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PRELIMINARY ASSESSMENT OF  
ELASMOBRANCH OCCURRENCE, AND  
MAPPING OF POTENTIAL OVERLAP WITH  
HUMAN ACTIVITIES, USING NON-  
INVASIVE METHODS: THE CASE STUDY  
OF THE BERLENGAS NATURAL RESERVE

CATARINA ABRIL

Orientador de Dissertação:

PROF. DOUTOR EMANUEL GONÇALVES

DOUTORA SOFIA HENRIQUES

DOUTOR MIGUEL PAIS

Professor de Seminário de Dissertação:

PROFESSOR DOUTOR EMANUEL GONÇALVES

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## Resumo

Como predadores e mesoconsumidores, os elasmobrânquios têm um papel fundamental em regular a saúde dos ecossistemas. Devido à enorme falta de conhecimento científico sobre estas espécies, e às suas características de vida vulneráveis (i.e., baixa fecundidade e maturidade tardia), os tubarões e raias têm-se tornado, progressivamente, uma preocupação na agenda da conservação. A Reserva Natural das Berlengas (RNB) é casa destas espécies com relatos históricos importantes habitats para estas espécies (Carreiro dos Cações). Neste estudo, a presença de elasmobrânquios foi avaliada através de três métodos não invasivos: câmaras com isco georreferenciadas (BRUVs), questionários semiestruturados aos diferentes usuários da área marinha protegida e dados de observações a bordo das frotas de palangre locais. Para além disso, as diferentes atividades que ocorrem dentro da MPA – pesca comercial, pesca recreativa e turismo náutico – foram caracterizadas e mapeadas usando o software QGIS. Para identificar potenciais áreas de risco de sobreposição de áreas humanas com espécies vulneráveis um índice de vulnerabilidade foi desenvolvido. Segundo o índice, áreas como o Rinchão e a zona a sul da ilha da Berlenga destacaram-se como apresentando risco elevado devido à presença de espécies de elevada sensibilidade, como o tubarão-anequim (*Isurus oxyrinchus*) e indivíduos da família *Sphyrnidae*, em zonas onde ocorrem atividades de alto impacto como pesca por palangre. Este trabalho contribuiu para a caracterização dos elasmobrânquios das Berlengas, na ausência de dados à priori, usando apenas dados não invasivos, provando assim o valor destas como fonte de informação complementar à informação científica.

Palavras-chave: elasmobrânquio; Berlengas; vulnerabilidade; métodos não invasivos

## Summary

As predators and mesoconsumers, elasmobranchs play key roles in regulating ecosystems' health. Due to the lack of knowledge about these species and to their vulnerable life-history traits (i.e. low fecundity and late maturity) sharks and rays have progressively become a concern in the conservation agenda. The Berlengas Natural Reserve (RNB) is home to these species with several historical reports of key habitats (Carreiro dos Cações) for elasmobranchs. In the present study, the occurrence of elasmobranchs was assessed using three non-invasive methods: georeferenced Baited Remote Underwater Videos (BRUVs), Local Ecological Knowledge (LEK) through map-based semi-structured questionnaires and on board observational data from the local longline fleets. Moreover the different activities – commercial and recreational fisheries and nautical tourism - occurring within the Marine Protected Area, were registered, and characterized. Both species occurrence and human presence were mapped out using the QGIS software. To identify possible risk zones where high impact activities overlap with sensitive shark and ray species, a vulnerability index was developed. According to the index, areas such as Rinchão and the southern side of the Berlenga island stood out as high risk areas due to presence of vulnerable species such as the shortfin mako shark (*Isurus oxyrinchus*) and individuals of the *Sphyrnidae* family overlapping with high impact activities such as longline. This study contributed for the characterization of the Berlengas' elasmobranch species occurrence, in the absence of information, using only non-invasive cost-effective methods proving their value as complementary approaches.

Keywords: elasmobranch; Berlengas; vulnerability; non-invasive methods.

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## 1. Introduction

From bottom dwelling mesoconsumers to pelagic apex predators, sharks and rays play a critical role in maintaining the fragile ecosystem balance (Rosa et al., 2017). Persistently exposed to anthropogenic impacts such as overexploitation (in particular fining), bycatch, habitat degradation and climate change many elasmobranchs species are currently facing extinction as 31% are now considered to be under severe threat by the IUCN Red List (Spiegel, 2001; Friedrich et al., 2014; Shiffman & Hammerschlag, 2016; Alves et al., 2016; Harrison et al., 2018).

The low fecundity, advanced age at first maturity and high longevity, coupled with slow growth rate of most elasmobranchs, make their rebound potential quite low (i.e. low resilience) compared to teleost fish, meaning that, once overexploited there is a low probability of full recovery (Dulvy et al., 2008; Lucifora et al., 2011; Biery & Pauly, 2012; Friedrich et al., 2014; Rosa et al., 2017).

Although most of these species are key in maintaining our ocean's health, given their high trophic level, they are still low on global priority lists when it comes to conservation due to their low value meat (Stevens et al., 2000; Dulvy et al., 2008). Therefore, these species remain exposed to an array of threats, such as habitat destruction from non-selective fishing gear such as trawls upon sandy bottoms and reef structures, bycatch, and finning (Stevens et al., 2000; Spiegel, 2001; Pennino et al., 2013; Dell'Apa et al., 2014; Campana et al., 2017).

Shallow sandy areas are important nursing grounds for small benthic sharks and skates (Hoff, 2010). Nurseries are vertically limited areas where oviparous females deposit the eggs and viviparous females give birth to neonates. Usually located in shallow spots, these habitats with high productivity and coverage such as marshes, mangrove fields, seagrass meadows and estuarine systems are of great importance due to food resources and shelter availability (Castro, 1993; Yates et al., 2015; Oñate-González et al., 2016).

To account for the protection of important habitats, several measures have been implemented such as seasonal closures of fishing grounds that overlap with these ecosystems and shark deterrents to mitigate shark-fishermen conflict (Dulvy et al., 2008; Huvneers et al., 2012; Friedrich et al., 2014; Oñate-González et al., 2016; Huvneers et al., 2018).

However, for all conservation measures to be properly enforced it is crucial to gather data on these species. Around 46% of elasmobranchs are listed as “data deficient” meaning no robust scientific assessment has ever been made for more than a third of the species known to man (White et al., 2015; Harrison et al., 2018). Moreover, habitat protection of key habitats, such as nurseries and foraging grounds, plays a pivotal role in the conservation of highly mobile species (Maxwell, 2015)

To successfully recover reliable scientific data several tools were developed and applied to the study of Chondrichthyes (sharks, rays, skates, and chimaeras). The most common tools can be either invasive – acoustic/satellite tagging and mark-recapture methods or non-invasive - photo identification and baited remote underwater videos (BRUVs).

Invasive tools often rely on fisheries for data recovery. Although these methods are highly beneficial to perform long term monitoring, they often result in the death of individuals and do not paint the full picture, as the sample sites are chosen for their commercial value (Pennino et al., 2016). The insertion of tags, for example, is usually invasive meaning the individuals must be caught to be handled which can induce stress and inflict skin and tissue damage. If poorly executed can result in organ puncturing and even be lethal (Oceanographic Research Institute, 1984; Gore et al., 2016). Moreover, most available tags have low retention rates, often shed easily after a short period of time and for the mark-recapture method it is dependent on recapture rates and provides no information about distribution (Queiroz et al., 2005; Gore et al., 2016). However, in the Azores, a study performed by *Fontes and colleagues* (2018) highlighted a new, non-invasive method, using harnesses to track large predators.

Although photo identification and BRUVs, are independent from fisheries and highly cost effective they also have handicaps (Clarke et al., 2019). Visual identification and BRUVs rely on high site fidelity and this last one might induce changes in behaviour through visual stimulus and the resurgence of a bait plume (Clarke et al., 2019; De Vos et al., 2015).

Regarding stakeholders, fishermen are often the main opposition to MPA enforcement because it usually is a synonym of restriction. To counteract this resistance a biocultural approach can boost cooperation through positive reinforcement, transparency, conflict management and proper education (Pendleton et al., 2017; Braga et al., 2018; Bennett et al., 2019).

Fishermen empirical knowledge or local ecological knowledge (LEK) incorporation in data collection has, for a long time, played an important role in informing policy making and local strategy development, particularly due to FAO's Code of Conduct that states that all intervenients are to be involved in the design and implementation of the regulations (Ruddle, 1995; FAO, 2009; Braga et al., 2018)

Fishermen observations are often disregarded even though they provide useful and reliable information about local extinctions and shifts in distribution patterns, empirical perception of migrations, seasonal variability, location of key habitats and stock status (Serra-Pereira et al., 2014).

Nonetheless, spatial monitoring is key to efficiently manage resources and has proven to be essential in several cases to enforce proper stock management and implement effective conservation strategies such as Marine Protected Areas (MPAs) (Wedding et al., 2011; Pennino et al., 2016; Hays et al., 2019).

Up until 2020 the target was set at 10% for protected areas coverage worldwide to achieve the Aichi Biodiversity targets. However this goal has now been updated to 30% until 2030 (DEFRA, 2020). Unfortunately, the goal set for 2020 was not met yet, as only 5.8% of the world's oceans are currently under protection according to the MPAtlas, with only 2.6% being fully protected (<http://www.mpatlas.org/>), with around 94% of marine protected areas allowing fisheries to occur (Costello & Ballantine, 2015).

Furthermore, the use of MPAs as a strategy for elasmobranch conservation is often undermined by the common misconception that all elasmobranchs are highly mobile. For rays and skates that portray seemingly high site fidelity, small scale MPAs might be very effective at protecting all life stages, particularly if they include nursing and foraging grounds (Guixé & Arroyo, 2011; Le Port et al., 2012; Sousa et al., 2019). Even though large-scale Marine Protected Areas (over 150.000 km<sup>2</sup> of extension) might account for species with wider dispersal, these usually lack in enforcement power (Lewis et al., 2017).

A study performed in 2017 by *Bonaldo et al.*, in the small scale MPAs of Namada and Votua (Fiji) demonstrated that even small scale recent protected areas (lower than 1 km<sup>2</sup> and less than 10 years of implementation) show signs of actively preserving the communities.

In this paper we present the case study of the Berlengas Natural Reserve. This small group of islands composed of two main islands, the Berlenga Grande and Farilhões and the islets of Estelas and Medas makes up the Berlengas Archipelago. As one of the oldest fishing communities in Portugal, the neighbouring city of Peniche is notorious for the fish market and eco-tourism companies that visit the Berlengas daily (Santos et al., 2012).

Declared in 1992 as a special conservation zone (ZEC) by the Natura Network 2000 and a UNESCO Biosphere Reserve in 2011, the Berlengas Archipelago is home to astonishing biodiversity due to its unique location near the Nazaré canyon. Data from the Peniche fishing harbour has contributed to describe local species.

However, the fish market does not pinpoint where the individuals were caught meaning these might have been fished somewhere else. The present study was made to further investigate the presence of shark and ray species in this ecosystem.

The main goals of this study are (1) to characterize elasmobranch communities in the Berlengas Archipelago using three methods: Baited Remote Underwater Video (BRUV) recordings, surveys to several stakeholders (commercial and recreational fishers, locals and ecotourism companies) and on board observations of bycatch data from the local longline fleets, (2) to identify key areas for these species through map-based inquiries to stakeholders and analysis of georeferenced on-board observations of fishing activities, (3) to pinpoint vulnerable zones of potential overlap between human uses and elasmobranchs distribution and (4) to reflect upon the Berlengas Natural Reserve plan of action (PORN) efficiency regarding shark and ray conservation.

## 2. Material and Methods

### Study Area

Known to have historically important sites for small sharks (Carreiro dos Cações) and through analysing records of high fisheries landings and fishermen' anecdotal reports, the Berlengas archipelago was chosen as the study area for its potential importance to elasmobranchs.

First established in 1981, the Berlenga Natural Reserve (BNR) is located 5.7 miles off the Northwest coast of Peniche, Portugal. This protected area includes the Berlenga island, the Farilhões islands, the little islets of Medas and Estelas and the surrounding marine area (9456 hectares) (Pardal & Azeiteiro, 2001; Mendes et al., 2009) (Fig.1).

Furthermore, the Berlengas Natural Reserve is located near the southern and western margins of the Nazaré Canyon. This deep-sea canyon extending for over 170 km with an average depth of 3000 m is responsible for intense seasonal upwelling contributing for higher prey densities and thus, attracting pelagic predators. This phenomenon is intensified by the strong northwestern winds that are originate from the warm Portugal current that flows from North to South along the Portuguese coastline (Amado et al., 2007; Inglês, 2010; Almeida et al., 2016; Gil, 2016).

The marine reserve seabed is composed of granite rock bottoms covered in algae and sessile invertebrates, flanked by long sandbanks, sheltering, and supporting the life-cycles of many species. Moreover, there is a distinct occurrence of submerged and partially submerged caves, acknowledged by the Habitats Directive of the Natura Network 2000, contributing to the conservation values of this protected area (Amado et al., 2007; Vasco-Rodrigues et al., 2011).

The BNR Marine Protected Area is divided into two “type I” partial protection areas, surrounded by two “type II” partial protection areas and all encapsulated within a complementary protection area (Fig.2).

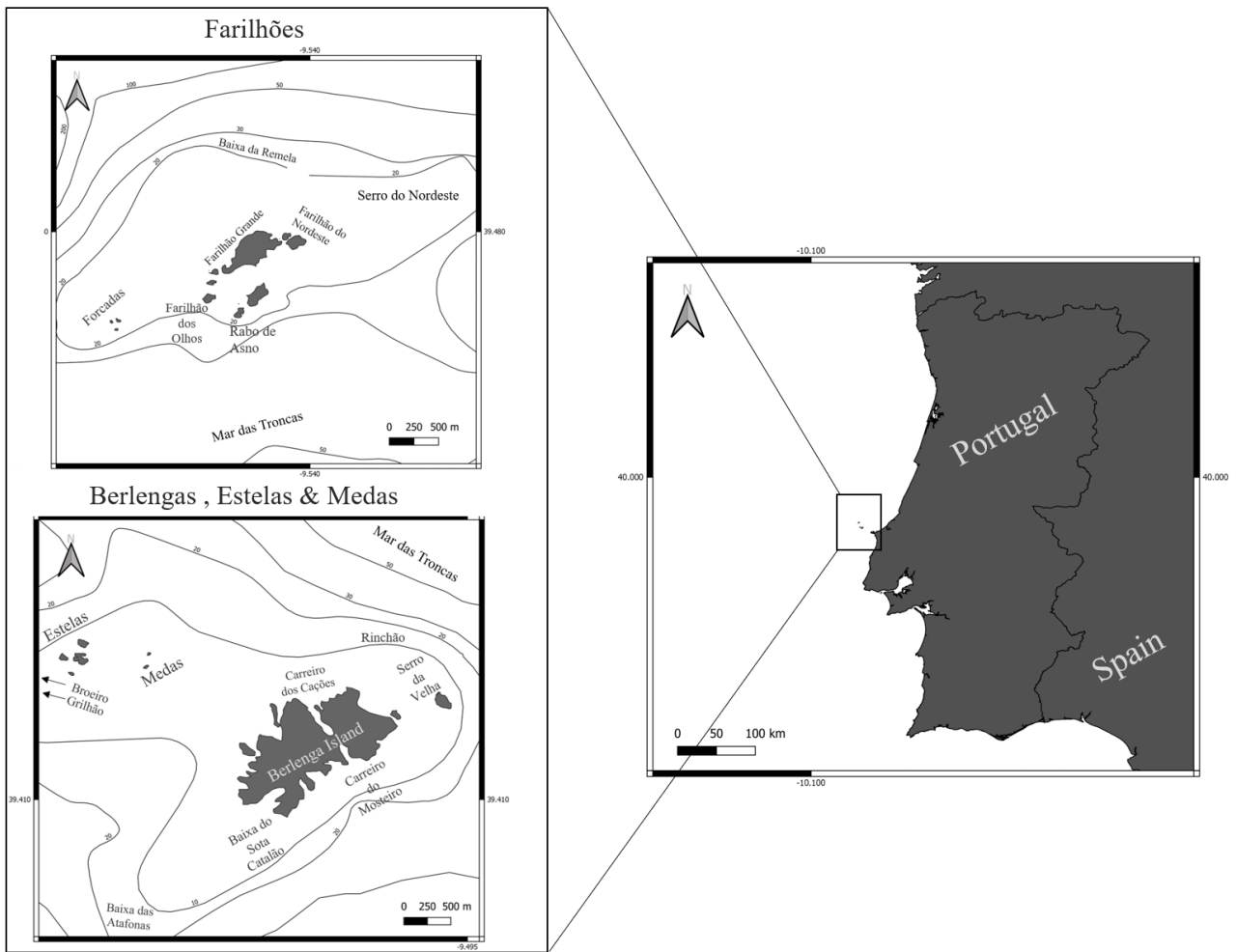


Figure 1 - The Berlingas Archipelago, located on the Northwest coast of Portugal

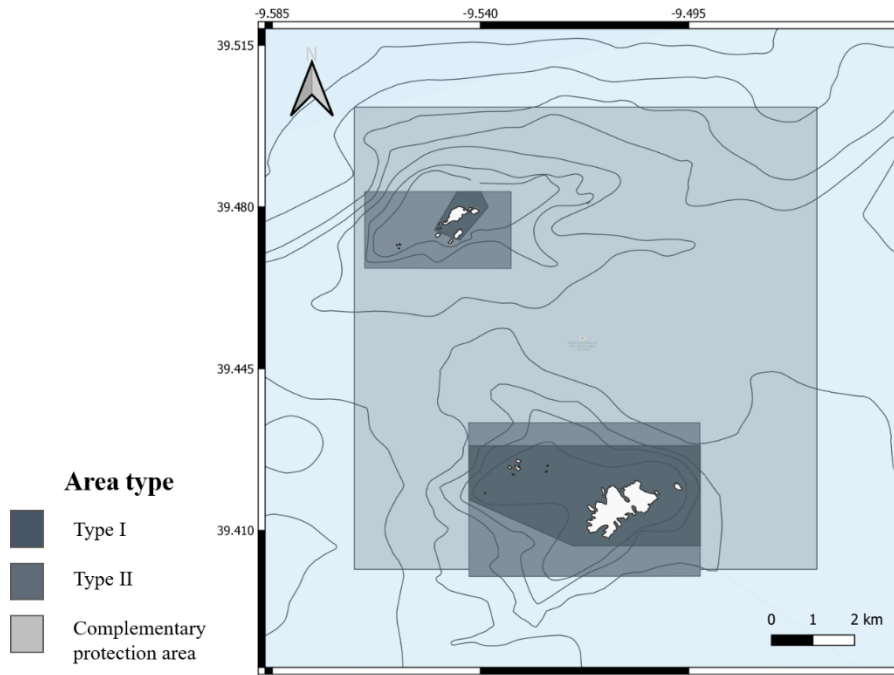


Figure 2 - Berlenga Marine Protected Area with the respective location of each protection type

Inside the Marine Protected Area a set of rules apply to every area no matter the level of protection. The capture and maintenance aboard of any specimen of marine mammal, seabird, migratory bird, sea turtle or individual of the *Epinephelus marginatus* species is forbidden, since these are protected under the plan of action. The introduction of new species, the use of noisy means of transportation (e.g. jet skis), the destruction of seabed and the eviction of non-treated effluents and solid residues are strictly prohibited (Resolução do Conselho de Ministros, 2008)

Restrictions concerning fisheries include the use of gill and trammel nets, trawlers, traps and scuba gear, the capture of molluscs and crustaceans with the exception of the Henslow's crab (*Polybius henslowii*), and the practice of spearfishing (Table 1).

Table 1 - Activities forbidden within each protection type area

<b>Area</b>	<b>Type of protection</b>	<b>Activities not allowed inside this area</b>
<b>Type I</b>	Partial	Longline vessels (>200 hooks) < 50 meters from landmasses. Coastal fisheries seasonally closed. Purse seiners. Gill and trammel nets. Traps. Trawlers. Capture of crustaceans and molluscs besides de <i>Polybius henslowii</i> crab.
<b>Type II</b>	Partial (buffer zone)	Gill and trammel nets. Traps. Trawlers. Capture of crustaceans and molluscs besides de <i>Polybius henslowii</i> crab. Recreational activities that exceed the RNB's human load capacity
<b>Complementary zone</b>	Complementary	Gill and trammel nets. Traps. Trawlers. Capture of crustaceans and molluscs besides de <i>Polybius henslowii</i> crab

Type I partial protection areas encompass valuable biodiversity and landscapes identified by their moderate to high ecological vulnerability. Resource extraction is allowed even if regulated. The operation of purse seiners, and longline vessels with an extension superior of 200 hooks, with openings over 9 mm, within a 50-meter distance of each landmass is prohibited. Traps are also prohibited within this area. Moreover, fishing from the coastline is seasonally closed between “Carreiro do Mosteiro” and the southern tip of “Ponta de França”. Type II partial protection areas act as buffers or transition zones between Type I areas and the complementary protection area, the external limit of the MPA. In this area the operation of purse seiners and longliners is already allowed (Resolução do Conselho de Ministros nº 180/2008).

As one of Portugal's main fishing ports, Peniche employs 6.4% of all its employed workers as fisherman with the main fishing fleets being purse seiners, trawlers, and multi-gear vessels (Gamito et al., 2016). In 2018, this harbour accounted for 1858 licensed fishers, having captured 12,774 tonnes of fish that same year of whom 319 tonnes (2.4%) were rays (INE, 2019).

### Data collection

The Berlengas MPA' elasmobranch community was assessed using multiple complementary non-invasive methods such as Baited Remote Underwater Video (BRUV) deployments, inquiries to the multiple stakeholders that operate within this area, the iNaturalist app records and the Society for the Study of Birds (SPEA)' on board observational data from bycatch occurring in the longline fleets.

