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Portuguese Artisanal Fishers' Knowledge About Elasmobranchs—A Case Study

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The high economic value of fisheries was historically associated to commercial teleost fishes. Since the 1970s, despite some elasmobranchs becoming an important target or a bycatch, relatively little research has been carried out on this group because of their low economic value. Due to their specific life history characteristics, sharks and rays are particularly vulnerable to overexploitation, taking several decades to recover after reaching an overexploitation status. In Portugal elasmobranch fishery results mainly from targeted longlining and bycatch from different fishing gears. During the last decade, the Total Allowable Catches (TACs) of rays have been decreasing, the European Union (EU) banned the capture of some ray species, the Portuguese government implemented both a closed season and a minimum landing size for some rays, and the EU prohibited target fishing for sharks. All these measures may have been highly responsible for the national and local landings reduction. Official landings from the last decade were analyzed, the landed species conservation status was consulted, and structured interviews using a questionnaire were conducted in the most important fishing port in the Portuguese mainland, the port of Sesimbra. Results led us to conclude that fishers' answers and landings data did not match. It also revealed a lack of awareness by fishers about the state of shark and ray populations, and about some aspects of their biology and ecology, like reproduction season and method. The present study highlights the need to fill in this existing gap in knowledge through the transfer of scientific knowledge and sharing of management responsibilities. Also, we aimed to demonstrate the necessity for awareness and education activities within fishing communities, an essential step to elasmobranch conservation.

Keywords: elasmobranchs, sharks, rays, fisheries, local knowledge, fishers' perceptions, Portugal

INTRODUCTION

The greatest economic value of fisheries has historically been attributed to commercial teleost fish species (Ellis et al., 2008). As economic values overlapped ecological concerns, sharks have not been a high priority for commercial exploitation compared to other fisheries due to their low economic value in most countries (Stevens et al., 2000; Jacques, 2010). However, as some fisheries expanded since 1970s, some sharks also became an important target or bycatch, being harvested for meat,

liver oil and fins (Ellis et al., 2008), mostly due to improvements in fishing technology, processing and consumer marketing, expanding human populations and declining in other fish stocks, leading to a market value increase (CSWD, 2009). At the beginning of the twenty-first century, there was a growing concern about fisheries impact on shark and ray populations (Stevens et al., 2000; Jacques, 2010).

Elasmobranchs (Subclass Elasmobranchii) include sharks (several Orders) and rays (Order Rajiformes), both cartilaginous fishes that comprised different species (Field et al., 2009). Despite the similarities, sharks and rays have some differences between them. Sharks are laterally compressed with lateral gills and are surface feeders while rays are dorsoventrally flat with ventral gills and are bottom feeders (Evans et al., 2004; Wetherbee and Cortés, 2004; Wilga and Lauder, 2004).

Elasmobranch catches in Portugal result mainly from target fishery (e.g., deep-sea and surface longlining), but are also caught as bycatch (e.g., in the deep-sea black scabbardfish, *Aphanopus carbo*, longlining and artisanal fisheries) (Correia and Smith, 2003; Machado et al., 2004; Baeta et al., 2010) that tend to be often discarded (dead or injured) (Coelho et al., 2005). The presence of elasmobranchs as discards or bycatch is mainly due to their null or low commercial value (Tiralongo et al., 2018). It is crucial to consider that official fisheries statistics data are based on fish sold at auction and can be misleading as, because they are discarded, they tend to not be accounted in statistics. Also, some elasmobranch species caught are often aggregated (for example *Raja* spp.) avoiding a clear distinction of catches by species (CSWD, 2009). Consequently, it is very difficult to collect information about the impact of fisheries on elasmobranch populations (Baeta et al., 2010).

In 2003, Correia and Smith (2003) reported that Portuguese elasmobranch fishery was not regulated. Since then, some efforts have been made by the European Union (EU) and the Portuguese Government to regulate this fishery. The lack of knowledge about the exploitation and vulnerability of rays to fishing led the EU to put in place a Total Allowable Catch (TAC) and to ban the capture of some species. One of these species was *Raja undulata* (undulate ray), a species of high economic and social important for the Portuguese local fleet. The Portuguese Government also adopted additional management measures (a closed season and a minimum landing size) (Ministério do Mar, 2016). Also, *Raja* spp. and *Leucoraja* spp. were prohibited to capture from May to June, except as a bycatch (5% of total catch) (Serra-Pereira et al., 2018). Fishers criticized the measures which have been implemented without considering their local knowledge. The national top-down management process exposed the inability of fishers' knowledge to influence national policy-making (Said et al., 2020).

