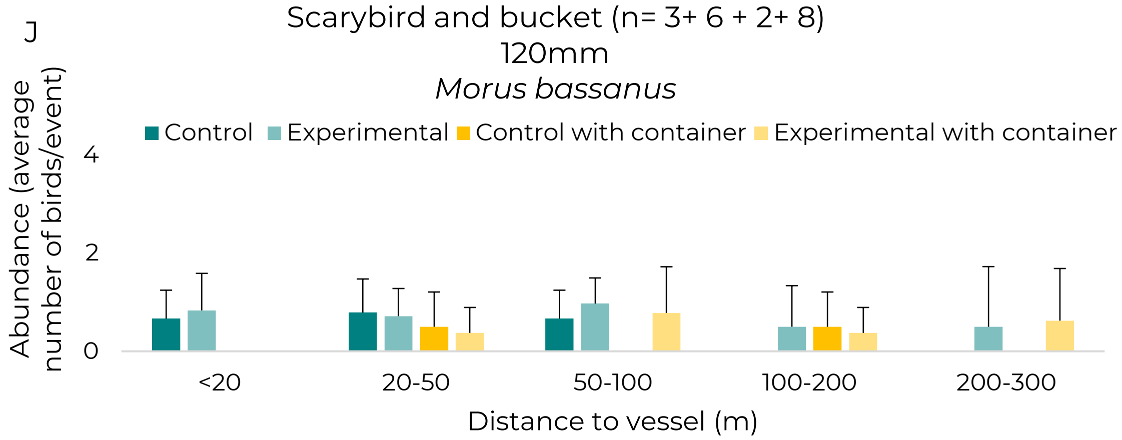


Figure 10 - Abundance of *Larus* spp. and *Morus bassanus* (average number of birds per event and standard deviation) in different range bands from the fishing vessel, operating both gillnets and trammel nets (A and B), gillnets (métier 60mm (C and D) 80mm (E and F), 220mm (G and H)) and trammel net (120mm, I and J), during the observations on board, testing the scarybird device (experimental or control) and behaviour change (with or without container).

3. Conclusions

In this study, the species that proved to be more abundant and the only ones allowing for analysis were seagulls (*Larus* spp.) and the northern gannet (*Morus bassanus*). These species exhibit the highest degree of interaction with bottom gillnet fisheries in Portugal and are prominently concentrated near the vessel during fishing operations (Almeida et 2023).

For *Larus* spp., ours results showed that the scarybird didn't work for all the métiers, except for the first three distances bands in the 60mm métier, however no significant differences were observed. In the case of *Morus bassanus*, the scarybird demonstrated its ability to deter birds across all gear types and specifically in the 220mm and 120mm gears. These findings align with the results obtained by Almeida *et al*. (2023)

Regarding the experiments involving the combined use of the scarybird and good practice measures for both species, they demonstrated a significant decrease in the number of birds in certain distance bands, specifically in the <20m and 20-50m bands for *Larus* spp.. Among the different gear types, these measures had a more pronounced impact on the 220mm and 120mm gears. However, overall, events with the container had a positive impact on deterring/preventing birds from approaching the vessel, demonstrating that behavioral changes are a simpler and more effective mitigation measure.