### Baited Remote Underwater Video (BRUV) recordings

Regarding BRUV footage collection a total of 226 deployments were made between the 30<sup>th</sup> of May of 2019 and the 29<sup>th</sup> of September of 2020, to collect visual data through the placement of baited cameras both on the water column and near the bottom. Each trip two to three deployments took place, and two to three replicates were made for each site with soaking times of around one hour and a half. For the pelagic BRUVs the replicates were made as close as possible to the same coordinate. As for the benthic deployments, replicates were made around a 500 m ray around the starting point.

Although prioritizing areas appointed by the fishermen as good for shark fishing, sampling strategy focused on covering as much area as possible around the Berlengas and Farilhões islands not just to maximize the probability of finding elasmobranchs but also to identify possible important sites that had not been pinpointed before, in order to have some independent coverage from fishers' reports.

As proposed in *Bouchet et al., 2018*, all BRUV deployments were conducted during the day from first hours of sunrise to late in the afternoon to make the most of sunlight availability and encompass the moments where these species are thought to be more active.

The bait used in every sampling trip was around 1,5kg of defrosted minced Atlantic chub mackerel (*Scomber colias*) as it proved to be an effective olfactory cue to attract elasmobranchs. For logistic purposes, the fish were finely chopped and completely frozen, and defrosted within the 24 hours prior to deployment. Studies show frozen bait has about the same efficacy as an olfactory cue as fresh bait (Becerril-García et al., 2020) Video recordings were made for both pelagic and benthic environments with a total of 47 benthic samples and 159 pelagic samples (Fig.3)

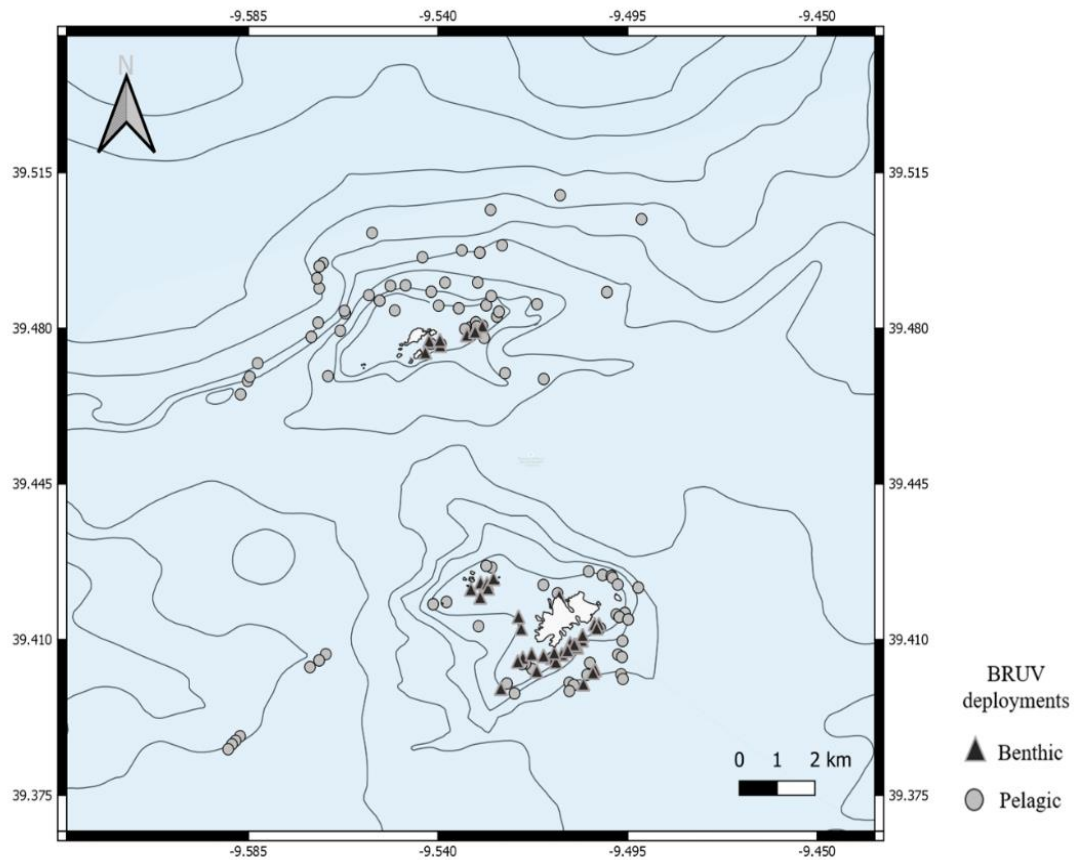


Figure 3 - BRUV deployments from May of 2019 to September of 2020 where the triangles represent the number of benthic deployments and the circles represent the number of pelagic deployments

Three types of BRUV rig setups were used (Fig.4) – a pelagic setup – to track pelagic species, such as the blue shark (*Prionace glauca*), in locations where anchoring was possible – a drifting setup – with the boat energy turned off, when depths did not allow the deployment of pelagic BRUVs, particularly in areas such as the northern region of the Farilhões islands, - and a benthic setup – to target benthopelagic species such as the small spotted catshark (*Scyliorhinus canicula*).

The BRUV rig used in the present study was composed of two stainless steel bars attached with metal pegs at a 90° angle.

When performing pelagic BRUVs, a 10-meter rope was attached to a 3-meter rope with hollow spheres to counterweight the rig, which in turn connected to a pair of floating buoys. The rig was then secured to the other end of the 10-meter rope. To keep its verticality, the rig carried a weight on the opposite extremity (5 kg) (Fig. 4B).

The buoys were secured, with either a 40- or 70-meter rope, to an anchor to keep the BRUV within a restricted sample site. During the recordings for the pelagic BRUVs, the camera stayed at around 10 to 12m below depth.

In some instances the rig was towed across several meters to perform drifting BRUVS in areas where anchoring was not an option (Fig. 4C). The maximum anchoring depth was 50 meters due to the boats own limitations.

Moreover the drifting method allowed the formation of a bait plume to attract larger pelagic sharks. The initial and final coordinates of the drift were registered. Regarding this setup, the rig was towed at a minimum of 70 meters from the boat.

In benthic BRUVS only the main rope connected to the anchor was used and the rig was hooked on to this rope to ensure the verticality of the bar carrying the camera. Hollow spheres were also looped into this main rope to keep the rope from drooping in front of the camera (Fig. 4A).

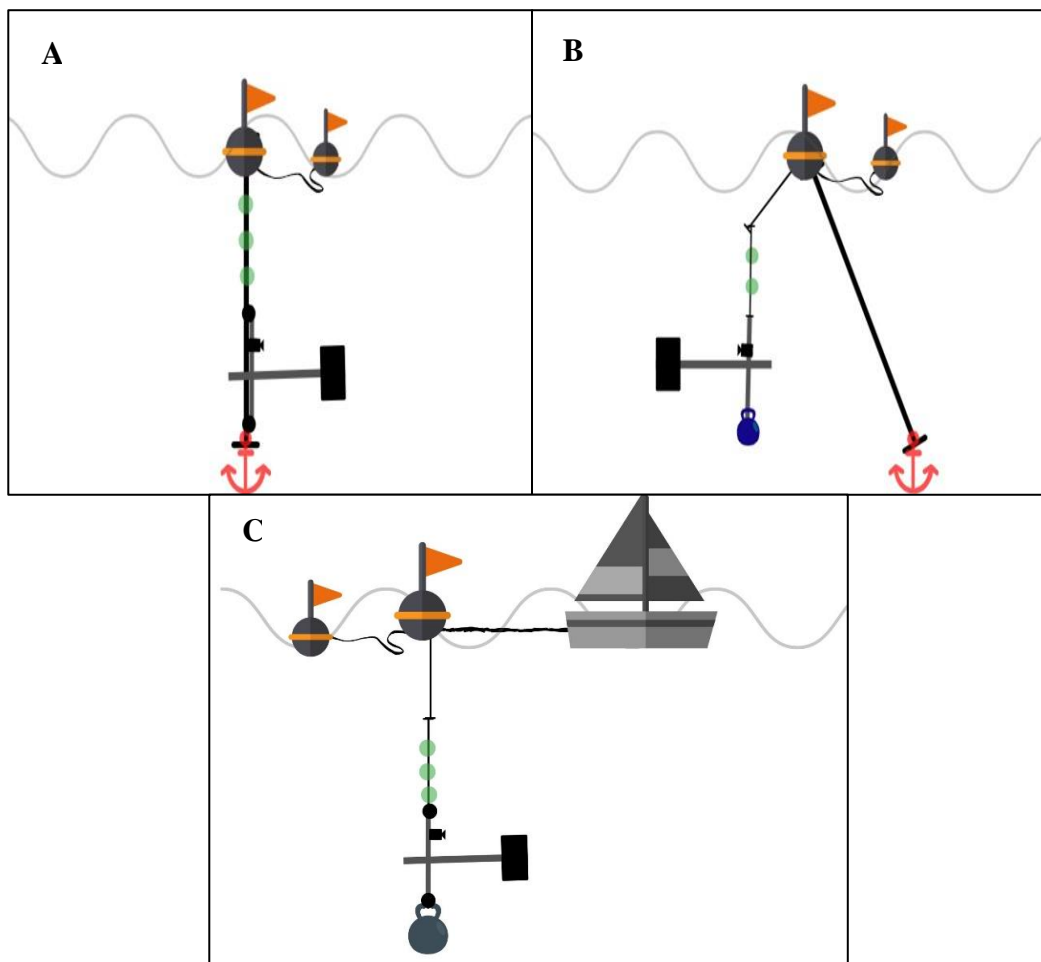


Figure 4 - Mono-BRUV rig schematic. A: benthic scheme; B: pelagic scheme; C: drift scheme

The maximum depth in which these BRUVs were deployed was limited by sunlight availability and the cameras housing capability of 30 m.

When performing the deployments, the coordinates of the deployment were registered. Moreover, depth, sea surface temperature and the season in which the deployments were made was registered.

### Stakeholder involvement and citizen science

Semi-structured map-based interviews were conducted to tourism companies, commercial and recreational fishermen operating inside the Berlengas Marine Reserve and near the perimeter of the MPA.

Prior to this study anecdotal reports from fishers were recorded and thus, with the existing information about the species assemblage of the Berlengas and the fishing harbour landing reports, a list was made. This list accounts for the presence of thirteen species of sharks (see Annex.1 for the detailed list of species and short ecological description)

Verbal consent was given by the interviewees in the beginning of each questionnaire session following the European (Directive 95/46/EC) legislation on data protection and anonymity, similarly to *Gamito et al., 2016*. A set of personal questions such as age, gender and first year of operation were registered prior to every survey. The questionnaires were split into four sections: description of the activity with extensive description of the boats that operate around the Berlengas Archipelago, shark and ray observations and ecological patterns, perception on temporal changes and opinion where a couple of questions were asked on the efficacy of the MPA from a user standpoint.

When recording data on elasmobranch observations both temporal and spatial perceptions were registered with the aid of three maps: one map of the archipelago (scale 1:50000 – 39° 30'); one map with the Berlenga island and, the Medas and Estelas islets (scale 1:25000 – 39°25'); and one map of the Farilhões islands (scale 1:25000 – 39°29'), all containing bathymetric and local reference points (Annex 2)

To accompany each survey a species identification catalogue was developed with all the elasmobranch species commonly described by local fishermen with both pictures and key traits described to facilitate the identification process (Annex 3)

The snowball sampling (Goodman, 1961) strategy was used, similarly to *Ramires et al., 2015*, by approaching an experienced fisherman at first that later referred us a set of new fishermen and so on.

A score was used, as a proxy for relative abundance of each species, to assess the observation frequency. This score was measured from 0 to 4 in which 0 was used to describe an absent species that was once present in the ecosystem, 1 was assigned to a rare species who appears every other year, 2 for species whose sightings are occasional (e.g. once a year), 3 for common species, that are observed every month or several times a year, and 4 for abundant species whose occurrence happens on a weekly basis.

A citizen science component was added to this project, using the iNaturalist app. Elasmobranch sightings, in the Portuguese coastline, were registered by providing a platform for accurate identification of the species, through photo submission (Annex 5) The iNaturalist app was created with the purpose of spreading quality information about species identification to the public and to aid scientists on gathering observational data (iNaturalist, 2020)

### On board observations

Bycatch data was collected by the Portuguese NGO “Society for the Study of Birds (SPEA)” aboard the surface and bottom longline vessels operating near the Berlengas islands. Surveys were done in February of 2012, and from January of 2016 to June of 2019, as part of the LIFE Berlengas project. Although on board observational data is a fishery-dependent method it does not cause extra mortality, being considered in the present study as a non-invasive method.

### Data analysis

#### Baited Remote Underwater Video recordings

Video analysis was done using VLC software (VideoLan, 2006). When analysing the BRUV footage, visibility was classified as low if the bait canister was not visible, medium if the bait canister was visible but there was either poor lighting, high density of particles floating or items blocking the field of view, and high if visibility allowed to perceive individuals beyond the bait canister clearly.

Species common and scientific names, bottom type, interactions with the bait canister and maximum number of individuals for each species in one frame (maxN) were recorded.

### Stakeholder involvement – inquiries

Species occurrence was estimated by summing up the number of mentions of each species throughout the questionnaires and through examining the overall scores attributed to each occurring species. To probe for factors that might have possibly skewed the interviewees perception, an analysis was made on the influence of age and occupation on score attribution, similarly to *Leitão et al., 2020*.

To test these hypotheses, the normality of the score data was tested through a Shapiro-Wilk test. Afterwards, Kruskal-Wallis tests were made to test for the null hypothesis of no significant differences on score attribution between different factors.

Due to the wide range of activities and ages of the interviewees, the multiple factors tested were age (ranging from 23 to 77), age class [23-43 (n=44); 45-53 (n=40); 55-77 (n=41)], activity (with the different activities being: surface longlining, bottom longlining, gillnetting, handlining, sightseeing, recreational diving, and marine mammal observation) and finally activity class (split into 2 categories: extractive and non-extractive activities). Age class was split into categories that allowed the sample size to be as close as possible to each other (around 40 individuals per group).

Questionnaire data was analysed using the RStudio software (RStudio Team, 2016).

### Spatial analysis

All spatial analysis was done using QGIS 3.12 Bucuresti and QGIS 2.18 Las Palmas (QGIS.org, 2021). A grid of 1km per 1km was used as a buffer to account for users' visual biases as appointed locations were oftentimes represented as dots on the map. Species occurrence and human activity distribution were measured through number of mentions in each grid cell. Species observations were categorized into two types of data: observational data, with visual confirmation, that include the BRUV footage, SPEA on board observations and citizen observations through the iNaturalist app, and inquiry data.

To map possible risk zones of human activity overlapping with sensitive species a vulnerability assessment was conducted. To do so, an index was developed, loosely based on the approaches of *Halpern et al. (2008)* and *Batista et al. (2014)*, by attributing relative scores from Low to Extremely High vulnerability, to each grid cell.

To account for species vulnerable features in the absence of biological and ecological data, the IUCN Red List status for European populations was used as a proxy for species sensitivity as this index already gathers information on factors such as population size, resilience potential and reproductive strategies (IUCN, 2010). Species registered within this area had IUCN Red List status ranging from Least Concern to Critically Endangered. Therefore, in the present study species sensitivity ( $S_{spp}$ ) was categorized from 1 to 5 with: 1(Least Concern), 2(Near Threatened), 3(Vulnerable), 4(Endangered) and 5(Critically Endangered). Similarly, a quantitative value was attributed to each activity that takes place in the Berlengas Archipelago ranging from 1 (non-extractive activities such as scuba diving, anchoring, sightseeing and marine mammal observation) to 3 (high impact extractive activities like bottom and surface longline) with 2 representing low impact extractive activities like handlining. Thus, human activity in an area of 1 km<sup>2</sup> ( $A_i$ ) was estimated by summing the values corresponding to the activities that take place in that same area. This index does not consider the number of users of each activity in each area but rather the presence of such activities.

Thus, the vulnerability index of each grid cell (VI) was then calculated with the formula

$$VI = [\sum(S_{spp} * PA_{spp})] * A_i$$

where  $PA_{spp}$  is the perceived abundance of each species, e.g. their mean scores given by the stakeholders' interviews.

These values were then converted into vulnerability percentages to fit in four quantiles from 0-25% (Low), 25-50% (Medium), 50-75% (High) and 75-100% (Very High). Areas marked as having “Low” vulnerability were either locations where only activities or species were reported, or the activities that took place in such areas were low impact and the occurring species were neither abundant nor fragile.

### 3. Results

#### Stakeholder involvement – inquiries

Overall, forty questionnaires were made of which 16 were professional fishermen, 13 were recreational fishers, 10 were marine tourism companies and the last one was performed to the captain of the National Republican Guard (GNR) “Coastline Control Unit”. According to *Morgan and colleagues* (2002), for populations with similar beliefs an average sampling effort of 20 to 30 interviews is considered representative. The respective inquiry layouts are listed in Annex 4.

All interviewees were men between the ages of 20 and 80 years old with around 32.5% being 40 to 50 years old. A total of 43 boats were registered of which 31 were boats operating within and around the Berlengas Natural Reserve. The remaining vessels operated either further south (Ericeira) or up north, in São Martinho do Porto. Regarding boat size, the vessels operating in this area were mostly (62%) around 5 to 10 meters with some boats reaching up to 25 meters in length. Concerning the fishing vessels that operate in this area, 4 were bottom longliners, 5 were surface longliners, 15 only fished with handline and one operator used traps. Outside the premises of the MPA, there were four trammel/gill net vessels operating, that periodically set traps to fish for octopus (*Octopus vulgaris*)(*Cuvier, 1797*).

To assess the presence of elasmobranch species the number of times a species was mentioned by the stakeholders was counted (Fig. 5). When observing the following image two species stand out as most mentioned: the blue shark (*Prionace glauca*) and the small spotted catshark (*Scyliorhinus canicula*), mentioned more than 20 times. The hammerhead sharks (*Sphyrna sp.*) (n=11), shortfin mako shark (*Isurus oxyrinchus*) (n=8) and the thornback ray (*Raja clavata*) (n=8) follow right after as the most mentioned species. In contrast, the least mentioned species were the white skate (*Rostroraja alba*) (n=2) and the soupfin shark (*Galeorhinus galeus*)(n=2).

Five species were left out of the analysis as these were only mentioned once: the sandbar shark (*Carcharhinus plumbeus*), the nursehound (*Scyliorhinus stellaris*), the eagle ray (*Aetomylaeus bovinus*), the basking shark (*Cetorhinus maximus*) and the whale shark (*Rhincodon typus*).

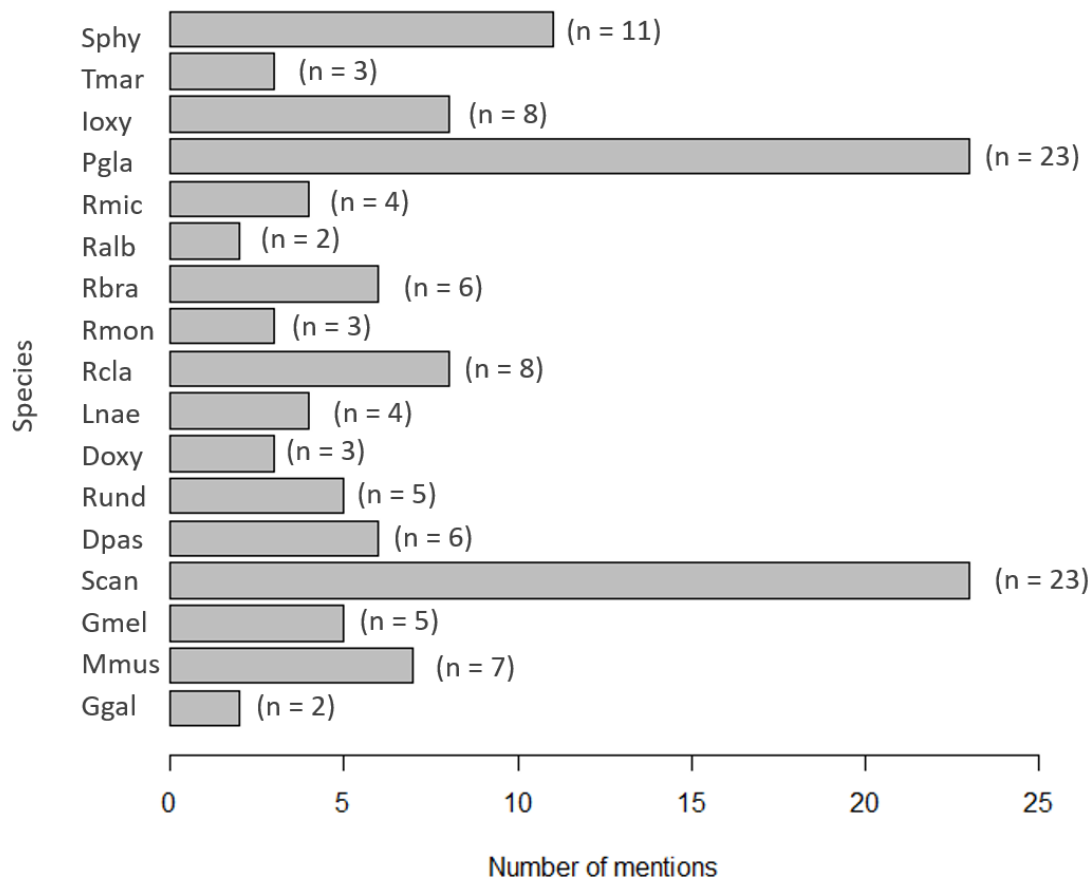


Figure 5 - Number of mentions of each species by the interviewees over the course of the inquiries: *Sphy* (*Sphyrna* spp.); *Tmar* (*Torpedo marmorata*); *Ioxy* (*Isurus oxyrinchus*); *Pgla* (*Prionace glauca*); *Rmic* (*Raja microocelata*); *Ralb* (*Rostroraja alba*); *Rbra* (*Raja brachyura*); *Rmon* (*Raja montagui*); *Rcla* (*Raja clavata*); *Lnae* (*Leucoraja naevus*); *Doxy* (*Dipturus oxyrinchus*); *Rund* (*Raja undulata*); *Dpas* (*Dasyatis pastinaca*); *Scan* (*Scyliorhinus canicula*); *Gmel* (*Galeus melastomus*); *Mmus* (*Mustelus mustelus*); and *Ggal* (*Galeorhinus galeus*)

The observation frequency was assessed through a comparison of scores (Fig. 6). In this analysis, the median was used as the final attributed score. Although species such as the blue shark and the small spotted catshark were frequently mentioned across all stakeholders, they were scored as “common” instead of “abundant”. The species scored as most abundant were the blackmouth catshark (*Galeus melastomus*), the longnosed skate (*Dipturus oxyrinchus*), the spotted ray (*Raja montagui*) and the blonde ray (*Raja brachyura*).