Regarding deep-sea sharks, the International Council for the Exploration of the Sea (ICES) advised that no target fishing should be permitted and deep-sea shark fishing has been prohibited in EU (Official Journal of the European Union, 2018). However, due to their unavoidable bycatch in directed fishery for black scabbardfish using longlines, a restrictive TAC was suggested to be maintained. According to the legislation, Member States sharing this concern (which included Portugal), should develop and establish

regional management measures for the black scabbardfish fishery and establish sharks data-collection measures (Official Journal of the European Union, 2018).

Considering that most shark and ray species are long-lived with slow growth rates and late sexual maturation, low fecundity and low reproductive potential, they appear to be particularly vulnerable to over-exploitation (Bonfil, 1994; Stevens et al., 2000). Once overfished, many populations take several decades to recuperate, either not achieving it or, at its best, being very slow to fully recover (Field et al., 2009). Over time, the number of elasmobranchs being listed in the IUCN Red List of Threatened Species have risen (Dulvy et al., 2014). The fragile attributes of elasmobranch populations pointed out the need for effective conservation and management measures (Correia and Smith, 2003; Worm et al., 2013).

Experienced fishers have knowledge based on decades of observations that has been passed down from one generation to the next (Freire and Garcia-Allut, 2000). Local Ecological Knowledge (LEK) is difficult to access and a challenge for scientists to deal with (Mackinson and Nottestad, 1998). Like other forms of knowledge (including science), sometimes it can be wrong either due to misinterpretations made by observers (e.g., fishers) or by collectors (e.g., researchers). Thereby, LEK should be analyzed as any other information and applied where it makes a difference in the quality of research and in the involvement of fishers in decisions that will affect them (Huntington, 2000). Previous pilot studies conducted around the world focused on fishers' perceptions about reef degradation (Bunce et al., 2008) and status of sharks (Jabado et al., 2015) and were based on a small number of interviews that were not representative of the country fishers' population but provided useful information. In the case of shark fishery, the interviews provided insights into local fishers' perception and a much-needed baseline for future investigations (Jabado et al., 2015). LEK was also assessed to identify shark habitats and fishers were a rich source of information that confirmed the presence of sharks (Rasalato et al., 2010).

This work provides new information on elasmobranch landings, conservation status and the complexity associated with fishers' knowledge and perception about species biology in Portugal.

MATERIALS AND METHODS

Study Area

Fishers' knowledge and perception were assessed through structured interviews using questionnaires conducted in Sesimbra, in the Southwest of Portugal. This is the most important fishing port in the Portuguese mainland, accounting for 30% of the total landings (in weight) and for 93% of the black scabbardfish landings (in weight), a fishery responsible for a large amount of elasmobranch bycatch.

Data Source

Landing Data and Conservation Status

Sesimbra official landings of elasmobranch species provided by Directorate General for Natural Resources, Safety and Maritime

Services (DGRM) were analyzed between 2009 and 2019. IUCN (2019) Red List for endangered species was consulted to determine the landed species Conservation status (by increasing level of concern: Least Concern, Near Threatened, Vulnerable, Endangered and Critically Endangered).

Survey

We conducted structured interviews with fishers from Sesimbra. A questionnaire was developed, in the Portuguese language, to collect information about captured species and fishers' knowledge about elasmobranch ecology and biology, with open-ended questions. Fishers were approached randomly in the harbor, from January 2019 to November 2020. Ethical review and approval was not required for the study. As written consent was not required and/or applicable, we proceeded with verbal consent. Fishers were informed about the purpose of the survey and the intended use of data, as well as how survey data from the project would be kept both anonymous and confidential, prior to being asked for verbal consent and proceeding with the survey. Face-to-face interviews were conducted with fishers who admitted to capture sharks and rays. Only one fisher per fishing vessel was interviewed. Considering that shark captures are only allowed as bycatch, we took the approach to only interview those fishers that admitted to have captured sharks accidentally. During the interview, illustrations of sharks and rays were presented to clarify species identification, since local names differ according to the area.