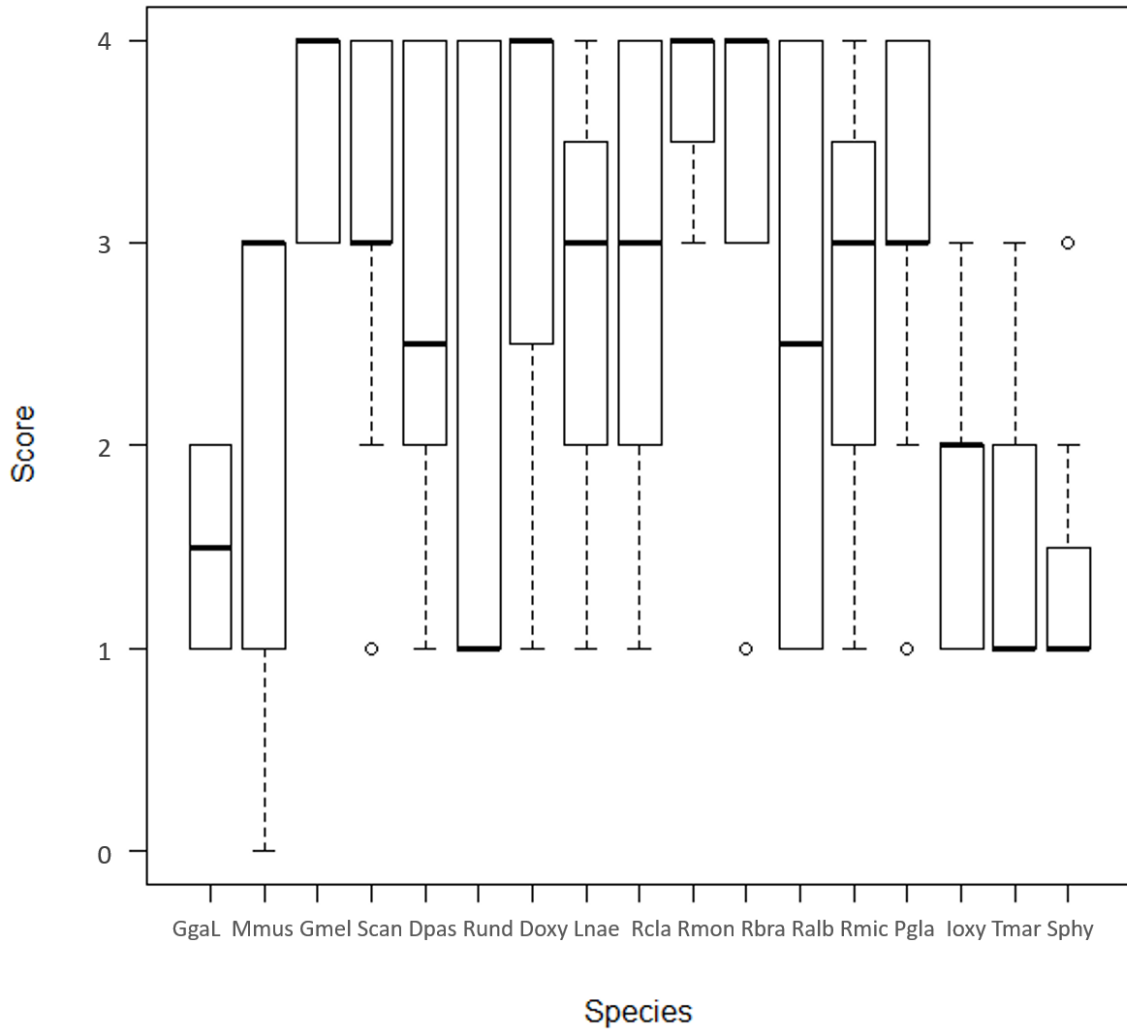


Figure 6 - Relative abundance of each species through a score from 0 to 4 in which: 0 (Absent); 1 (Rare); 2 (Occasional); 3 (Common); and 4 (Abundant). The follow abbreviations are: Ggal (*Galeorhinus galeus*); Tmar (*Torpedo marmorata*); Gmel (*Galeus melastomus*); Scan (*Scyliorhinus canicula*); Dpas (*Dasyatis pastinaca*); Rund (*Raja undulata*); Doxy (*Dipturus oxyrinchus*); Lnae (*Leucoraja naevus*); Rcla (*Raja clavata*); Rmon (*Raja montagui*); Rbra (*Raja brachyura*); Ralb (*Rostroraja alba*); Rmic (*Raja microocelata*); Pgla (*Prionace glauca*); Ioxy (*Isurus oxyrinchus*); Tmar (*Torpedo marmorata*); Sphy (*Sphyrna spp.*)

Even though some fishermen appointed the smooth-hound shark (*Mustelus mustelus*) as common, and it was one of the most mentioned species, three of the interviewees scored this species with zero, meaning this species existed in that ecosystem but is no longer observed.

### The effect of age and activity in score attribution

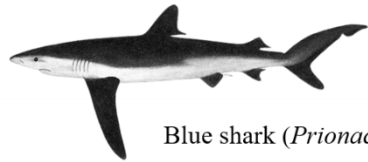
To assess the influence of age and occupation on species frequency scores and given the score data did not comply with assumptions of normality ( $W=0.83926$ ,  $p<0.05$ ), Kruskal-Wallis tests were performed for each species and factor (Table 2).

This evaluation was made for the species that were either most frequently mentioned in the inquiries or to whom high scores were attributed such as the blue shark (*Prionace glauca*), the shortfin mako (*Isurus oxyrinchus*), the hammerhead sharks (*Sphyrna spp.*), the small spotted catshark (*Scyliorhinus canicula*), the thornback ray (*Raja clavata*), the blonde ray (*Raja brachyura*), the common stingray (*Dasyatis pastinaca*), the undulate ray (*Raja undulata*) and the blackmouth catshark (*Galeus melastomus*). This analysis was also performed for the smooth-hound (*Mustelus mustelus*).

Regarding the results, only the blue shark (*Prionace glauca*) and the small spotted catshark (*Scyliorhinus canicula*) showed significant differences. The blue shark had significant differences between activities (Kruskal Wallis: chi-squared = 6.8018: p-value < 0.05) with higher scores attributed by surface and bottom longline vessels (Fig.7A), and there were significant differences between age classes (Kruskal Wallis: chi-squared = 8.4543: p-value < 0.05) of which the younger age class scored this species as abundant (Fig.7B)

Table 2 - Kruskal-Wallis test results for influence of age and activity on score delivery with the factors age (ranging from 23 to 77), age class [23-43 (n=44); 45-53 (n=40); 55-77 (n=41)], activity (with the different activities being: surface longlining, bottom longlining, gillnetting, handlining, sightseeing, recreational diving, and marine mammal observation) and activity class (split into 2 categories: extractive and non-extractive activities). Df = degrees of freedom; Values highlighted in **bold** are statistically significant for 0.05.

	Blue shark ( <i>Prionace glauca</i> )			Shortfin mako ( <i>Isurus oxyrinchus</i> )			Hammerhead sharks ( <i>Sphyrna spp.</i> )			Small spotted catshark ( <i>Scyliorhinus canicula</i> )			Thornback ray ( <i>Raja clavata</i> )		
	df	chi-squared	p-value	df	chi-squared	p-value	df	chi-squared	p-value	df	chi-squared	p-value	df	chi-squared	p-value
<b>Age</b>	15	17.68	0.2798	5	3.4	0.6386	8	5.0185	0.7556	17	17.043	0.4514	4	6.0801	0.1932
<b>3 level class age</b>	2	8.4543	<b>0.01459</b>	2	0.3375	0.8447	2	0.83333	0.6592	2	2.6008	0.2724	2	1.1816	0.5539
<b>Activity</b>	6	6.8018	<b>0.03396</b>	3	0.975	0.8073	5	4.9352	0.4238	5	11.131	<b>0.04884</b>	4	5.3397	0.2542
<b>2 level class activity</b>	1	3.0066	0.08292				1	0.016975	0.8963	1	6.4196	<b>0.01129</b>	1	1.9145	0.1665
	Blonde ray ( <i>Raja brachyura</i> )			Common stingray ( <i>Dasyatis pastinaca</i> )			Undulate ray ( <i>Raja undulata</i> )			Smooth-hound shark ( <i>Mustelus mustelus</i> )			Blackmouth catshark ( <i>Galeus melastomus</i> )		
	df	chi-squared	p-value	df	chi-squared	p-value	df	chi-squared	p-value	df	chi-squared	p-value	df	chi-squared	p-value
<b>Age</b>	4	5	0.2873	5	5	0.4159	3	2.3333	0.5062	4	5.1667	0.2706	4	4	0.406
<b>3 level class age</b>	2	3.3333	0.1889	2	3.2955	0.1925	2	0.66667	0.7165	2	2.0444	0.3598	2	0.66667	0.7165
<b>Activity</b>	3	5	0.1718	1	2.2727	0.1317	2	1.7778	0.4111	3	3.0333	0.3865	2	1.7778	0.4111
<b>2 level class activity</b>	1	3	0.08326	1	2.2727	0.1317	1	0.66667	0.4142	1	1.9444	0.1632			



Blue shark (*Prionace glauca*)

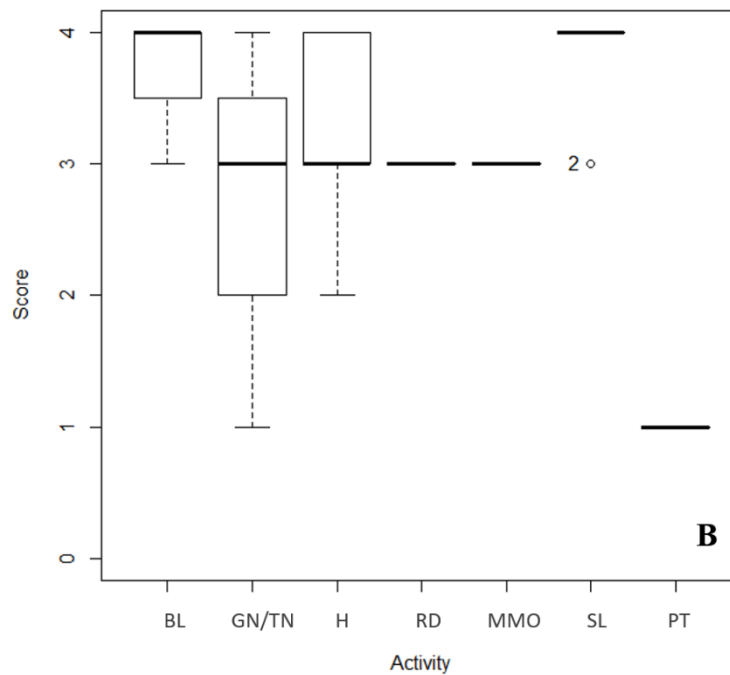
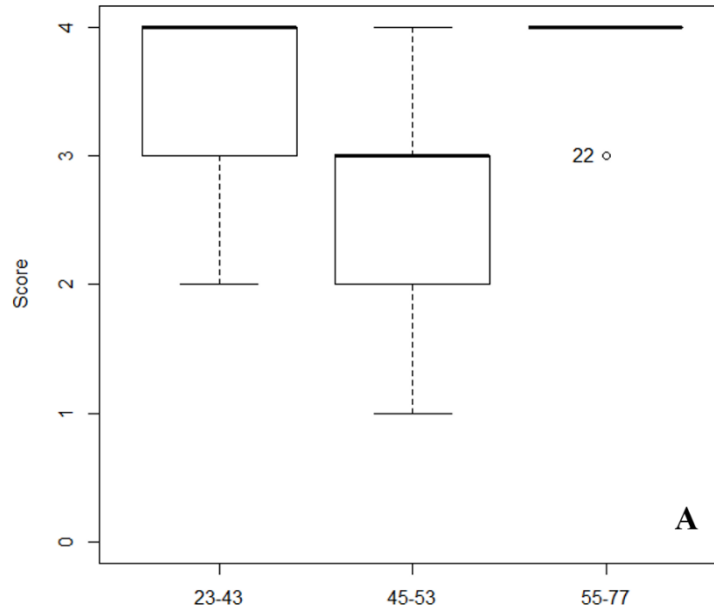


Figure 7 - A) Boxplot of score by 3 level age class factor age class [23-43 (n=44); 45-53 (n=40); 55-77 (n=41)], for the blue shark (*Prionace glauca*); B) Boxplot of score by activity, for the blue shark (*Prionace glauca*): BL = bottom longline; GN/TN = gillnets and trammel nets; H = handline; RD = recreational dive; MMO = marine mammal observation; SL = surface longline; and PT = passenger transport [Illustration adapted from Ann Hecht ©]

Regarding the attribution of scores to the small spotted catshark (*Scyliorhinus canicula*), the factors activity and activity class had significant influence. There were significant differences between activities (Kruskal Wallis: chi-squared = 11.131; p-value < 0.05) particularly with higher scores being attributed by the bottom longline and handline operators (Fig. 8A). As a result, there were also significant differences (Kruskal Wallis: chi-squared = 6.4196; p-value < 0.05) between the two types of activities (Fig.8B).



Small spotted catshark (*Scyliorhinus canicula*)

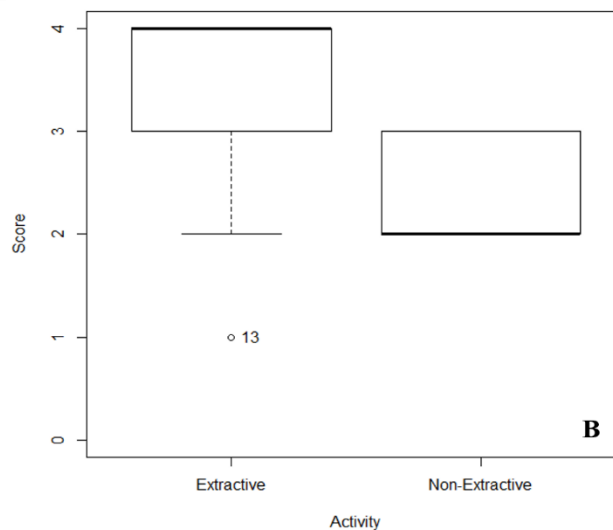
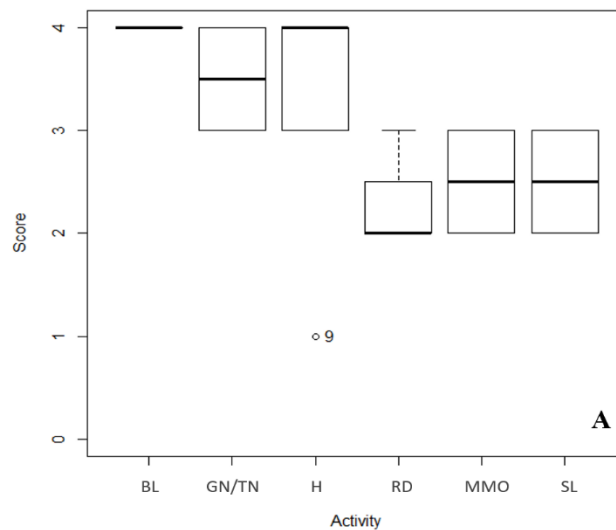


Figure 8 - A) Boxplot of score by activity, for the small spotted catshark (*Scyliorhinus canicula*): BL = bottom longline; GN/TN = gillnets and trammel nets; H = handline; RD = recreational dive; MMO = marine mammal observation; and SL = surface longline; B) Boxplot of score by activity class factor age class (extractive and non-extractive activities) the small spotted catshark (*Scyliorhinus canicula*) [Illustration adapted from Scandinavian Fishing Year Book ©]

### Spatial analysis of human ecosystem usage and species distribution

After dividing the study area into a 1 square km cells, the level of human activity was measured through the number of activities per cell, to account for observational bias. It was then split between extractive activities (which include fisheries such as bottom longlining, surface longlining and handlining) and non-extractive activities such as recreational scuba diving, cave exploring, sightseeing, marine mammal observation and anchoring.

Overall, human presence is higher on the eastern side of the main Island near Carreiro dos Caçães, Rinchão and Serro da Velha, on Baixa das Atafonas, near Estelas and Medas and on the southern and eastern side of the Farilhões islands (in Farilhão dos Olhos, Rabo de Asno and Serro do Nordeste)(Fig.9A).

The number of extractive activities (Fig.9B) was higher on the southwestern side of the Berlenga Island, in a place known by locals as Baixa das Atafonas, and on the northeastern side in Rinchão, followed by the Estelas and Medas islets (particularly in Broeiro and Grilhão), and the western side of the Berlenga island commonly known as Serro da Velha. Most surface activities occur on the Rinchão and Serro da Velha areas, around the Estelas and Medas islets and in Baixa das Atafonas, whereas bottom focused activities occur mainly on Baixa do Sota Catalão and in Mar das Troncas, a wide sand bottom around 30 to 50 meters below surface between the Berlenga Island and the Farilhões islands.

Non-extractive activities (Fig.9C), on the other hand, are more prominent closer to the main island due to passenger drop-offs on Carreiro do Mosteiro, scuba diving tryouts in Primavera (between Forte de São João Baptista and Carreiro do Mosteiro) and marine mammal observations on the north-eastern side of the island. Furthermore, scuba diving activities and whale watching activities contribute to higher levels of human presence on the Farilhões islands.

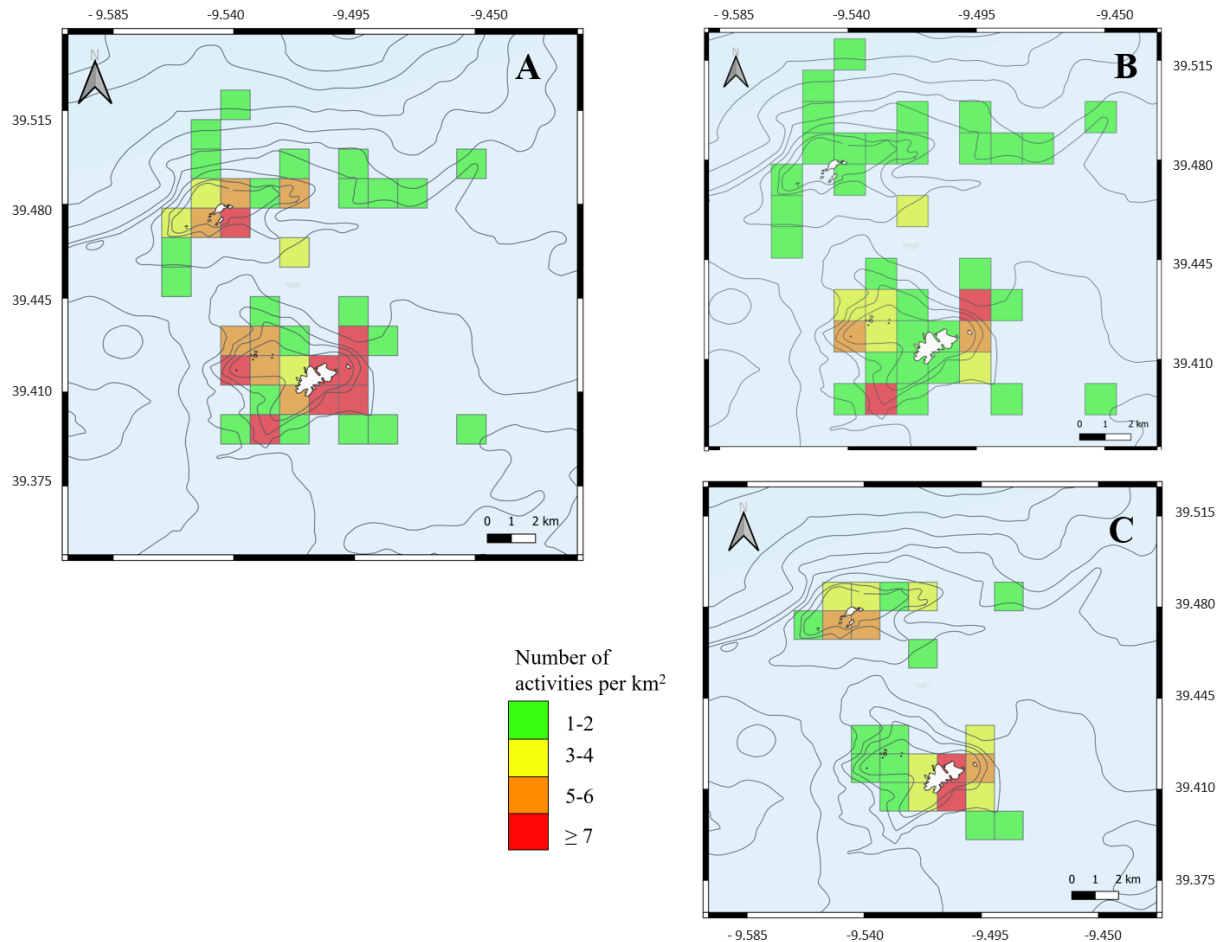


Figure 9 - Number of anthropogenic activities per km<sup>2</sup>: A) Total number of activities ; B) Extractive activities; C) Non-extractive activities

Similarly to the quantification of activities, species occurrence was measured by counting the number of individuals, either observed or mentioned, in each 1km<sup>2</sup> cell.

Observational data (Fig.10A) lists species occurrence as highest around the Farilhões Islands, particularly for pelagic species recorded as bycatch. When analysing the SPEA on board observations (which makes up 83% of the observational data), ten species of elasmobranch were present, five of which were shark species, four were skates and only one was a ray species (*Myliobatis aquila*). In total, 60 individuals were unintentionally captured by these fleets with 60% of captures being represented by pelagic sharks, such as the blue shark (*Prionace glauca*) (N=33) and the shortfin mako shark (*Isurus oxyrinchus*) (N=3).

In opposition benthopelagic species occurred predominantly closer to the Berlenga island, of which 6 individuals were small spotted catsharks (*Scyliorhinus canicula*) and one was a thornback ray (*Raja clavata*), which were detected within the BRUV footage.

Inquiry data (Fig. 10B) shows, on the other hand, a higher number of mentions in Baixa das Atafonas, on the southern side of the Berlenga Island, on the western side in Rinchão and Serro da Velha, near Broeiro and Grilhão (Estelas & Medas islets) and on the western side of the Farilhões Islands, in Serro do Nordeste.

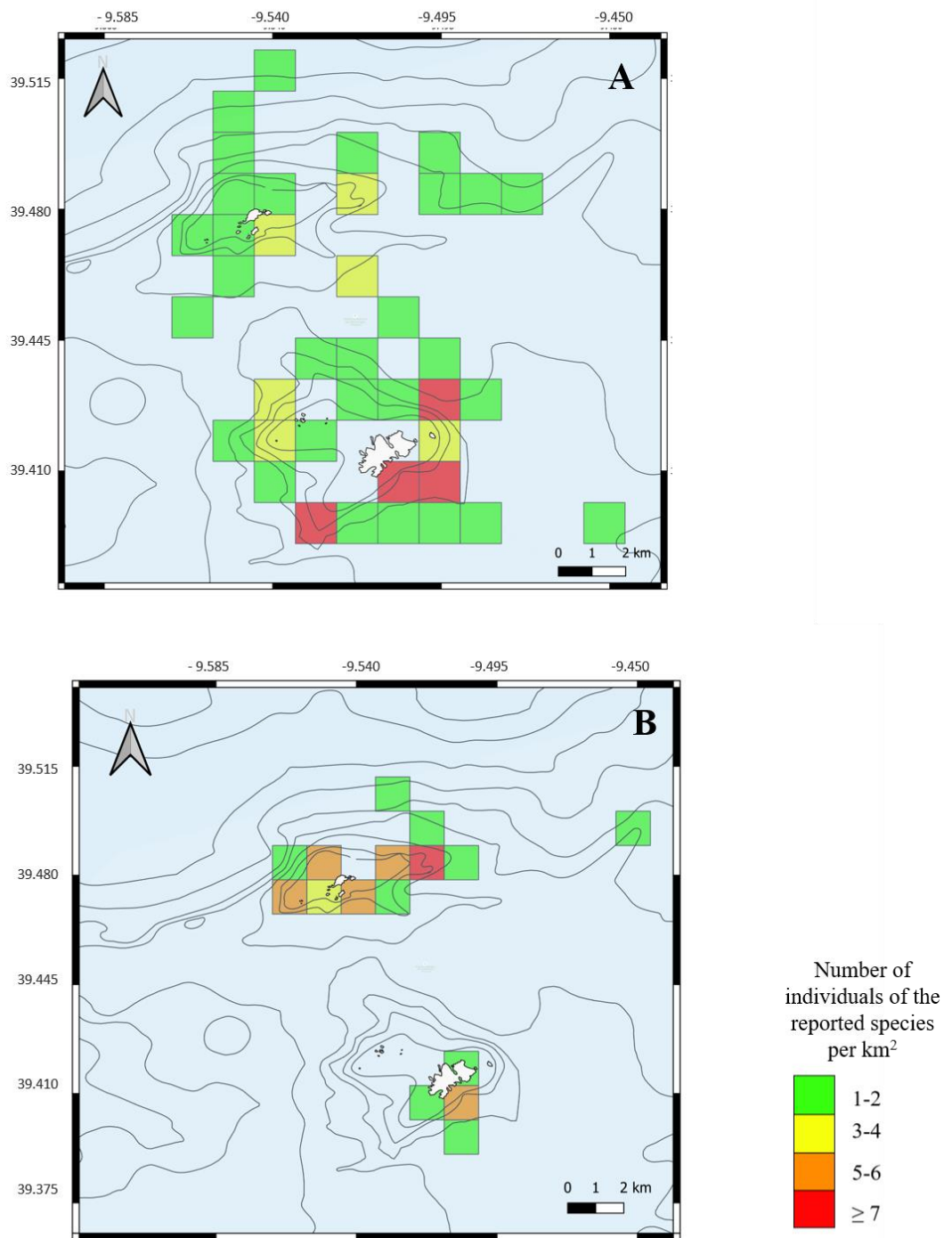


Figure 10 - Number of individuals of the previously referred species array per km<sup>2</sup>: A) Observational data; B) Inquiry data

When looking at the overview (Fig.11), most species occur once again on the south side of the Berlenga Island, on the southwestern area of Baixa das Atafonas and near the northeastern side of the island. In addition, there is a high incidence of individuals around the Farilhões islands, particularly on the southern area and on the western area of Serro do Nordeste.

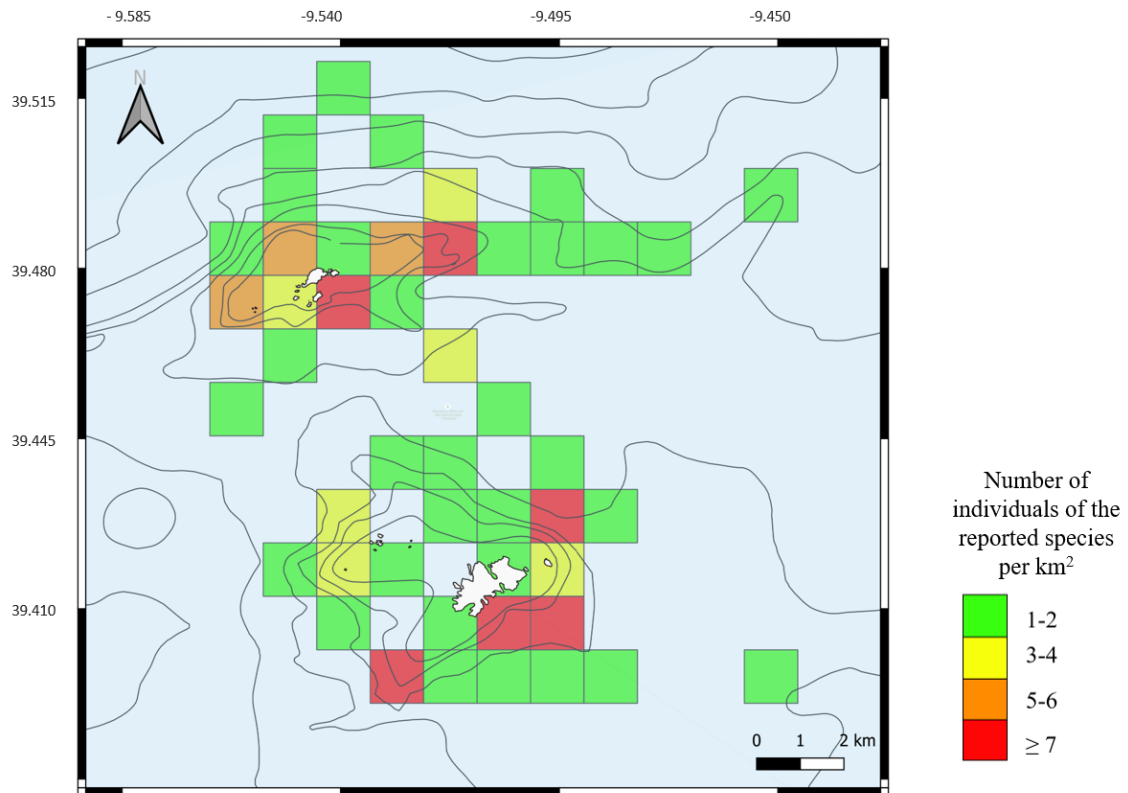


Figure 11 - Overview of species occurrence as a result of the observational data coupled with the inquiry data

### Spatial Vulnerability Assessment

After combining occurrence with activity data into a vulnerability index (see Material and Methods), two locations stood out as extremely vulnerable – Rinchão and the southern side of the Berlenga island (Fig.12). Rinchão is a sought after spot for both bottom and surface longlining as well as for recreational fishing. The surrounding area of Rinchão is also a popular diving spot. When looking at the species composition of this site, we find mentions of two particularly vulnerable species – hammerhead sharks (*Sphyrna spp.*), whose IUCN statuses are described as Critically Endangered, for their European populations, and the common stingray (*Dasyatis pastinaca*) listed as Vulnerable in the IUCN Red List.

On the other hand, the southern side of the Berlenga Island has a high prevalence of activities particularly because the main visitor entrance to the island is located here.

Furthermore, activities such as scuba diving initiations, recreational fisheries, surface longline and marine mammal observation take place in this sheltered side of the island. Although the species described for this area are listed as Least Concern and Near Threatened, species such as the small spotted catshark (*Scyliorhinus canicula*) and the thornback ray (*Raja clavata*) were scored, by the stakeholders, as abundant and common, respectively, contributing to the overall high sensitivity of the area and thus raising its vulnerability.

Serro da Velha (Northeast of the Berlenga Island) and Serro do Nordeste (Northeast of the Farilhões Islands) portrayed high vulnerability due to shortfin mako (*Isurus oxyrinchus*) presence on both sites and the occurrence of activities such as surface and bottom longline as well as recreational diving, handling and sightseeing. Scored as Occasional by the interviewees, the shortfin mako shark is listed as Endangered on the IUCN Red List.

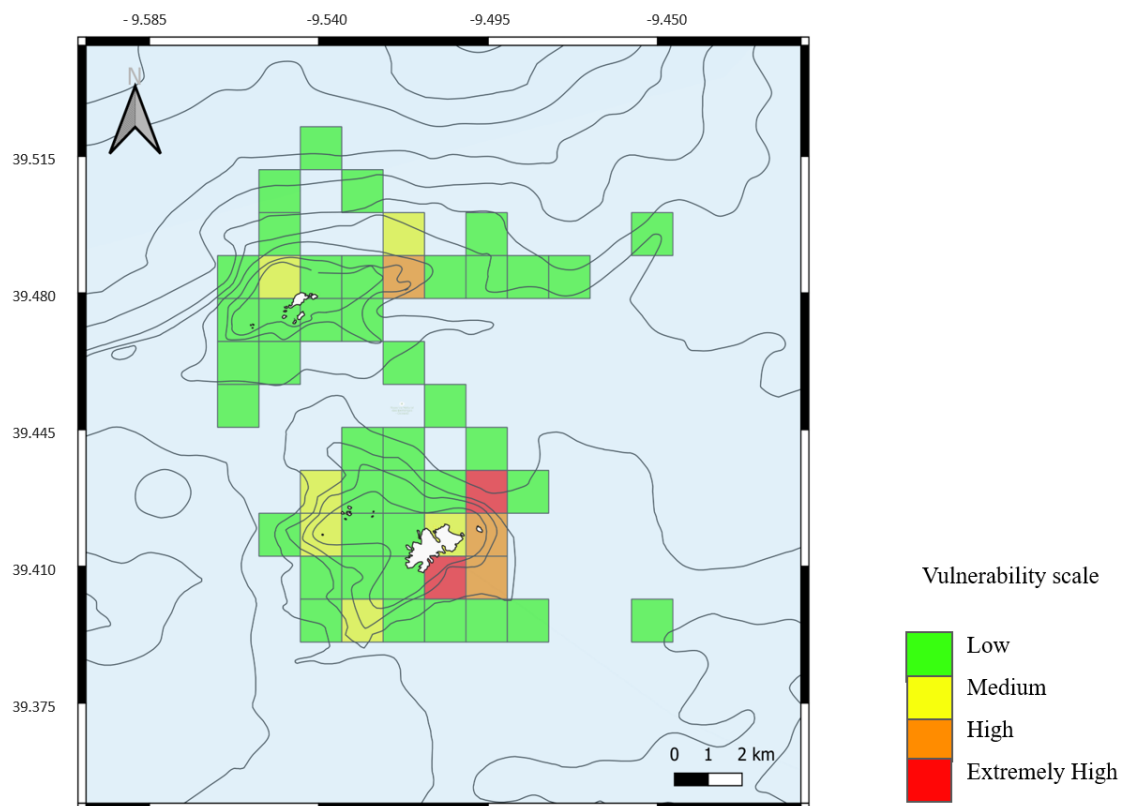


Figure 12 - Vulnerability index – overlap of high impact activities with sensitive species of each 1km<sup>2</sup> area of the Berlengas Archipelago

### Stakeholder opinion of the Marine Protected Area

A question about the stakeholders' opinion on the MPA implementation was asked during the questionnaires in which 25% responded positively and 37.5% had a neutral opinion about the impact of the reserve. However 37.5% of the 40 interviewees gave a negative opinion on the MPA efficacy. When probed about their opinion the interviewees justified their answers with a crescent need for improvement in monitoring and enforcement strategies.

## **4. Discussion and conclusion**

The present study contributed to shine a light on the occurrence of elasmobranch species off the coast of the Berlengas archipelago, highlighting several areas where species overlap with human activity. To do so a vulnerability index was developed to pinpoint possible risk areas that result from overlap of sensitive species and impacting human activities. The impact values for the index were achieved through comparing and scoring the possible impacts an activity might have on these species, based on *Batista et al.* (2014), while species vulnerability was based on IUCN Red List Status (IUCN, 2020).

Given the known vulnerability of most elasmobranch species worldwide and the scarce scientific knowledge on their ecology, this preliminary approach is of the utmost importance to inform scientists and decision makers. Thus, it was proven that it is possible to gather information on rare, highly mobile, species mostly based on local ecological knowledge (LEK). Even on the absence of data prior to this study, the inquiry data in conjunction with the on board observations and the underwater video recordings enabled the mapping of species and activities in this area which is of high relevance to support conservation measures implementation when more robust scientific data is lacking (e.g. long-term data series)

The results show the main extractive activities occurring inside of the MPA are bottom and surface longlining. These fishing gears are known to contribute for the incidental catch of blue shark (*Prionace glauca*) and shortfin mako shark (*Isurus oxyrinchus*) (Mandelman et al., 2008; Campana et al., 2009; Campana et al., 2011), two of the most common species in this study, both mentioned by the stakeholders and present in the on board observational data.

Often following preys' distribution patterns pelagic sharks are caught on the hooks when feeding, a phenomenon called “depredation” (Mitchell et al., 2018). In the Berlengas MPA, this happens when these pelagic sharks pursue the target species of longlines, such as the European seabass (*Dicentrarchus labrax*) and the gilthead seabream (*Sparus aurata*) in the case of the surface longline fleet, particularly in areas such as Rinchão and Serro do Nordeste (fishers' personal communication). As a result, these species might be the most impacted within this MPA, with Rinchão highlighted (according to the vulnerability index results) as the most conflict area between the occurrence of these species and human presence.

On the other hand the small spotted catshark (*Scyliorhinus canicula*), also often mentioned by stakeholders and observed in BRUVs, has high survival rates when captured and released (Rodríguez-Cabello et al., 2005). Listed as Least Concern by the IUCN Red List, this species can be found from shallow areas to 100 meters depth across an array of bottom types. From sandy and rock bottoms to muddy and algae covered reefs, the small spotted catshark feeds on crustaceans and lays its eggs in algae conglomerates (Moreira, 2018). Spatial segregation is known to occur as juveniles tend to inhabit deeper waters (Lopes, 2019). Since most bottom focused fisheries are not allowed in this area, it is unlikely that this species will be heavily impacted by human presence.

Despite the fact that rays and skates were not amongst the most mentioned species, they were considered, by local stakeholders, as relatively “abundant”. Of the fisheries that take place inside the marine reserve only the bottom longline fleet frequently captures these species (fishers' personal communication). However it is not expected that these catches have a huge impact as the main fishing fleets that have shown to have high levels of impact are gill and trammel nets as well as, trawlers (Serra-Pereira et al., 2005; Biton-Porsmoguer & Lloret, 2020), none of which allowed inside the perimeter of the marine protected area. According to Serra-Pereira et al. (2015), ray species occur mostly near 40 m deep. This was corroborated in the current study as Mar das Troncas, a sandbank between the Berlenga Island and the Farilhões Island at depths between 30 to 50 m, was appointed by the stakeholders as the main location where these can be found. Listed as “Near threatened” by the IUCN Red List, species such as the spotted ray (*Raja montagui*), the blonde ray (*Raja brachyura*) and the undulate ray (*Raja undulata*) are often landed under the “Raja spp.” category. As a result, there is an information gap regarding landing volumes of these species (Serra-Pereira et al., 2005; Serra-Pereira et al., 2015), making it hard to assess species-specific risk.

The presence of activities such as marine fauna observation and scuba diving might influence elasmobranch behaviour (Semeniuk et al., 2009). For other species such as the whale shark (*Rhincodon typus*) and the whitetip reef shark (*Triaenodon obesus*), the effects of boat presence have shown to induce stress by increasing their metabolic rates, when diving deeper for prolonged periods of time (Barnett et al., 2016; Montero-Quitana et al., 2018). As shown by inquiry data, 9 ecotourism companies operate in this area of which 3 are recreational diving companies that often operate in the same sites.

Thus, although these activities are unlikely to have high impacts as these have not yet been reported for the occurring species in this MPA, their effect should be studied.

By establishing a trustworthy relationship with the locals, surveys can be a powerful tool for assessing the human element of the ecosystems. When combined with complementary data, local ecological knowledge (LEK) is known to be a helpful ally in informing policy development as shown in studies such as *Bevilacqua et al.*, (2016) in which questionnaires were combined with scientific data from literature to model the trophic web in Baía Formosa (Brazil), and *Lima et al.* (2017) where surveys, in conjunction with on board observational data, were used to assess fishing effort in Rio Grande do Sul (Brazil).

A study performed by *Dinkel & Sánchez-Lizaso* (2020) where semi-structured interviews were used to estimate the conservation state of the shortfin mako (*Isurus oxyrinchus*) and the blue shark (*Prionace glauca*) populations in the Atlantic Ocean highlights the importance of using all available data when studying rare species.

In this study a similar approach to Lima et al. (2017), regarding the combination on LEK with scientific knowledge (SK), was used as virtually no information existed on the occurrence of elasmobranch species, prior to this study, in this area, particularly concerning sharks.

Although questionnaire data might have some biases due to intentional non-disclosure of fishing grounds, dependence on photographic memory and stakeholder's capability of identifying species (Close & Hall, 2006), there are some ways to increase the reliability of this data. The use of an identification guide was extremely helpful to guarantee that the interviewees were describing the exact species (see Annex 3).

The approach was followed and, when possible, visual confirmation was asked for, particularly from ecotourism companies as they usually keep and share this information. To counteract possible distrust problems the surveys were done anonymously, and over the course of the data collection a proximity relationship was developed with the local community, as it was done by *Ramires et al.* (2015). Maintaining contact with the stakeholders allows for continuous registration of observations as close to the actual data of the occurrence as possible.

Non-invasive methods were used to avoid the introduction of unnecessary stressors on the ecosystem when recovering data. BRUV footage and on board observations were used to validate local ecological knowledge (LEK). Even though the underwater footage recordings rely on light availability and depth limits (Bouchet et al., 2018), they are extremely cost-effective and allow for the description of not just species, but their surrounding habitats too.

In this study, the depth reached by the rig was around 30 to 40 meters which was not enough to comprehensively study the sand bottom of the Mar das Troncas area. Concerning the Nazaré Canyon, drifting BRUVs were deployed in order to counteract the depth limitations. However due to the extreme ocean conditions on the northern side of the Farilhões islands, fewer deployments were made in this area even though it is considered by the local fishermen as a shark hotspot. In the future, a random sampling strategy could be used to have better coverage as BRUV deployment' sites were mostly focused on sites where species were already observed. Moreover, bait preference might be a factor influencing the attraction of the species to the bait canister (Ghazilou et al., 2016; Jones et al., 2020) as these species have different prey preferences (see Annex. 1) and thus should be studied.

Several studies have shown the importance of mapping threats in the ecosystem and understanding how these overlap with shark's distribution (Coelho et al., 2015; Queiroz et al., 2019). A study from *Queiroz et al.* (2016) using satellite tracking has highlighted the importance of mapping fishing effort, and its overlap with shark distribution, to efficiently inform management strategies suggesting implementation of seasonal closures and the establishment of catch quotas.

Different approaches have been used to assess cumulative impact on species by overlapping activities. In 2008, *Halpern and colleagues*, developed a standardized cumulative impact index by applying a logarithmic function to the multiplication of either the absence or presence of a certain activity by its magnitude and the presence and absence of several habitats, within a 1km<sup>2</sup> grid cell (Halpern et al., 2008). This approach known as “cumulative pressure and impact assessment (CPIA)” was used in *Bevilacqua et al.* (2018)

Adapted from the Halpern method, the approach followed by *Batista et al.* (2014), used intensity, frequency, and magnitude of activities in several habitats to map human pressure along the Portuguese coast and inside the main Marine Protected Areas. This index attributed relative scores to each component of the activities and was thus used as a support for the development of the index in this study.

As shown in the spatial vulnerability assessment, the southern side of the Berlenga Island is considered in this study a high risk zone. Though the species described for this area, namely the small spotted catshark (*Scyliorhinus canicula*), the marbled electric ray (*Torpedo marmorata*) and the thornback ray (*Raja clavata*), are considered less sensitive according to their IUCN Red List statuses, an extended array of activities take place in this area. Heavily sheltered, this side is the main entrance of the island. In this area passenger drop off occurs, several boats are anchored, and most recreational activities take place. Recreational use if poorly controlled can have negative impact on the habitats these species depend on (Schohn et al., 2019).

To perform a better assessment of stakeholder usage of the island space, each activity that takes place in the Berlengas archipelago should be quantified as the developed index did not measure the number of boats from each activity operating. By counting how many boats operate within each activity we can better understand how much does each activity weigh on the system. Likewise, an in-depth analysis of the habitats would enrich this analysis bringing it closer to the CPIA and indices approaches (Halpern et al., 2008; Batista et al., 2014).