The questionnaire was composed of open-ended questions to avoid any bias (resulting from suggested options) and to give fishers the opportunity to freely express their opinion about these issues. Fishers were asked about captured species (identification through illustrations) ("Which species of sharks and/or rays do you catch?"), area and/or season of higher catches ("Is there a season or area of higher catches?"), area or season where juveniles were present in catch ("Is there a season or area where you catch/find juveniles?"), relative abundance of elasmobranchs (compared with the past) and reasons for that trend ("Do you think there is more or less sharks and rays over the years? Why?"), feeding habits ("What do rays and sharks eat?"), type of reproduction ("How do sharks and rays reproduce?"), reproductive season ("When do sharks and rays born?"), their opinion about elasmobranchs being threatened or not ("Do you think sharks and rays are endangered?") and also if elasmobranchs should be protected ("Do you think sharks and rays should be protected?") and, finally, for suggestions for management measures ("What measures would you suggest as important for their protection?"). A total of 28 fishers participated. According to the Directorate General for Natural Resources, Safety and Maritime Services (DGRM), a total of 188 vessels landed sharks or rays in Sesimbra fishing port. As such, the 28 interviews accounted for 15% of all vessels landing sharks and rays. Nearly half of the fishers used nets and the other half used longlines. The same regarding the size of the fishing vessel with half of the fishers operating local vessel (up to 9 meters in total length) and the other half coastal vessels (between 9 and 33 meters in total length). Most fishers declared to fish whenever possible, resulting in

a range between 3 and 5 days per week, depending on the weather conditions.

Data Analysis

We combine official landings analysis and structured interviews conducted with fishers. Annual landings of sharks and rays in Sesimbra between 2009 and 2019 were considered to reveal landings variation. Also, landed species were grouped by IUCN status to estimate the proportion of each category landed by year. Due to the difficulty to distinguish *Scyliorhinus stellaris* and *Scyliorhinus canicula* because of their similar phenotype, and their similar common name, we chose to combine both and interpret landings and fishers' answers as *Scyliorhinus* spp. for the present work.

Qualitative research can allow for a good understanding of the reasons behind fishers' attitudes and improve knowledge of their reaction toward management measures (Barclay et al., 2017). Empirical analysis of questionnaires allowed us to understand fishers' perception about elasmobranchs biology. The responses to open-ended questions were coded into categories and the predominant ones identified and presented as percentages. Although the coding process can be subject to interpretation by the coder, in this case the questions were very focused and direct, hence coding was straight forward and left little room for interpretation.

RESULTS

Landing Data, Conservation Status and Fishers' Perception

The analysis of elasmobranchs official landings between 2009 and 2019 showed that 16 different shark species (plus 3 identifications till genus) and 10 ray species (plus 2 genera identified) were landed in Sesimbra, even if only once.

During the considered time period, the official landings of shark species showed a steep and continuous decrease over time. In 2009, 863 t were landed while in 2019 this value dropped to 124 t. Additionally, ray landings peaked in 2011 (167 t) but increased and decreased in small amounts during the entire time-series (Figure 1).

Out of the 27 shark and ray species landed, 26 are classified with a threatened category by the IUCN Red List of Threatened Species: 1 as Critically Endangered (CE) (*Centrophorus granulosus*); 4 as Endangered (E) (*Raja circularis*, *Raja undulata*, *Isurus oxyrinchus*, *Squalus acanthias*), 7 as Vulnerable (V) (*Myliobatis aquila*, *Alopias vulpinus*, *Centrophorus lusitanicus*, *Centrophorus squamosus*, *Galeorhinus galeus*, *Mustelus mustelus*, *Oxynotus centrina*), 7 as Near Threatened (NT) (*Centroscymnus coelolepis*, *Mustelus asterias*, *Prionace glauca*, *Dipturus oxyrinchus*, *Raja brachyura*, *Raja clavata*, *Raja microocellata*) and 7 as Least Concerned (*Centroscymnus crepidater*, *Deania calcea*, *Galeus melastomus*, *Scymnodon ringens*, *Leucoraja naevus*, *Raja miraletus*, and *Raja montagui*). The only species missing (*Myliobatis aquila*) is classified as Data Deficient. Over the years landings were mainly dominated by Near Threatened species (between 30 and 88%), except in 2012 and 2013 that most of the