To ensure that proper measurements are in place to mitigate the risk level in these areas, it is crucial to have a holistic approach. Known as ecosystem-based management), the embracement of both biological and socio-economic factors is extremely important to enforce conservation strategies (Browman & Stergiou, 2004; Link & Browman, 2017).

Currently there are no targeted conservation measurements for elasmobranch conservation in the Berlengas Natural Reserve although some benthopelagic species such as skates and the small spotted catshark may benefit from the restrictions applied to extractive activities. According to the results there is a concentration on bottom dependent species near the Berlenga island and in Mar das Troncas. Therefore, in these areas the absence of bottom focused fishing gear is benefiting these species.

Since 2011, the Portuguese Directorate-General for Natural Resources, Safety and Maritime Services (DGRM) has implemented a national seasonal closure on ray captures between the months of May and June (up to July for the undulate ray (*Raja undulata*) to the overall mainland Portuguese coast.

Nonetheless, according to *Holden, 1975*, for species such as the thornback ray (*Raja clavata*) fecundity might be intrinsically related to sea surface temperature and the egg-laying cycle can occur from December to August, peaking in June. In addition, a study by *Serra-Pereira et al., (2015)* showed that the undulate ray (*Raja undulata*) follows a similar reproductive strategy. Thus, although the seasonal closure protects gestating females it does not defend their offspring in their most vulnerable lifestage.

There are several barriers in implementing legal strategies for mobile species in a timely manner (Runge et al., 2014). Despite the great achievements obtained on this study regarding the knowledge about the occurrence and distribution of elasmobranchs on this MPA, additional information on species abundance and habitat use, and magnitude of the activities is needed to inform decision makers and support management strategies.

Several tools can be used to further complement the data presented by this work. Stereo-BRUV deployments (Santana-Garcon et al., 2014; Schramm et al., 2020) can be used to record variables such as size and habitat preference, which is critical particularly if spatial segregation by size occurs, between juveniles and adults (Maxwell et al., 2017; Tous et al., 2019; Di Lorenzo et al., 2020). Moreover the use of non-invasive tags (Fontes et al., 2018) to track highly mobile species dispersal could be beneficial to inform on the degree of residency of these species within the MPA. Additional methods such as acoustic telemetry (Hussey et al., 2015) and experimental fishing surveys (Skomal et al., 2008) may reveal key information about important areas (i.e. feeding, spawning, nursery areas), and species abundance and distribution .

However these methods are invasive and studies concerning the impact and the probability of survival of each species under these methods should take place before establishing the monitoring plan, in order to assess the cos-benefit of the possible sampling methods.

A Food and Agriculture Organization (FAO), in 2019, portrayed how the sheer change of local's habits, from all around the world, has contributed to the conservation of commercially exploited species (FAO, 2019).

Since the main activities impacting this area are the longliners, mitigation methods might include the use of circular hooks and leader type filaments to decrease mortality rates in bycatch, instead of J hooks and nylon threads (Domingo et al., 2009). Considering many pelagic sharks such as blue sharks (*Prionace glauca*) prey on longline target species, soak time plays a key role in incidentally catching this species and therefore should be managed efficiently (Patterson et al., 2014). Regarding ecotourism the operators must be mindful not to anchor over vulnerable habitats such as rocky reefs (Lawrence et al., 2017) particularly on the southern side of the Berlengas and in Mar das Troncas where most benthopelagic species were described.

With the emerging commitment of protecting 30% of the world's oceans until 2030, proposed by the Global Ocean Alliance, there is an increasing need for information to support the implementation of Marine Protected Areas, and to enforce higher levels of protection in already existing ones (DEFRA, 2020). Thus, it is pivotal that every single piece of information available is used to map vulnerable areas that should be prioritized. In this way, the vulnerability index developed can be used to identify these areas. Due to its premises being the quantification and the magnitude of impacts, and the measurement of species sensitivity, this index can be used anywhere and with other types of data (i.e. abundance could be estimated using any sampling method), for any species, as almost every species has been attributed an IUCN conservation status. Although inquiries were used in this study, the index allows for the incorporation of scientific data such as fishing effort, fleet size, habitat vulnerability and species rebound potential to further enrich its outcomes. Moreover, this index can be used to inform fisheries management, in a sustainable manner, by mapping potentially overly pressured areas that may ultimately lead to unsustainable impacts or high mortality.

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## 6. Attachments

### State of the Art

#### The role of marine predators

Standing near the top of the trophic web, marine predators are persistently exposed to cumulative anthropogenic threats such as overexploitation, bycatch, pollution and climate change (Stevens et al., 2000).

Trophic ecology plays a critical task in both the evolution and conservation of a species. Thus, comprehending the role of upper-level predators in an ecosystem is of the utmost importance (Hammerschlag et al., 2018). Predators can exert their influence through direct consumption or through risk effects – anti-predatorial behaviour and induced stress (Heithaus et al., 2008; Hammerschlag et al., 2018). As the ecosystem's immune system, predators keep populations of prey in check and prey on sick individuals. Therefore, trophic cascades can result in increasing disease dissemination, since these keystone species act as bioindicators of the community's health (Maxwell et al., 2013).

Studies in the Pacific found a link between an increase of pelagic mesoconsumers such as the pelagic stingray (*Dasyatis violacea*) and the depletion of larger bodied predators such as pelagic sharks and tunas. Meanwhile, in the Northwestern Atlantic Ocean, there has been an increase of cownose ray (*Rhinoptera bonasus*) landings due to a 9% decrease in shark' abundance. Coincidentally, the high abundance of cownose ray has had a big impact in North Carolina's bay scallop (*Argopecten irradians*) populations, a species with high commercial value, proving that the removal of large predators can result in trophic cascades (Heithaus et al., 2008; Friedrich et al., 2014; Iloulian, 2017).

In the western Aleutian Islands, in 1974, a study has brought insight to the impact of removing predators from an ecosystem through studying the interaction between sea otters, sea urchins and grazing of kelp forests. This study presented substantial evidence that sea otters are keystone species by maintaining herbivores abundance in check and, in turn, avoiding excessive grazing of the kelp forests (Estes & Palmisano, 1974)

Despite contrary belief, the premise that trophic cascading can only occur via direct predation is fallacious. Predators' presence has a strong effect on prey behaviour particularly when it comes to shifting energy from reproduction to anti-predatory behaviour. According to a study from *Hammerschalg et al.* (2018), in predator abundant communities, a prey's fitness may increase by investing in larger eyes and wider fins to face being preyed on, under low-light conditions. Nonetheless, having bigger eyes and fins comes with energetic costs resulting in a shift of the necessary energy for reproducing. Another example is the impact of tiger sharks (*Galeocerdo cuvier*) on large herbivores distribution. Shallow banks are this species main hunting grounds and thus, more dangerous compared to deeper waters where prey can easily evade predators (Heithaus et al., 2008).

Furthermore, there is a clear difference in prey distribution between the edges of seagrass banks and the low visibility interior as visibility portrays a decisive role in tiger sharks preying strategy (Heithaus et al., 2008). Overall, tiger shark's presence reduces grazing by influencing prey distribution, which in turn has a big impact in coastal protection from erosion and floods (Atwood & Hammill, 2018).

However, predator-prey equilibrium depends heavily on the predator's strategy. On one hand, if the predator targets only one species as this species decreases so will the predator's consumption. On the other hand, some predators might be opportunistic, preying on multiple species, which allows them to shift between prey species in low abundance circumstances (Katz, 1985).

#### The case of elasmobranchs

As apex predators and mesoconsumers, elasmobranchs (sharks, rays, and skates) usually stand at higher levels of the food chain. Most rays, sharks and skates are extremely vulnerable due to their low growth rates, late maturity, low fecundity, high longevity and overall K selected life history strategy hence producing fewer offspring at a more developed state who have higher probability of surviving, meaning once overfished this group of species has lower resilience and lower recovery potential (Stevens et al., 2000; Dulvy et al., 2004; Dulvy et al., 2008; Lucifora et al., 2011; Biery & Pauly, 2012; Friedrich et al., 2014; Rosa et al., 2017).

Often highly migratory, most pelagic sharks and rays are exposed to an array of threats across both the high seas and countries jurisdictions resulting in around 31% of elasmobranchs being qualified as “Threatened” (Pistevos et al., 2015; Alves et al., 2016; Shiffman & Hammerschlag, 2016; Harrison et al., 2018) A clear example is the barndoor skate (*Dipturus laevis*) Northwestern Atlantic stock which has now declined substantially and has had a significant reduction in its spatial distribution due to severe overfishing (Dulvy et al., 2004)

Consistently exposed to high concentrations of both persistent organic pollutants and heavy metals through bioaccumulation processes along the food web, they play the pivotal role of bioindicators for marine pollution and ecosystem health (Alves et al., 2016)

However, this ecosystem service might be at stake as elasmobranchs face the imminent threat of ocean acidification and global warming (Rosa et al., 2017). It has been empirically proven that for some shark species such as the bamboo shark (*Chiloscyllium punctatum*) and the smooth dogfish (*Mustelus canis*), ocean warming due to anthropogenic greenhouse gas emissions might affect juvenile growth and hunting behaviour (Pistevos et al., 2015).

Although this may be true for some species it does not apply to all, as studies have shown the epaulette shark (*Hemiscyllium ocellatum*) can tolerate relatively high inputs of CO<sub>2</sub>. Moreover, it is important to consider that most studies regarding ocean acidification and SST (sea surface temperature) rise are short term lab conducted experiences and might not reflect future impacts (Pistevos et al., 2015). Predicting possible climate change impacts on distribution, density and abundance of highly migratory predators is of the utmost importance to effectively manage them. To do so, it is crucial to understand spatial functioning of marine ecosystems to identify vulnerable habitats such as nursing and spawning grounds as well as foraging areas (Block et al., 2011; Sadykova et al., 2020).

Regarding the shark commercial industry, they are primarily harvested for fins liver oil (-which was believed to cure blindness in ancient times) meat and jaws. From the 1980’s forward, with China’s economic expansion, a high demand for shark fin soup arose. Driven by this high demand, the practice of shark finning – removing a shark’s primary set of fins (both pectorals, first and second dorsal and lower caudal fin) at high sea and discarding the remaining body still alive – became extremely common (Stevens et al., 2000; Biery & Pauly, 2012; Friedrich et al., 2014; Shiffman & Hammerschlag, 2016).

Despite being considered an illegal practice it is difficult to fully perceive the extent of the finning trade, since the fins are often landed without the corresponding body. Not only different species of sharks have varying numbers of fins with distinct lengths, but it is also extremely hard to identify a species based only on their fins. To mitigate this issue, a first attempt at preventing finning was done by implementing a fin to carcass ratio of 5% in 2003. However, this ratio was usually applied to wet-fin-to-round-mass and not wet-fin-to-dressed-carcass-mass allowing there to be a loophole in the legislation (Spiegel, 2001; Biery & Pauly, 2012).

Overall, fin to carcass ratios can vary from 1.52 for Australia to 6.06 in Portugal. This happens primarily due to different methods of cutting the fins, whether through crude cutting it or cutting it in a half-moon shape leaving higher meat content attached, which makes this legislation considerably inaccurate. In recent years, the practice of mixing different shark carcasses to mislead proper identification, particularly to avoid trading authorities such as CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), has become increasingly frequent (Chapman et al., 2003; Biery & Pauly, 2012).

To further cover these loopholes a “fins naturally attached” policy was put in action. Since 2013, the removal of fins has been prohibited, stating that all elasmobranchs must be landed with their fins attached (Biery & Pauly, 2012; European Parliament and Council of the European Union, 2013).

Lastly, even though recreational fisheries are not the main threat to elasmobranch stocks it has been proven to take a significant toll in the populations as seen in the data recorded for landings of large sharks along the Atlantic coast of the Gulf of Mexico in 1996, accounting for 5.8 million fished chondrichthyans (Stevens et al., 2000).

However, shark fisheries can only be sustainable for some species and require appropriate enforcement, such as the Canadian spiny dogfish (*Squalus acanthias*) industry that has been granted an MSC (Marine Stewardship Council) certification (Shiffman & Hammerschlag, 2016).

Apart from intentional catches, elasmobranchs are often a product of bycatch – the act of unintentionally capturing non-target species – by the gillnet, purse seine and longline industries mainly because they tend to follow the same distribution pattern of tunas and swordfishes displaying higher biodiversity in latitudes between 30 and 40 degrees.

As an outcome, shark and rays' captures are often mislabelled when reported, resulting in a high discrepancy from FAO (Food and Agriculture Organization)'s landing reports (Dulvy et al., 2008; Lucifora et al., 2011; Friedrich et al., 2014).

Sharks have historically been low on almost every country's priority list for conservation due to distorted public perceptions. Movies like *Jaws* and media coverage have framed these as mindless man-eating killers. Instead of pushing for their conservation, these opinions have led the public to exert a great amount of pressure upon governments to enforce "shark population control measures". A great example of this was the instalment of drumlines in Australia in 1962, the main country reporting negative shark-human interactions (Dulvy et al., 2008; Friedrich et al., 2014; Huveneers et al., 2018).

In order to cope with the anthropogenic pressures a set of policy tools were developed. These can be categorized as target-based fisheries management regulations or limit-based conservation regulations. While target-based policies aim for the sustainable exploitation of sharks, rays, and skates through slight alterations in common fishing practices, limit-based solutions advocate for full protection of chondrichthyes (Shiffman & Hammerschlag, 2016).

Sustainable policies may comprehend gear alterations such as changing J hooks for circular hooks to decrease bycatch. Studies conducted by Willey et al. in 2016 off the coast of Maryland (United States) demonstrated that circular hooks have lower chances of deep hooking (hooking in the throat or gut) and therefore decrease mortality for non-target species.

Additionally other measures can be implemented such as size limits to protect vulnerable life stages, pre-established quotas such as total allowable catches (TACs), temporary closures of pinpointed areas under higher anthropogenic pressure and territorial use rights for fishing (TURFs) that assign restrict permission, to specific groups, to a certain area and finally species-specific restrictions at both international (CITES) and national level (Shiffman & Hammerschlag, 2016).

As for limit-based policies, it either restricts commercial trade of shark products (e.g. fin ban) or bans shark fishing. Under the category of marine protected areas, areas where shark fishing is prohibited can be classified as either "marine reserves", if no extraction is allowed, or "shark sanctuaries" if only sharks are not allowed to be capture in that area (Shiffman & Hammerschlag, 2016).

### Current legal framework on elasmobranch conservation

Highly migratory species such as pelagic elasmobranchs are exposed to a wider range of anthropogenic threats because their distribution is transboundary and susceptible to each country's policy (Maxwell et al., 2013).

The problem of jurisdiction led some countries to constitute international legislative organs such as Regional Fisheries Management Organizations (RFMOs), the International Council for the Exploration of the Sea (ICES) and the International Union for the Conservation of Nature (IUCN), and even signing treaties such as United Nations Convention on Migratory Species in 1979 (CMS) and the UN Convention on the Law of the Sea (UNCLOS)' 1995 Fish Stocks Agreement (UNFSA) in 2001 (Spiegel, 2001; Biery & Pauly, 2012; Iloulian, 2017). Despite aiming to promote international cooperation all these management entities and agreements are non-binding meaning it relies on a country's willingness to enforce this agreement (Biery & Pauly, 2012).

RFMOs such as the International Commission for the Conservation of Atlantic Tunas (ICCAT), are the main instrument for regulating fish stocks across all country's jurisdictions and on the open ocean (Harrison et al., 2018). Even though RFMO's attempt at regulating finning through the fin-to-carcass ratio was somewhat successful it still failed as according to the 2016 UNFSA conference review, most countries weren't following the International Plan of Action for the conservation and management of sharks (IPOA-Sharks) guidelines (Iloulian, 2017). Portugal is under the ICCAT jurisdiction as this is the RFMO responsible for regulating fisheries in the Atlantic Ocean.

Based on the 1999 Food and Agriculture Organization (FAO)'s IPOA-sharks the European Union put in action in 2009 a plan of action of its own (EUPOA-Sharks). The EU plan of action for the conservation of sharks aims to guarantee that all shark fisheries are sustainable while gathering expertise on shark species and their fisheries. According to the European Commission communication of 2009, fifty-six thousand tonnes of sharks, rays and skates are yearly captured in the Atlantic Ocean, most of them demersal (European Commission, 2009)

Nonetheless, pelagic fishing gear such as surface longliners are responsible for 68% of shark bycatch of which approximately 75% is blue shark (*Prionace glauca*). The second most caught species is the shortfin mako (*Isurus oxyrinchus*). Bycatch countermeasures include the insertion of on-board observers in vessels over 24 meters that record bycatch over 10%. Moreover, the action plan promotes data collection and ensures stakeholder education and participation (European Commission, 2009)

In 2003, the European Union banned the practice of finning. However, due to the “best practices” rule, that states that if fishermen can find a better use for the remaining carcass, they can keep the fins. This legislation has proved to be ineffective (Iloulian, 2017)

IUCN and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) originally aimed at the conservation of terrestrial species such as mammals and birds. In 1996 the IUCN Red List protocols were first applied to marine species (Dulvy et al., 2004). To further incite transboundary cooperation, as part of the Species Survival Commission, IUCN created close to one hundred Specialist groups including a Shark Specialist Group (SSG) in order to effectively assess species conservation status worldwide, periodically (Fowler, 1991)

Several amendments have been made to the CITES Appendix listings in recent years regarding elasmobranch trade. The 2019’s Commission Regulation (EU) 2019/2117 amending Council Regulation (EC) No 338/97 on the protection of species of wild fauna and flora by regulating trade therein brings light to the recent changes to both appendices. Appendix I lists high priority species that are on the verge of extinction and only allows trade to take place for scientific purposes. No commercial trade regarding these species is to occur (CITES, 2019).

When it comes to elasmobranchs only the *Pristidae* family (e.g. sawfishes) is currently listed in Appendix I. As for Appendix II, it lists currently non-endangered species whose unregulated trade might drive them to become extinct. Nine elasmobranch families are represented amongst which the following species are listed: silky shark (*Carcharinus falciformis*), oceanic whitetip shark (*Carcharinus longimanus*), scalloped hammerhead shark (*Sphyrna lewini*), great hammerhead shark (*Sphyrna mokarran*), smooth hammerhead shark (*Sphyrna zygaena*), basking shark (*Cetorhinus maximus*), great white shark (*Carcharodon carcharias*), shortfin mako (*Isurus oxyrinchus*), longfin mako (*Isurus paucus*), porbeagle (*Lamna nasus*), whale shark (*Rhincodon typus*) and all members of the Alopiidae, Glaucostegidae and Rhinidae families along with all species of the Alopias, Manta and Mobula genus (European Commission, 2019).

Signed in 1979, the Bonn Convention or Convention on Migratory Species (CMS) aims to boost international cooperation on the conservation of highly migratory species through periodical scientific review presented in the Conference of Parties every three years. Similarly to CITES, CMS has two appendixes that list priority endangered species and species that currently face unfavourable conservation status. Appendix I elasmobranch species are equivalent to CITES listings even though CMS lists the blue shark (*Prionace glauca*) (Convention on Migratory Species, 1979).

Although restricting trade is an important measure to ensure species survival, CITES does not regulate over each country's permission to capture such species. To do so the International Council for the Exploration of the Sea (ICES) regulates over which stocks can be harvested within its 20 member countries jurisdictions, each one corresponding to a subarea. For subareas IX and X, corresponding to Portuguese mainland waters and the Azores, respectively, some species are prohibited from being captured, hold on board, and landed such as the common skate (*Dipturus batis*), the white skate (*Rostroraja alba*), the undulate ray (*Raja undulata*) if not a product of bycatch, all species of guitarfishes (Rhinobatidae) and the picked dogfish (*Squalus acanthias*).

Additionally, a group of species is strictly forbidden to be harvest in all European Union waters which are described in the following table (Table 3) (Council of the European Union, 2019).

Table 3 - Species whose capture, maintenance aboard or landing is forbidden by the European Union

<b>Common name</b>	<b>Scientific name</b>
Great White shark	<i>Carcharodon carcharias</i>
Basking shark	<i>Cetorhinus maximus</i>
Porbeagle	<i>Lamna nasus</i>
Devil fish	<i>Mobula mobular</i>
Lesser Guinean devil ray	<i>Mobula rochebrunei</i>
Spinetail mobula	<i>Mobula japonica</i>
Smoothtail mobula	<i>Mobula thurstoni</i>
Longhorned mobula	<i>Mobula eregoodootenkee</i>
Munk's devil ray	<i>Mobula munkiana</i>
Chilean devil ray	<i>Mobula tarapacana</i>
Shortfin devil ray	<i>Mobula kuhlii</i>
Lesser devil ray	<i>Mobula hypostoma</i>
Reef manta ray	<i>Mobula alfredi</i>
Giant manta ray	<i>Mobula birostitis</i>
Pointed sawfish	<i>Anoxypristis cuspidata</i>
Dwarf sawfish	<i>Pristis clavata</i>
Smalltooth sawfish	<i>Pristis pectinata</i>
Largetooth sawfish	<i>Pristis pristis</i>
Green sawfish	<i>Pristis zijsron</i>
Whale shark	<i>Rhincodon typus</i>
Angel shark	<i>Squatina squatina</i>

Moreover, ICES plays the essential task of establishing each signatory country's annual total allowable catches (TAC) for each group of species concerning each subarea. In subarea IX, regarding skates and rays, Portugal can capture 1463 tonnes where only 15 tonnes at max can be composed of undulate ray (*Raja undulata*) and only as a bycatch product. As for the Atlantic blue shark (*Prionace glauca*) stock no TAC was established by country, having only a set total allowable catch effort for the European Union of 39102 tonnes per year.

Also according to the 2019 “Regulation (EU) 2019/1241 of the European Parliament and of the Council of 20 June 2019 on the conservation of fisheries resources and the protection of marine ecosystems through technical measures”, it is illegal to capture individuals of the bluntnose sixgill shark (*Hexanchus griseus*) and the basking shark (*Cetorhinus maximus*) species, and all species of the Alopiidae, Carcharinidae, Sphyrnidae, Isuridae and Lamnidae families using entangling nets, trammel nets or bottom-set gillnets. In addition, a request for all fisheries below 200 m to be stopped was made in order to protect deep sea species (European Parliament and the Council of the European Union, 2019).

### The Berlengas Archipelago

Established in September of 1981, the Berlengas marine reserve is located northwest of Peniche, a small fishing village in Portugal belonging to the district of Leiria. This marine reserve was originally limited to the 30 m bathymetric line surrounding both the main island of the “Berlenga Grande” and the remaining islets of “Estelas” “Medas” and “Farilhões” (Decreto-Lei n. ° 264/81)

In May of 1992, the Directive 92/43/CEE of the European Union Council relating to preservation of natural habitats and wild fauna and flora from Natura Network 2000 defined a set of special conservation zones (ZEC). Amongst these is the Berlengas marine protected area, a mixed MPA with several levels of protection. However, this document states that the habitats directive does not account for highly mobile species conservation (ICNF, 2005)

Yet, in 1998 according to the Regulatory Decree n° 30/98 from 23 of December its limits were extended to meet the required extension to successfully protect Berlengas’ marine resources officially naming it as Berlengas Natural Reserve (Resolução do Conselho de Ministros n. ° 180/2008).

Enforcement of the Berlengas Natural Reserve management plan (PORN) is assured by the Portuguese Institute for the Conservation of Nature and Biodiversity (ICNF).

Being a highly prized area for scuba diving and wildlife observation this marine reserve is often under strong anthropogenic pressure, primarily in the months of May to August, which correspond to the “high season”. PORNB main objectives are to educate visitors on environmental awareness, promote scientific research, preserve marine biodiversity, promote sustainable ecotourism and good practices across all extractive activities. In the marine natural reserve of the Berlengas several species are protected such as all seabirds, marine turtles and marine mammals, and the dusky grouper (*Epinephelus marginatus*) (Resolução do Conselho de Ministros n. ° 180/2008). Additionally, inside the MPA it is prohibited the use of trawlers, gillnets, the use of traditional trap devices and shellfish collection, apart from the manual capture of one species of Henslow’s crab (*Polybius henslowii*) and gooseneck barnacle (*Pollicipes pollicipes*) (Resolução do Conselho de Ministros n. ° 180/2008; Vasco-Rodrigues et al., 2011).

Currently, the Berlengas Marine Protected Area plan of action does not include active measures to ensure elasmobranch conservation even though fishermen report high abundance of sharks and rays and DOCAPESCA – main Portuguese fisheries management entity - records daily landings of these species in the Peniche harbour. This is due to a severe lack of information about the occurring species ,and their abundance. Although Peniche’s harbour landings might reflect fisheries outside of the MPA, fishers’ anecdotal reports and recent sightings contribute for the belief that elasmobranchs occur in this area.

## Review of methodologies

### Local ecological knowledge (LEK) and map-based inquiries

Though fishermen spend most of their days out at sea, their perceptions and empiric knowledge is often overlooked when developing policy strategies.

Most species are often reported through anecdotal reports from fishermen before they are even discovered. The Giant Squid (*Architeuthis dux*) was thought to be a figure of fishermen's imagination until several whales washed up with seemingly large squid "beaks" in their digestive system, proving several years later that, in fact, this species was real (Close & Hall, 2006)

By crossing scientific knowledge with this method, commonly known as "Local Ecological Knowledge (LEK), decision makers can enforce efficient Ecosystem-based management. Particularly for no-take Marine Protected Areas, these approaches rely heavily on stakeholder compliance and involvement (Scholz et al., 2010; Bevilacqua et al., 2016).

Several approaches have been used to incorporate LEK in scientific assessments. In *Bevilacqua et al.* (2016) the Delphi method was used in which a group of "expert fishermen" appointed by their communities as knowledgeable responded to surveys multiple times until reaching a consensus. Although beneficial this method relies on a proximity relationship with fishermen who are willing to go through this process. In Lima et al, (2017) however, the surveying effort was focused in 3 species and the local ecological knowledge was used to inform about fishing effort in the Rio Grande do Sul region.

Similarly, *Hallwass and colleagues* (2013) used landing data and local ecological knowledge to assess the impact of dams on small scale fisheries.

Studies such as *Braga et al., 2018* have shown the benefits of including fishermen's empirical knowledge, from the Berlengas Natural Reserve, in their climate change impact assessment. Because a fisher's activity relies heavily on a healthy environment, having the input of someone that experiences the consequences of climate change, on daily basis, is extremely useful.

A similar study has been performed by *Serra-Pereira et al., 2014* through using Local Ecological Knowledge, highlighting once more the valuable contribution of the Peniche fishermen communities to assess skates (Rajidae) distribution patterns on the Western Central Portuguese coast.

### Baited remote underwater videos (BRUVs)

Baited remote underwater video recording is a non-evasive method used in marine ecology studies characterized by the use of one (mono-BRUV) or multiple recording cameras (stereo-BRUV) mounted on a rig pointing to a bait cannister (Bouchet et al., 2018).

This method is particularly useful due to its cost-effectiveness and ability to assess both commercial and non-commercial species and complex ecosystems by being a fishery-independent method (De Vos et al., 2015; Jabado et al., 2018; Clarke et al., 2019).

Moreover, BRUV deployments are highly beneficial for studying highly mobile evasive species. Thus, several studies with large-bodied marine species have been conducted over the years (Jabado et al., 2018; Pimentel et al., 2019; Bruns & Henderson, 2020; Gore et al., 2020; Schmid et al., 2020).

Overall there are two types of BRUVS – stereo and mono. Particularly with chondrichthyans, most studies use stereo-BRUVS to monitor species growth as this particular type of rigs allows for the measurement of individuals by calibrating two cameras at a known distance and later measuring the time between these two fixed points in software such as SeaGIS EventMeasure (e.g. Harasti et al., 2019). On the other hand, mono-BRUV studies focus mostly on diversity and abundance of elasmobranch species, and their distribution (White et al., 2013; Jabado et al., 2018; Osgood et al., 2019). Although stereo-BRUVs, due to the multiple camera setup, give information with more detail they are expensive compared to mono-BRUV setups and the processing of the data is more time consuming.

Similarly to this study, several others have been carried out with sharks and rays within a marine protected area context. In 2013 a study within the Great Barrier Reef National Park, was made by *White et al.*, to assess shark-like batoids distribution using benthic mono-BRUVS. This study showed this method is extremely efficient to cross habitat composition with species abundance since visual data can portray substrate type preference, thus highlighting the importance of protecting not just the species but also their surrounding habitats.

In 2019 a similar study by *Osgood et al.*, showed BRUVs are an important tool to monitor and preserve evasive endemic species in countries such as South Africa by implementing an assessment program along the Cape Whale Coast Hope spot area, comparing areas such as the Betty's Bay marine protected area and adjacent non protected and seasonally protected areas (Walker Bay Whale Sanctuary). Endemic species are a priority from a conservation standpoint due to their low range of dispersion making remote underwater cameras an excellent method to keep track of these populations.

Although this method has proven to be successful it comes with its own set of limitations such as the decrease of quality under low light and high turbidity conditions, the fact that different species might respond to different non-olfactory cues and/or have different prey species and the propensity to count the same individual multiple times creating bias in abundance assessments (White et al., 2013; Bouchet et al., 2018).

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## Annexes

### Annex 1 - Local species ecological features

Table 4 - Shark species reported for the Berlengas Archipelago and respective ecological features

Common Name (English)	Common Name (Portuguese)	Scientific Name	Symbol	Habitat use	Habitat type	Temperature range	Depth range	Diet
Hammerhead sharks	Tubarão-martelo	<i>Sphyrna spp.</i>	TMO	Pelagic	Water column	17 to 29 °C	Surface to 200 m	Small sharks, skates, stingrays, bony fish, crustaceans, and cephalopods
Sandbar shark	Tubarão-corre-costa	<i>Carcharhinus plumbeus</i> (Nardo, 1827)	TCC	Pelagic	Water column	23 to 27 °C	Surface to 500 m	Shrimp, cephalopods, bony fish, and small sharks
Blue shark	Tubarão-azul /Tintureira	<i>Prionace glauca</i> (Linnaeus, 1758)	T	Pelagic	Water column	7 to 21 °C	Surface to 220 m	Herring, hake, mackerel, squid
Shortfin Mako shark	Tubarão-mako/Anequim /Rinquim	<i>Isurus oxyrinchus</i> (Rafinesque, 1810)	TA	Pelagic	Water column	>16°C	Surface to 750 m	Small cetaceans, small sharks, mackerel, tuna, anchovies, herring
Small-spotted catshark	Pata-roxa	<i>Scyliorhinus canicula</i> (Linnaeus, 1758)	PRC	Benthopelagic	Sandy and algae covered rocky corals	7 to 16 °C	10 to 400 m	Flatfish, gurnard, pilchard, swimming crabs, mackerel, small crustaceans, and small molluscs
Nursehound shark	Pata-roxa	<i>Scyliorhinus stellaris</i> (Linnaeus, 1758)	PRS	Benthopelagic	Rocky and coralline bottoms	8 to 20 °C	1 to 125 m	Swimming crabs, squid, octopus, mackerel, flatfish, and shrimp
Smooth-hound shark	Cação-liso	<i>Mustelus mustelus</i> (Linnaeus, 1758)	CL	Benthopelagic	Rough sandy bottoms	9 to 28 °C	5 to 350 m	Crab, lobster, eel, octopus, and shrimp
Starry smooth-hound shark	Cação-pintado	<i>Mustelus asterias</i> (Linnaeus, 1758)	CP	Benthopelagic	Sandy and gravelly bottoms	7 to 17 °C	0 to 100 m	Predominantly crustaceans
Blackmouth catshark	Leitão/Litão	<i>Galeus melastomus</i> (Rafinesque, 1810)	L	Benthopelagic	Muddy habitats	4 to 15 °C	55 to 1873 m	Lanternfish and small bottom invertebrates
Tope shark / Soupfin shark	Cação-bico-de-cristal	<i>Galeorhinus galeus</i> (Linnaeus, 1758)	CBC	Benthopelagic		6 to 24 °C	2 to 472 m	Pilchards, sardines, hake, barracudas, flatfish, other elasmobranchs

Table 5 - Ray and skate species reported for the Berlengas Archipelago with the respective ecological features

Common Name (English)	Common Name (Portuguese)	Scientific Name	Symbol	Habitat use	Habitat type	Temperature range (°C)	Depth range	Diet
<b>Thornback ray</b>	Raia-lenga	<i>Raja clavata</i> (Linnaeus, 1758)	RL	Benthic	Muddy and sandy bottoms	7 to 16	10 to 300 m	Mainly crustaceans
<b>Blonde ray</b>	Raia-pontuada	<i>Raja brachyura</i> (Lafont, 1871)	RP	Benthic	Sandy and rocky bottoms	7 to 16	10 to 380 m	Zoobenthos
<b>Spotted ray</b>	Raia-manchada	<i>Raja montagui</i> (Fowler, 1910)	RM	Benthic	Muddy and sandy bottoms	7 to 16	8 to 530 m	Mainly crustaceans
<b>Sandy ray</b>	Raia-santiago	<i>Leucoraja circularis</i> (Couch, 1838)	RSP	Benthic	Sandy bottoms	7 to 14.	70 to 670 m	Zoobenthos
<b>Cuckoo ray</b>	Raia-de-dois-olhos	<i>Leucoraja naevus</i> (Muller & Henle, 1841)	RDO	Benthic	Muddy and sandy bottoms	7 to 17	20 to 250	Zoobenthos
<b>Undulate ray</b>	Raia-curva	<i>Raja undulata</i> (Lacepède, 1802)	RC	Benthic	Muddy and sandy bottoms	10 to 17	50 to 200 m	Zoobenthos
<b>Small-eyed ray</b>	Raia-zimbreira	<i>Raja microocellata</i> (Montagu, 1818)	RZ	Benthic	Sandy bottoms	10 to 15	100 m	Predominantly fish
<b>Brown ray</b>	Raia-de-quatro-olhos	<i>Raja miraletus</i> (Linnaeus, 1758)	RQO	Benthic	Muddy and sandy bottoms	13 to 26.	17 to 300 m	Zoobenthos and demersal fish
<b>Longnosed skate</b>	Raia-bicuda	<i>Dipturus oxyrinchus</i> (Linnaeus, 1758)	RCA	Benthopelagic	Sandy and rocky bottoms	5 to 14	70 to 1200 m	Cephalopods and crustaceans
<b>White skate</b>	Raia-tairoga	<i>Rostroraja alba</i> (Lacepède, 1803)	RT	Benthic	Sandy and rocky bottoms	8 to 18	30 to 600 m	Other elasmobranchs, crab, shrimp, octopus, and cuttlefish
<b>Bull ray</b>	Ratão-bispo	<i>Aetomylaeus bovinus</i> (Geoffroy Saint-Hilaire, 1817)	RBO	Benthopelagic	Water column	14 to 25	10 to 150 m	Crustaceans and mollusks
<b>Common eagle ray</b>	Ratão-águia	<i>Myliobatis aquila</i> (Linnaeus, 1758)	RA	Benthopelagic	Water column	12 to 20	1 to 300 m	Crustaceans, mollusks and fish
<b>Common torpedo</b>	Tremelga-de-olhos	<i>Torpedo torpedo</i> (Linnaeus, 1758)	TO	Benthic	Sandy bottoms	13 to 20	2 to 400 m	Small fish
<b>Marbled electric ray</b>	Tremelga-marmoreada	<i>Torpedo marmorata</i> (Risso, 1810)	TM	Benthic	Rocky reefs with seagrass adjacent to sandy bottoms	< 20° C	2 to 370 m	Small fish and crustaceans
<b>Atlantic torpedo</b>	Tremelga-negra	<i>Tetronarce nobiliana</i> (Bonaparte, 1835)	TN	Benthopelagic/ Pelagic	Soft bottoms near coral reefs/ Water column	7 to 28	2 to 800 m	Small bony fish and small sharks
<b>Common stingray</b>	Ratão/ Rato/ Uge	<i>Dasyatis pastinaca</i> (Linnaeus, 1758)	R	Benthic	Sandy and muddy bottoms near rocky reefs	10 to 26	5 to 200 m	Fish, crustaceans and mollusks



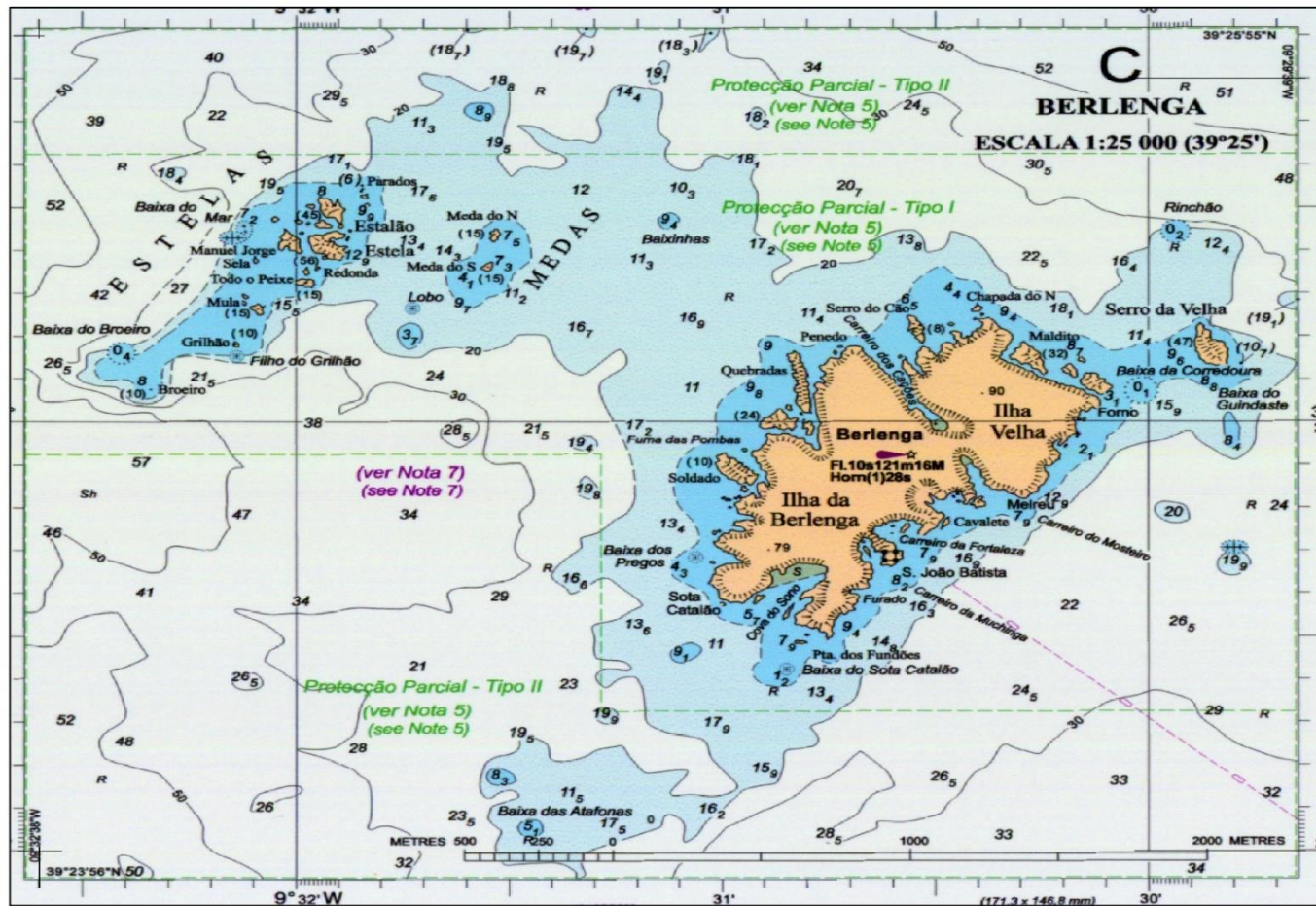


Figure 14 - Map of the Berlenga island and, the Medas and Estelas islets (scale 1:25000 – 39°25') – from the Portuguese nautical charts

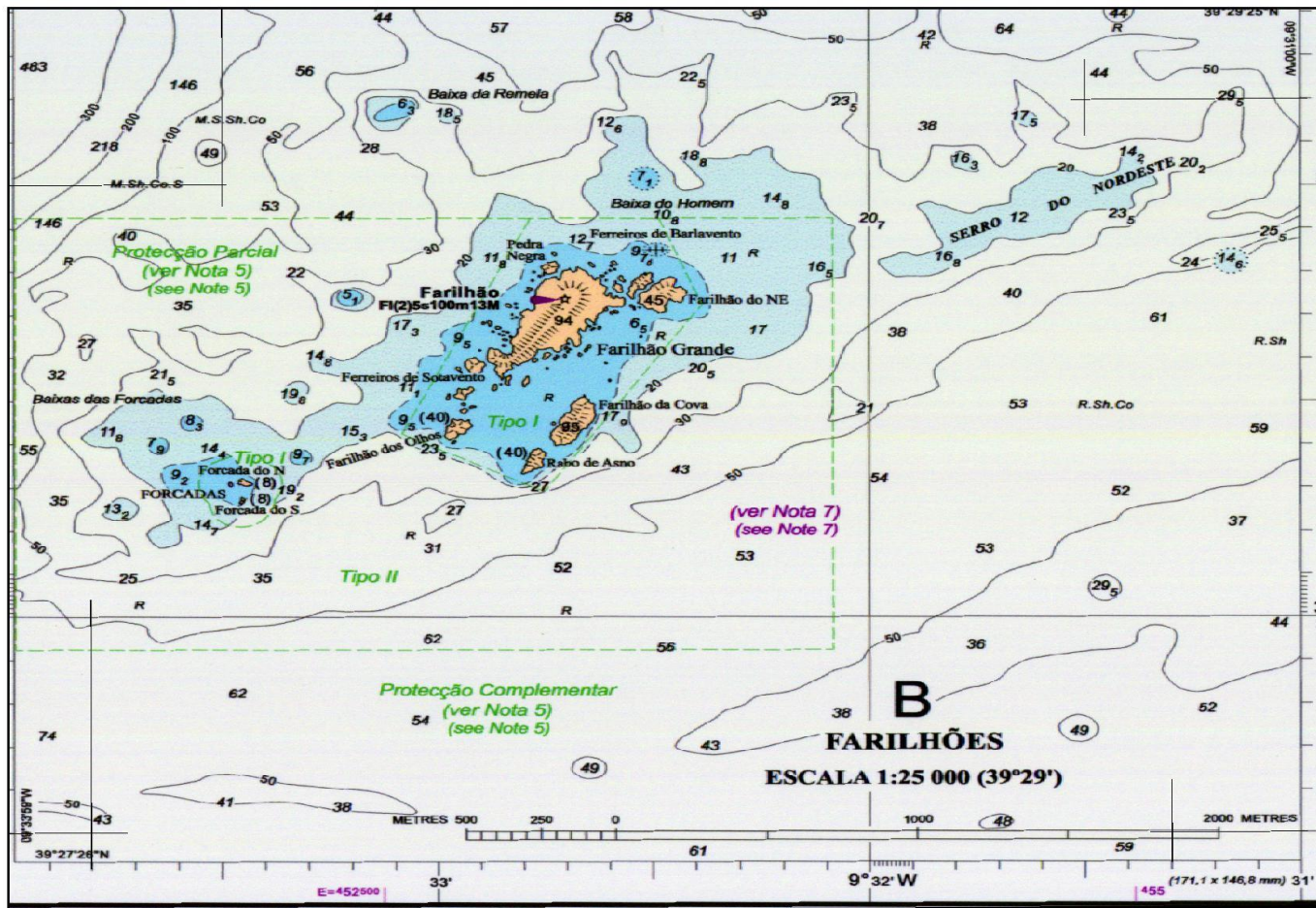


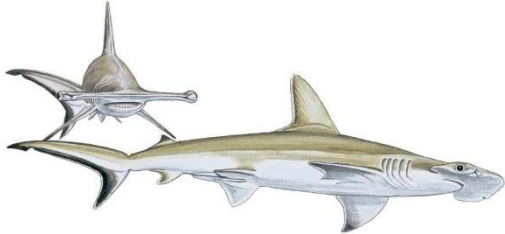
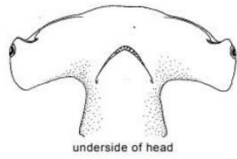
Figure 15 - Map of the Farilhões islands (scale 1:25000 – 39°29') – from the Portuguese nautical charts

CATÁLOGO  
IDENTIFICAÇÃO DE  
TUBARÕES E RAIAS

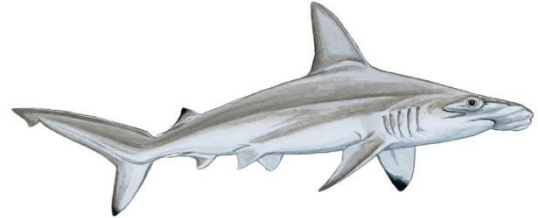
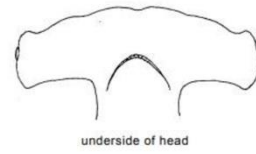
BERLENGAS

FindRayShark

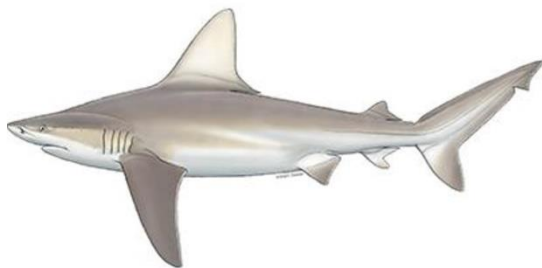
TUBARÃO-MARTELO-LISO  
(*Sphyrna zygaena*)



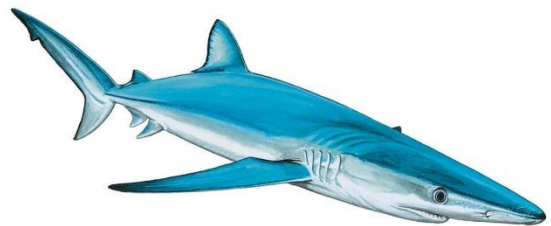
TUBARÃO-MARTELO-  
RECORTADO (*Sphyrna lewini*)



TUBARÃO-CORRE-COSTA  
(*Carcharhinus plumbeus*)

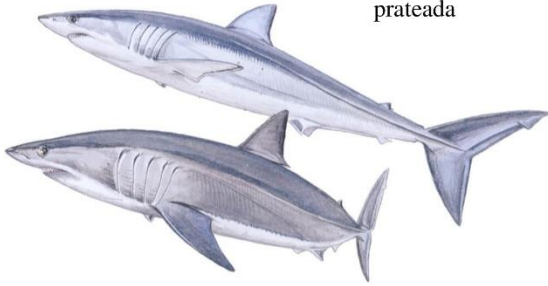


TUBARÃO-AZUL  
(*Prionace glauca*)

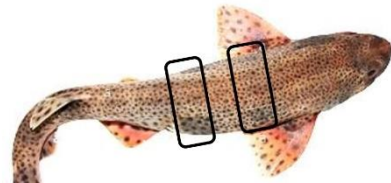


TUBARÃO-MAKO  
(*Isurus oxyrinchus*)

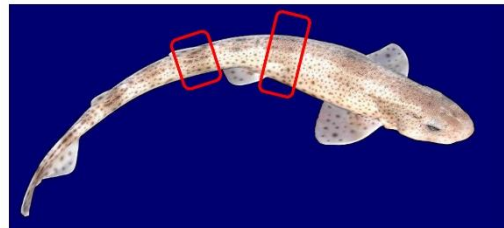
Coloração  
prateada



PATA-ROXA  
(*Scyliorhinus canicula*)



Corpo esguio  
"Pele" pouco áspera  
Com sela  
Abas nasais expandidas – atingem a boca



PATA-ROXA  
(*Scyliorhinus stellaris*)

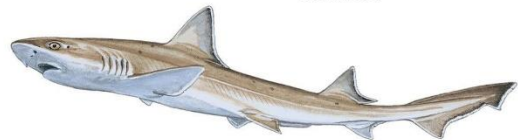


Corpo largo  
"Pele" áspera  
Sem sela  
Abas nasais pequenas – não atingem a boca



CAÇÃO-LISO  
(*Mustelus mustelus*)

Pode conter pontos pretas  
no dorso



CAÇÃO-PINTADO  
(*Mustelus asterias*)



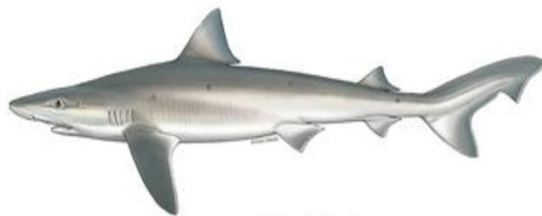
Pontos brancos no dorso



LEITÃO/LITÃO  
(*Galeus melastomus*)



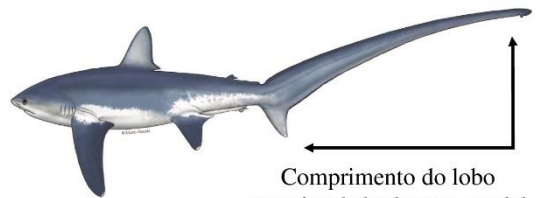
CAÇÃO-BICO-DE-CRISTAL  
(*Galeorhinus galeus*)



“Focinho”  
transparente



TUBARÃO-RAPOSO-COMUM  
(*Alopias vulpinus*)

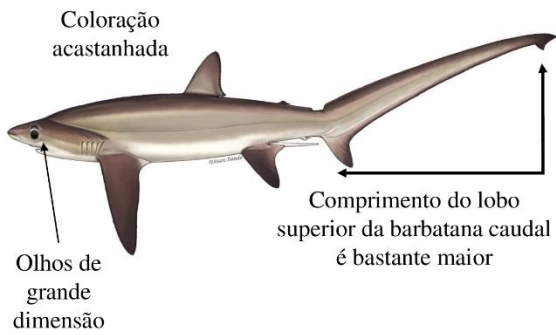


Comprimento do lobo  
superior da barbatana caudal  
é bastante maior

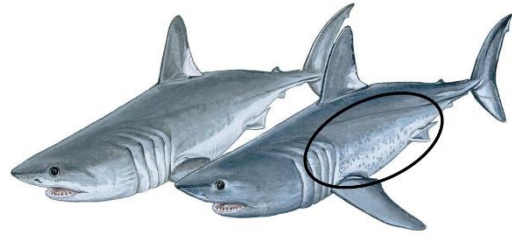
Coloração  
cinzenta azulada



**TUBARÃO-RAPOSO-OLHUDO**  
(*Alopias supercilliosus*)



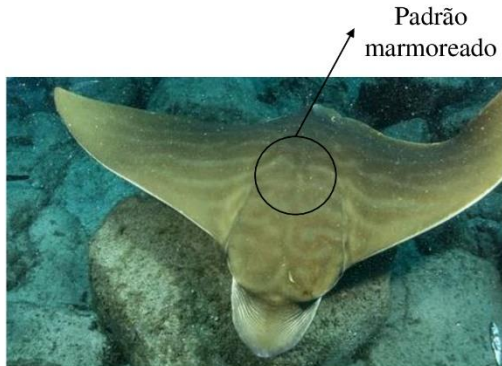
**TUBARÃO-SARDO**  
(*Lamna nasus*)



Dorso cinzento escuro e ventre branco com por vezes manchas escuras



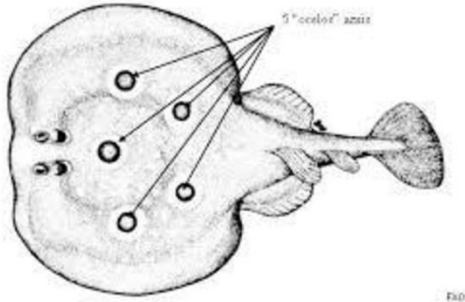
**RATÃO-BISPO**  
(*Pteromylaeus bovinus*)



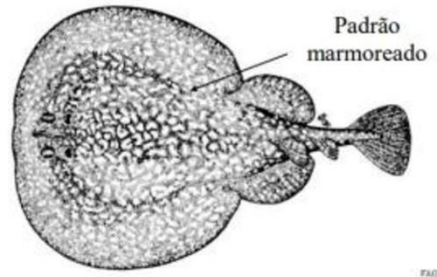
**RATÃO-ÁGUIA**  
(*Myliobatis aquila*)



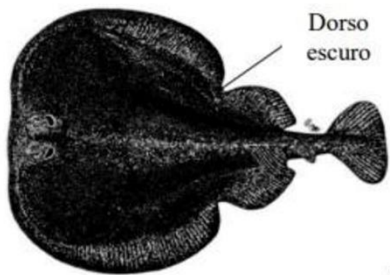
TREMELGA-DE-OLHOS  
(*Torpedo torpedo*)



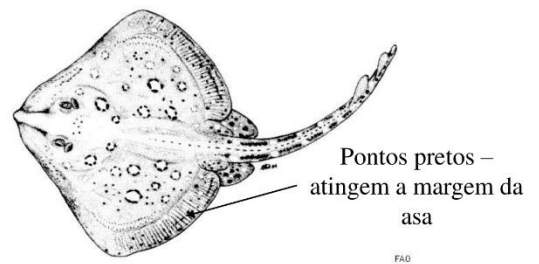
TREMELGA-MARMOREADA  
(*Torpedo marmorata*)



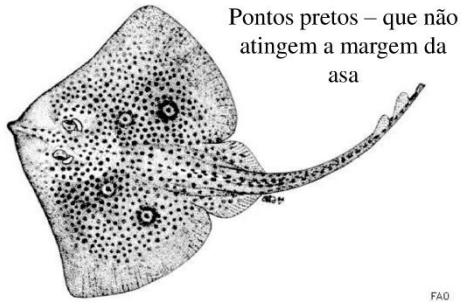
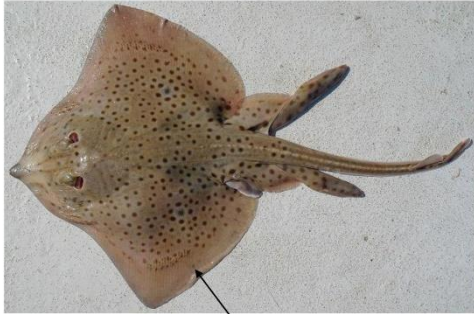
TREMELGA-NEGRA  
(*Tetronarce nobiliana*)



RAIA-PONTUADA  
(*Raja brachyura*)



**RAIA-MANCHADA**  
(*Raja montagui*)



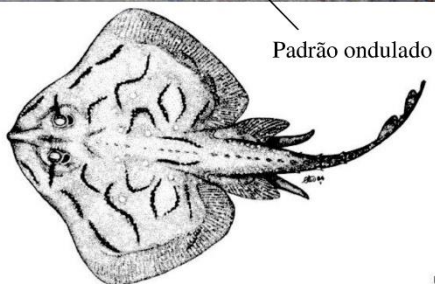
FAO

**RAIA-LENGA**  
(*Raja clavata*)



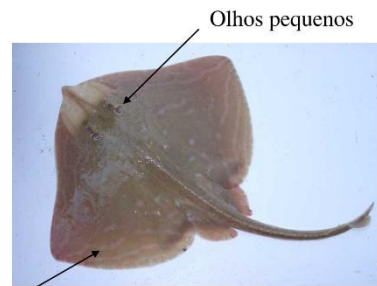
Cauda com padrão  
anelado que alterna  
entre anel escuro e  
anel claro

**RAIA-CURVA**  
(*Raja undulata*)

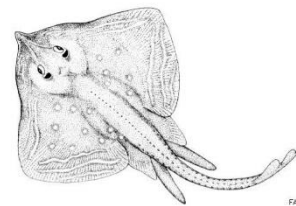


F

**RAIA-ZIMBREIRA**  
(*Raja microocellata*)

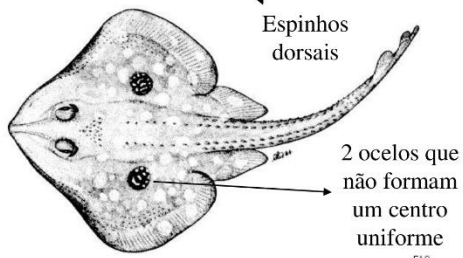
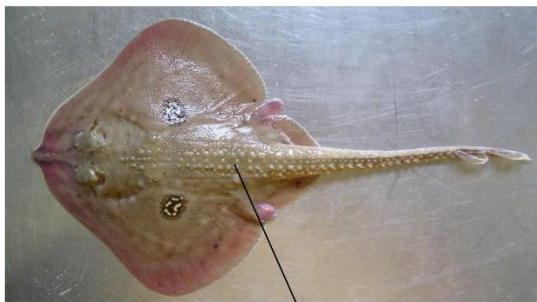


Pontos brancos e riscas brancas paralelas às asas

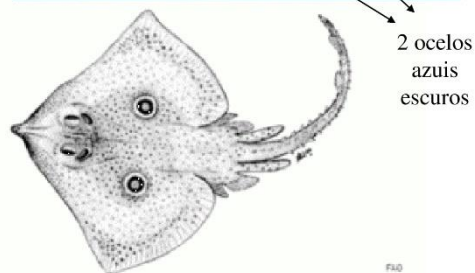


FAO

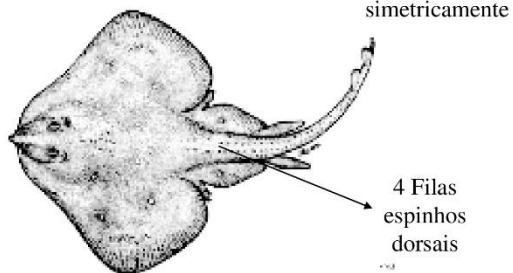
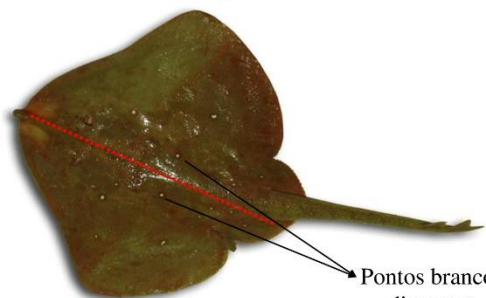
RAIA-DE-DOIS-OLHOS  
(*Leucoraja naevus*)



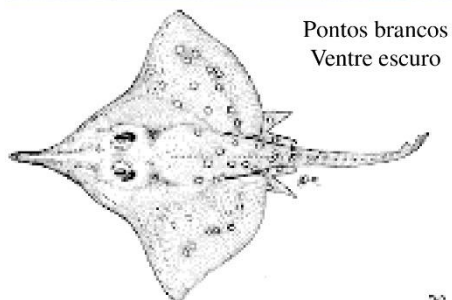
RAIA-DE-QUATRO-OLHOS  
(*Raja miraletus*)



RAIA-SANTIAGA  
(*Leucoraja circularis*)



RAIA-BICUDA  
(*Dipturus oxyrinchus*)



RAIA-TAIROGA  
(*Rostroraja alba*)



Ventre  
claro

RAIA-UGE  
(*Taeniura grabata*)



Disco  
redondo

“Pele” suave

RATÃO  
(*Dasyatis pastinaca*)



Disco  
em forma de  
diamante

Cauda móvel  
tipo chicote



## Annex 4. Questionnaire layout

### Annex 4.1. Commercial fisheries questionnaire



## TUBARÕES E RAIAS NAS BERLENGAS

- a- Inquérito para o trabalho de mestrado da Catarina Abril (ISPA), integrado no projeto FindRayShark.
- b- O objetivo geral do trabalho é analisar a importância das Berlengas para os tubarões e raias, para isso serão utilizados dados recolhidos com câmaras de filmar iscadas e de inquéritos/ entrevistas.
- c- Os inquéritos/entrevistas serão realizados a diferentes grupos de utilizadores desta área que podem frequentemente avistar estas espécies: pescadores, empresas e utilizadores marítimo-turísticos, tais como escolas de mergulho e mergulhadores, pescadores lúdicos, etc.
- d- Este inquérito tem por objetivo a recolha de informação sobre a distribuição espacial e temporal de espécies de tubarões e raias.

Tomei conhecimento dos objetivos desta entrevista e disponibilizo-me a responder a este questionário	<input type="checkbox"/>
Esta entrevista é de carácter voluntário e em qualquer momento da entrevista posso-me recusar a responder a qualquer questão com a qual não me sinta confortável	<input type="checkbox"/>
Tomei conhecimento de que esta entrevista é anónima e quaisquer dados pessoais (idade, sexo, etc..) serão utilizados apenas para análise estatística e caracterização da atividade nas Berlengas	<input type="checkbox"/>

### INQUÉRITO – Setor da pesca comercial

#### 1. DADOS PESSOAIS

1.1. Idade: \_\_\_\_\_ 1.2. Sexo: M  F

1.3. A pesca é a sua principal ocupação? Sim  Não

Se não, qual a sua principal ocupação: \_\_\_\_\_

1.3.1. Em que ano começou a pescar? \_\_\_\_\_ E nas Berlengas? \_\_\_\_\_

## 2. CARACTERIZAÇÃO DA EMBARCAÇÃO

Comprimento (m)	Potência (kW/ HP)	Nº de pescadores	Ano de registo	Notas

## 3. CARACTERIZAÇÃO DA ARTE DE PESCA

### 3.1. Artes de pesca dominantes:

A) Pesca à linha  B) Palangre de fundo  C) Palangre de superfície

D) Redes de emalhar  E) Redes de tresmalho  F) Arrasto Pelágico

G) Arrasto de Fundo  H) Cerco  I) Armadilhas

#### Secção:

A) a C)

D/E)

Nº de anzóis: \_\_\_\_\_

Comprimento total: \_\_\_\_\_ m

Tempo dentro de água: \_\_\_\_\_

Nº redes/ caçada \_\_\_\_\_ Nº de caçadas: \_\_\_\_\_

Dimensão da rede: c \_\_\_\_\_ x a \_\_\_\_\_

Tamanho da malha: \_\_\_\_\_

#### F/G)

Comprimento do saco: \_\_\_\_\_

Malha do saco: \_\_\_\_\_

Dimensão da boca do arrasto: \_\_\_\_\_

Tempo médio de arrasto: \_\_\_\_\_

D

Covos      Alcatruzes      Outro \_\_\_\_\_

#### H)

Nº cercos por dia \_\_\_\_\_

Dimensões: c \_\_\_\_\_ x a \_\_\_\_\_

Tamanho da malha: \_\_\_\_\_

Nº armadilhas/caçada: \_\_\_\_\_ Nº de caçadas: \_\_\_\_\_

Dimensão da armadilha: c \_\_\_\_\_ x l \_\_\_\_\_ x a \_\_\_\_\_

Tamanho da malha: \_\_\_\_\_

Tempo dentro de água: \_\_\_\_\_ Isco: \_\_\_\_\_

3.2. Quantas embarcações de pesca semelhante à sua utilizam a mesma arte de pesca? \_\_\_\_\_

#### 4. CARACTERIZAÇÃO DO DIA DE PESCA

Preencha os dados na tabela, incluindo alterações na dinâmica de pesca ao longo do ano, caso existam. Para indicação das zonas de pesca utilize o mapa

Espécie-alvo	Arte de pesca	Época	Hora de saída	Hora de regresso	Tempo médio de pesca	Nº dias de pesca por semana	Zona	Tipo de fundo

#### 5. ESPÉCIES-ALVO E OUTRAS (PERSPETIVAS ESPACIAL E TEMPORAL)

5.1. Para além das espécies alvo o que captura com maior frequência (com ou sem valor comercial)?

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5.2. Nota alguma diferença no número ou tamanho dos peixes que pesca desde os anos 80?

Não  Sim

5.2.1. Se sim, que espécies e em que sentido? (Aumento - ↑ ; Decréscimo - ↓)

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5.2.2. E de tubarões? Não  Sim

5.2.3. Se sim, que espécies e em que sentido? (Aumento - ↑ ; Decréscimo - ↓)

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5.3. Relativamente aos indivíduos pequenos (juvenis)

São libertados com vida  Espécies: \_\_\_\_\_

Habitualmente estão mortos quando as artes são levantadas  Espécies: \_\_\_\_\_

Aproveita para venda ou consumo próprio  Espécies: \_\_\_\_\_

Rejeita ao mar sem vida  Espécies: \_\_\_\_\_

5.4. Espécies de tubarão e raia capturadas

Por favor classifique de **0 a 4** a presença das espécies em que:

**0 (Ausente – não aparece de todo); 1(Raro – não aparece todos os anos); 2 (Ocasional – aparece 1 vez por ano); 3 (Comum – aparece todos os meses); e 4 (Abundante – aparece todas as semanas)** e assinale no mapa usando o símbolo as zonas de pesca atuais e passadas, caso existam alterações

**TUBARÕES**

	Símb.	Anos 70	Anos 80	Anos 90	2000's	2010's	2019	Estação do ano	Zona	Alteração da zona de ocorrência	Tipo de fundo	Prof.	Arte de pesca	Dimensão	Tend.
<b>Tubarão-corre-costa</b> ( <i>Carcharhinus plumbeus</i> )	TCC														
<b>Tintureira/Quelha</b> ( <i>Prionace glauca</i> )	T														
<b>Tubarão-martelo</b> ( <i>Sphyrna sp.</i> )	TM														
<b>Tubarão-anequim</b> ( <i>Isurus oxyrinchus</i> )	TA														
<b>Cação-liso</b> ( <i>Mustelus mustelus</i> )	CL														
<b>Cação-pintado</b> ( <i>Mustelus asterias</i> )	CP														
<b>Pata-roxa</b> ( <i>Scyliorhinus canicula</i> )	PRC														
<b>Pata-roxa</b> ( <i>Scyliorhinus stellaris</i> )	PRS														
<b>Cação-bico-de-cristal</b> ( <i>Galeorhinus galeus</i> )	CBC														
<b>Leitão/Litão</b> ( <i>Galeus melastomus</i> )	L														

Notas:

**RAIAS**

	Símb.	Anos 70	Anos 80	Anos 90	2000's	2010's	2019	Estação do ano	Zona	Alteração da zona de ocorrência	Tipo de fundo	Prof.	Arte de pesca	Dimensão	Tend.
<b>Raia-lenga</b> ( <i>Raja clavata</i> )	RL														
<b>Raia-pontuada</b> ( <i>Raja brachyura</i> )	RP														
<b>Raia-manchada</b> ( <i>Raja montagui</i> )	RM														
<b>Raia santiaga</b> <b>Raia de S.Pedro</b> ( <i>Leucoraja circularis</i> )	RSP														
<b>Raia-de-dois-olhos</b> <b>Raia de S.Pedro</b> ( <i>Leucoraja naevus</i> )	RDO														
<b>Raia-curva</b> ( <i>Raja undulata</i> )	RC														
<b>Raia-bicuda</b> ( <i>Dipturus oxyrinchus</i> )	RCA														
<b>Raia-tairoga</b> ( <i>Rostroraja alba</i> )	RT														
<b>Raia-zimbreira</b> ( <i>Raja microocellata</i> )	RZ														
<b>Raia-de-quatro-olhos</b> ( <i>Raja miraletus</i> )	RQO														
<b>Ratão-bispo</b> ( <i>Pteromylaeus bovinus</i> )	RBO														
<b>Ratão-águia</b> ( <i>Myliobatis aquila</i> )	RA														
<b>Tremelga-de-olhos</b> ( <i>Torpedo torpedo</i> )	TO														
<b>Tremelga-marmoreada</b> ( <i>Torpedo marmorata</i> )	TM														
<b>Tremelga-negra</b> ( <i>Tetronarce nobiliana</i> )	TN														
<b>Ratão</b> ( <i>Dasyatis pastinaca</i> )	R														

Notas:

## 6. PERCEÇÃO DE ALTERAÇÕES ECOLÓGICAS AO LONGO DO TEMPO

6.1. Qual o maior tubarão/raia que já pescou (espécie, tamanho e/ou peso)?

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6.2. No decorrer da sua atividade, há alguma espécie de tubarão ou raia que se tenha tornado bastante abundante//rara ou que tenha desaparecido? Se sim, qual?

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6.3. Na sua opinião qual a razão/razões que podem ter levado ao desaparecimento ou escassez das espécies de raias e tubarões que mencionou acima? Alguma outra espécie que tenha seguido esta tendência?

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6.4. Quais as condições meteorológicas que considera favoráveis à pesca de tubarões e raias?

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## 7. OPINIÃO

7.1. Na sua opinião qual o impacto que a criação da Reserva Marinha das Berlengas tem nas pescarias?

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7.2. Considera que os tubarões perturbam a sua atividade?

Sim  Não  Se sim, de que modo: \_\_\_\_\_

7.2.1. Que solução sugere para este problema?

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7.2.2. Já ouviu falar em dispositivos repelentes para tubarões (e.g. Shark Shield, etc)?

Sim  Não  Acha que pode ter sucesso nesta área? Sim  Não

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Agradecemos a sua participação!

Estaria disponível para futuros contactos para reportar avistamento de tubarões e raias? Se sim por favor deixe o seu contacto

## Annex 4.2. Recreational fisheries questionnaire



# TUBARÕES E RAIAS NAS BERLENGAS

- e- Inquérito para o trabalho de mestrado da Catarina Abril (ISPA), integrado no projeto FindRayShark.
- f- O objetivo geral do trabalho é analisar a importância da Reserva Natural das Berlengas para os tubarões e raias, para isso serão utilizados dados recolhidos com câmaras de filmar iscadas e de inquéritos/ entrevistas.
- g- Os inquéritos/entrevistas serão realizados a diferentes grupos de utilizadores desta área que podem frequentemente avistar estas espécies: pescadores, empresas e utilizadores marítimo-turísticos, tais como escolas de mergulho e mergulhadores, pescadores lúdicos, etc.
- h- Este inquérito tem por objetivo a recolha de informação sobre a distribuição espacial e temporal de espécies de tubarões e raias.

Tomei conhecimento dos objetivos desta entrevista e disponibilizo-me a responder a este questionário	<input type="checkbox"/>
Esta entrevista é de carácter voluntário e em qualquer momento da entrevista posso-me recusar a responder a qualquer questão com a qual não me sinta confortável	<input type="checkbox"/>
Tomei conhecimento de que esta entrevista é anónima e quaisquer dados pessoais (idade, sexo, etc..) serão utilizados apenas para análise estatística e caracterização da atividade nas Berlengas	<input type="checkbox"/>

## INQUÉRITO – Setor da pesca lúdica e desportiva

### 2. DADOS PESSOAIS

2.1. Idade: \_\_\_\_\_ 1.2. Sexo: M  F

5.3. A pesca é a sua principal ocupação? Sim  Não

Se não, qual a sua principal ocupação: \_\_\_\_\_

5.3.1. Em que ano começou a fazer pesca lúdica? \_\_\_\_\_ E nas Berlengas? \_\_\_\_\_

### 3. CARACTERIZAÇÃO DA EMBARCAÇÃO

Comprimento (m)	Potência (kW)	Nº de pescadores	Ano de início de atividade	Notas

### 4. CARACTERIZAÇÃO DA ATIVIDADE

#### 4.1. Tipo de atividade

Pesca lúdica   
  Pesca desportiva   
  Caça submarina

#### 4.2. Artes de pesca utilizadas

Pesca à linha   
  Pesca com cana   
  Palhaço/Toneira  
 Arma de caça submarina   
  Faca de mariscar   
  Bicheiro/Puxeiro  
 Arrelhada/Arrilhada

Nº de anzóis: \_\_\_\_\_

Comprimento: \_\_\_\_\_ m

Tempo dentro de água: \_\_\_\_\_

4.3. Qual o isco que utiliza? \_\_\_\_\_

4.4. Quantas embarcações de pesca semelhante à sua utilizam a mesma arte de pesca? \_\_\_\_\_

### 5. CARACTERIZAÇÃO DO DIA DE PESCA

Preencha os dados na tabela, incluindo alterações na dinâmica de pesca ao longo do ano, caso existam. Para indicação das zonas de pesca utilize o mapa

Espécie-alvo	Arte de pesca	Época	Hora de saída	Hora de regresso	Tempo médio de pesca	Nº dias de pesca por semana	Zona	Tipo de fundo

5.1. Participa regularmente em competições na área da Reserva Marinha das Berlengas?

Sim   
  Não   
 Se Sim, quantas vezes por ano: \_\_\_\_\_

**6. ESPÉCIES-ALVO E OUTRAS (PERSPETIVAS ESPACIAL E TEMPORAL)**

6.1. Para além das espécies alvo o que captura com maior frequência (com ou sem valor comercial)?

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6.2. Nota alguma diferença no número ou tamanho dos peixes que pesca desde os anos 80?

Não Sim

6.2.1. Se sim, que espécies e em que sentido? (Aumento - ↑ ; Decréscimo - ↓)

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6.2.2. E de tubarões? Não  Sim

6.2.3. Se sim, que espécies e em que sentido? (Aumento - ↑ ; Decréscimo - ↓)

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---

---

6.3. Relativamente aos indivíduos pequenos (juvenis)

São libertados com vida  Espécies: \_\_\_\_\_

Habitualmente estão mortos quando as artes são levantadas  Espécies: \_\_\_\_\_

Aproveita para venda ou consumo próprio  Espécies: \_\_\_\_\_

Rejeita ao mar sem vida  Espécies: \_\_\_\_\_

6.4. Espécies de tubarão e raia capturadas

Por favor classifique de **0 a 4** a presença das espécies em que:

**0 (Ausente – não aparece de todo); 1(Raro – não aparece todos os anos); 2 (Ocasional – aparece 1 vez por ano); 3 (Comum – aparece todos os meses); e 4 (Abundante – aparece todas as semanas)** e assinale no mapa usando o símbolo as zonas de pesca atuais e passadas, caso existam alterações

**TUBARÕES**

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Notas:

**RAIAS**

	Símb.	Anos 70	Anos 80	Anos 90	2000's	2010's	2019	Estação do ano	Zona	Alteração da zona de ocorrência	Tipo de fundo	Prof.	Arte de pesca	Dimensão	Tend.
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<b>Raia-pontuada</b> ( <i>Raja brachyura</i> )	RP														
<b>Raia-manchada</b> ( <i>Raja montagui</i> )	RM														
<b>Raia santiaga</b> <b>Raia de S.Pedro</b> ( <i>Leucoraja circularis</i> )	RSP														
<b>Raia-de-dois-olhos</b> <b>Raia de S.Pedro</b> ( <i>Leucoraja naevus</i> )	RDO														
<b>Raia-curva</b> ( <i>Raja undulata</i> )	RC														
<b>Raia-bicuda</b> ( <i>Dipturus oxyrinchus</i> )	RCA														
<b>Raia-tairoga</b> ( <i>Rostroraja alba</i> )	RT														
<b>Raia-zimbreira</b> ( <i>Raja microocellata</i> )	RZ														
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<b>Ratão-bispo</b> ( <i>Pteromylaeus bovinus</i> )	RBO														
<b>Ratão-águia</b> ( <i>Myliobatis aquila</i> )	RA														
<b>Tremelga-de-olhos</b> ( <i>Torpedo torpedo</i> )	TO														
<b>Tremelga-marmoreada</b> ( <i>Torpedo marmorata</i> )	TM														
<b>Tremelga-negra</b> ( <i>Tetronarce nobiliana</i> )	TN														
<b>Ratão</b> ( <i>Dasyatis pastinaca</i> )															

Notas:

6.5. As aves marinhas costumam ficar presas nas artes?

Sim  Não  Não sei

6.6. Que espécies de aves ficam presas nas artes? Não sei

*Por favor detalhe o número de animais capturados no último ano:*

- |   |  |
|---|--|
| <input type="checkbox"/> Alcatraz – nº de capturas _____        | <input type="checkbox"/> Painhos – nº de capturas _____    |
| <input type="checkbox"/> Airo/Torda – nº de capturas _____      | <input type="checkbox"/> Pardela – nº de capturas _____    |
| <input type="checkbox"/> Cagarra – nº de capturas _____         | <input type="checkbox"/> Pato-preto – nº de capturas _____ |
| <input type="checkbox"/> Corvo-marinho – nº de capturas _____   | <input type="checkbox"/> _____                             |
| <input type="checkbox"/> Gaivota – nº de capturas _____         | <input type="checkbox"/> _____                             |
| <input type="checkbox"/> Garajau – nº de capturas _____         | <input type="checkbox"/> _____                             |
| <input type="checkbox"/> Moleiro/Alcaide – nº de capturas _____ | <input type="checkbox"/> _____                             |

6.7. As aves são tiradas da arte vivas ou mortas?

% vivas \_\_\_\_\_  
%  
mortas \_\_\_\_\_

Não sei

## 7. PERCEÇÃO DE ALTERAÇÕES ECOLÓGICAS AO LONGO DO TEMPO

7.1. Qual o maior tubarão/raia que já pescou (espécie, tamanho e/ou peso)?

---

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7.2. No decorrer da sua atividade, há alguma espécie de tubarão ou raia que se tenha tornado bastante abundante//rara ou que tenha desaparecido? Se sim, qual?

---

---

7.3. Na sua opinião qual a razão/razões que podem ter levado ao desaparecimento ou escassez das espécies de raias e tubarões que mencionou acima? Alguma outra espécie que tenha seguido esta tendência?

---

---

7.4. Quais as condições meteorológicas que considera favoráveis à pesca de tubarões e raias?

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## 8. OPINIÃO

8.1. Na sua opinião qual o impacto que a criação da Reserva Marinha das Berlengas tem nas pescarias?

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Agradecemos a sua participação! Estaria disponível para futuros contactos para reportar avistamento de tubarões e raias? Se sim por favor deixe o seu contacto



## TUBARÕES E RAIAS NAS BERLENGAS

- i- Inquérito para o trabalho de mestrado da Catarina Abril (ISPA), integrado no projeto FindRayShark.
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- k- Os inquéritos/entrevistas serão realizados a diferentes grupos de utilizadores desta área que podem frequentemente avistar estas espécies: pescadores, empresas e utilizadores marítimo-turísticos, tais como escolas de mergulho e mergulhadores, pescadores lúdicos, etc.
- l- Este inquérito tem por objetivo a recolha de informação sobre a distribuição espacial e temporal de espécies de tubarões e raias.

Tomei conhecimento dos objetivos desta entrevista e disponibilizo-me a responder a este questionário	<input type="checkbox"/>
Esta entrevista é de carácter voluntário e em qualquer momento da entrevista posso-me recusar a responder a qualquer questão com a qual não me sinta confortável	<input type="checkbox"/>
Tomei conhecimento de que esta entrevista é anónima e quaisquer dados pessoais (idade, sexo, etc..) serão utilizados apenas para análise estatística e caracterização da atividade nas Berlengas	<input type="checkbox"/>

### INQUÉRITO – Turismo náutico

#### 9. DADOS PESSOAIS

9.1. Idade: \_\_\_\_\_ 1.2. Sexo: M  F

9.2. Atividade

A) Empresa Marítimo-turística  B) Utilizador individual<sup>1</sup>

9.3. Em que ano iniciou atividade: \_\_\_\_\_ 1.4.1 – E atividade nas Berlengas: \_\_\_\_\_

<sup>1</sup> Responda às questões seguintes do ponto de vista de utilizador individual, em vez de empresa

## 10. CARACTERIZAÇÃO DA ATIVIDADE

10.1. Exerce a sua atividade o ano inteiro?

Sim  Não

10.1.1. Se Não, indique o período em que se encontra na água: de \_\_\_\_\_ a \_\_\_\_\_

10.1.2. Por favor indique a sua:

Época alta: \_\_\_\_\_ Época baixa: \_\_\_\_\_

10.2. Que tipo de atividades a sua empresa realiza?

10.2.1. Transporte de turistas para a ilha da Berlenga (TT)

10.2.2. Observação de fauna marinha (OFM)

10.2.2.1. Aves  Cetáceos  Outros: \_\_\_\_\_

10.2.3. Visitas a locais de interesse à volta das ilhas (ex:grutas) (VLI)

10.2.3.1. Quais? \_\_\_\_\_

10.2.4. Transporte para pesca lúdica (TPL)

10.2.5. Mergulho recreativo (MR)

Profundidade das zonas de mergulho: mín \_\_\_\_\_ máx \_\_\_\_\_ Habitual \_\_\_\_\_

Duração do mergulho: \_\_\_\_\_

Nº de mergulhos por saída: \_\_\_\_\_

10.2.6. Outras atividades Quais? \_\_\_\_\_

## 11. CARACTERIZAÇÃO DA EMBARCAÇÃO

11.1. Quantas embarcações tem a operar: \_\_\_\_\_

Nº da Emb	Comp (m)	Pot (kW/HP)	Nº de tripul. máx	Ano de início de atividade	Duração da viagem (H)	Nº saídas por dia	Nº pessoas por saída*	Atividade/ Notas

\*Época Alta

## 12. AVISTAMENTOS E PERCEÇÃO ECOLÓGICA (PERSPETIVAS ESPACIAL E TEMPORAL)

12.1. Em que zonas exerce a sua atividade?

12.1.1. Costuma fundear a embarcação?

Sim  Não  Se Sim por favor indique no mapa (X)

12.2. Nota alguma diferença no número ou tamanho dos tubarões e raias que avista desde os anos 80?

Não  Sim

12.2.1. Se sim, que espécies e em que sentido? (Aumento - ↑ ; Decréscimo - ↓)

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12.2.1.1. Na sua opinião quais são os fatores que poderão estar a influenciar estas diferenças?

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12.3. Espécies avistadas (com auxílio de catálogo/mapa):

Por favor classifique de **0 a 4** a presença das espécies (x) em que:

**0 (Ausente – não aparece de todo); 1(Raro – não aparece todos os anos); 2 (Ocasional – aparece 1 vez por ano); 3 (Comum – aparece todos os meses); e 4 (Abundante – aparece todas as semanas)** e assinale no mapa usando o símbolo as zonas de avistamentos atuais e passadas, caso existam alterações

<b>TUBARÕES</b>	<b>Símbolo</b>	<b>Anos 70</b>	<b>Anos 80</b>	<b>Anos 90</b>	<b>2000's</b>	<b>2010's</b>	<b>2019</b>	<b>Época do ano</b>	<b>Zona</b>	<b>Alteração da zona de ocorrência</b>	<b>Tipo de fundo</b>	<b>Prof.</b>
<b>Tubarão-corre-costa</b> ( <i>Carcharhinus plumbeus</i> )	TCC											
<b>Tintureira</b> ( <i>Prionace glauca</i> )	T											
<b>Tubarão-martelo</b> ( <i>Sphyrna sp.</i> )	TMO											
<b>Tubarão-anequim</b> ( <i>Isurus oxyrinchus</i> )	TA											
<b>Cação-liso</b> ( <i>Mustelus mustelus</i> )	CL											
<b>Cação-pintado</b> ( <i>Mustelus asterias</i> )	CP											
<b>Pata-roxa</b> ( <i>Scyliorhinus canicula</i> )	PRC											
<b>Pata-roxa</b> ( <i>Scyliorhinus stellaris</i> )	PRS											
<b>Cação-bico-de-cristal</b> ( <i>Galeorhinus galeus</i> )	CBC											
<b>Leitão/Litão</b> ( <i>Galeus melastomus</i> )	L											

Notas:

<b>RAIAS</b>	<b>Símbolo</b>	<b>Anos 70</b>	<b>Anos 80</b>	<b>Anos 90</b>	<b>2000's</b>	<b>2010's</b>	<b>2019</b>	<b>Estação do ano</b>	<b>Zona</b>	<b>Alteração da zona de ocorrência</b>	<b>Tipo de fundo</b>	<b>Prof.</b>
<b>Raia-lenga</b> <i>(Raja clavata)</i>	RL											
<b>Raia-pontuada</b> <i>(Raja brachyura)</i>	RP											
<b>Raia-manchada</b> <i>(Raja montagui)</i>	RM											
<b>Raia santiaga</b> <b>Raia de S.Pedro</b> <i>(Leucoraja circularis)</i>	RSP											
<b>Raia-de-dois-olhos</b> <b>Raia de S.Pedro</b> <i>(Leucoraja naevus)</i>	RDO											
<b>Raia-curva</b> <i>(Raja undulata)</i>	RC											
<b>Raia-bicuda</b> <i>(Dipturus oxyrinchus)</i>	RBA											
<b>Raia-tairoga</b> <i>(Rostroraja alba)</i>	RT											
<b>Raia-zimbreira</b> <i>(Raja microocellata)</i>	RZ											
<b>Raia-de-quatro-olhos</b> <i>(Raja miraletus)</i>	RQO											
<b>Ratão-bispo</b> <i>(Pteromylaeus bovinus)</i>	RBO											
<b>Ratão-águia</b> <i>(Myliobatis aquila)</i>	RA											
<b>Tremelga-de-olhos</b> <i>(Torpedo torpedo)</i>	TO											
<b>Tremelga-marmoreada</b> <i>(Torpedo marmorata)</i>	TM											
<b>Tremelga-negra</b> <i>(Tetronarce nobiliana)</i>	TN											
<b>Ratão</b> <i>(Dasyatis pastinaca)</i>	R											

Notas:

### 13. PERCEÇÃO DE ALTERAÇÕES ECOLÓGICAS AO LONGO DO TEMPO

13.1. No decorrer dos anos na sua atividade, há alguma espécie de tubarão ou raia que se tenha tornado bastante abundante//rara ou que tenha desaparecido em termos de avistamentos? Se sim, qual?

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13.2. Na sua opinião qual a razão que aponta para a alteração de abundância das espécies acima referidas?

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13.3. Quais as condições meteorológicas que considera favoráveis ao avistamento de tubarões e raias, ou de outras espécies que referiu acima?

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### 14. OPINIÃO

14.1. Na sua opinião qual o impacto que a criação da Reserva Marinha das Berlengas teve na sua atividade?

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14.1.1. Na sua opinião o que podia melhorar no plano que existe para a Reserva Marinha das Berlengas?

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Agradecemos a sua participação!

Estaria disponível para futuros contactos para reportar avistamento de tubarões e raias?

Sim

Não

Se Sim por favor deixe o seu contacto

Annex 5 – iNaturalist (Biodiversity4All) x FindRayShark flyer



**O FINDRAYSHARK TEM COMO OBJETIVO COMPILAR INFORMAÇÃO SOBRE A DISTRIBUIÇÃO DE RAIAS E TUBARÕES EM PORTUGAL**

**VIU UMA RAIÁ OU UM TUBARÃO?**

**FAÇA O DOWNLOAD DA APP E REGISTE A SUA OBSERVAÇÃO!**

Download on the App Store

Download from Google Play

**Naturalist**

**COMO PARTICIPAR?**

**PASSO 1: ASSOCIE UMA FOTOGRAFIA**

**PASSO 2: IDENTIFICAR A ESPÉCIE OBSERVADA USANDO AS SUGESTÕES AUTOMÁTICAS**

**SE NÃO SOUBER NÃO TEM PROBLEMA! PODE DEIXAR COMO "DESCONHECIDA" OU APENAS "TUBARÃO" OU "RAIA"**

**PASSO 3: REGISTRAR A LOCALIZAÇÃO E SUBMETER**

ACOMPANHE AS OBSERVAÇÕES EM [BIODIVERSITY4ALL.ORG/PROJECTS/FINDRAYSHARK](https://BIODIVERSITY4ALL.ORG/PROJECTS/FINDRAYSHARK)

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