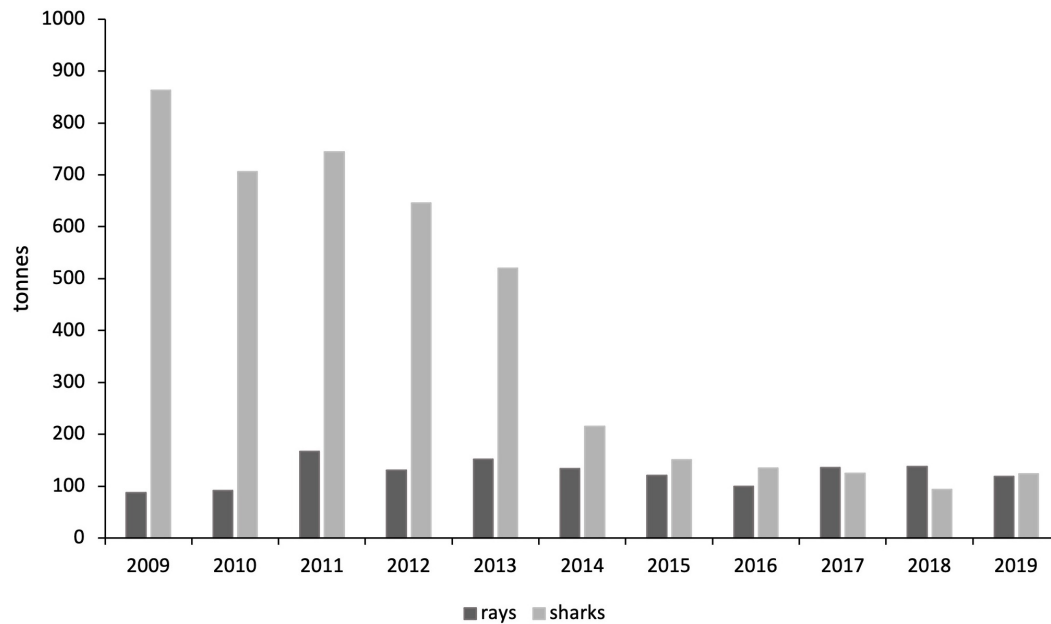


FIGURE 1 | Official landings of elasmobranchs in Sesimbra fishing port from 2009 to 2019.

landings were Vulnerable species (55%). Since 2014 and 2015, respectively, Endangered and Vulnerable species captures have been declining to less than 10% (**Figure 2**).

Between 2009 and 2013, Sesimbra shark landings were mainly of two species—*Centrophorus lusitanicus* (V) and *Prionace glauca* (NT), together representing between 57 and 80% of landings. In 2014 *Galeorhinus galeus* (V) and *Scyliorhinus* spp. dominated the landings. From 2014 onward, *Scyliorhinus* spp. maintain its position as landings leader.

Several shark species occurred in less than half the time-series considered in a residual amount: *Centrophorus granulosus* and *Scymnodon ringens* were only landed between 2009 and 2011; *Centroscymnus crepidater* only landed in 2009 and 2010, and *Galeorhinus galeus* in 2014 and 2015.

Considering ray species, in 2009 *Raja montagui* led the landings (75%) and decreased to 29% in the next year. Since then, landings were dominated by *Raja clavata* (NT) ranging between 52% (2010) and 71% (2019). *Raja microocellata* (NT), *Raja miraletus* and *Raja undulata* (E) have just started to be landed since 2016. Again, several species occurred in less than half the time-series under analysis in a residual quantity: *Raja miraletus* (2016, 2018 and 2019), *Raja microocellata* (between 2017 and 2019) and *Raja undulata* (from 2016 onward).

When fishers were asked about elasmobranch fishery, most of them affirmed not to capture sharks, only rays. However, after showing them species illustrations, they have identified several sharks as species they captured. Thus, all interviewed fishers have stated to have caught both. This difficulty to point out which were shark species revealed a lack of knowledge.

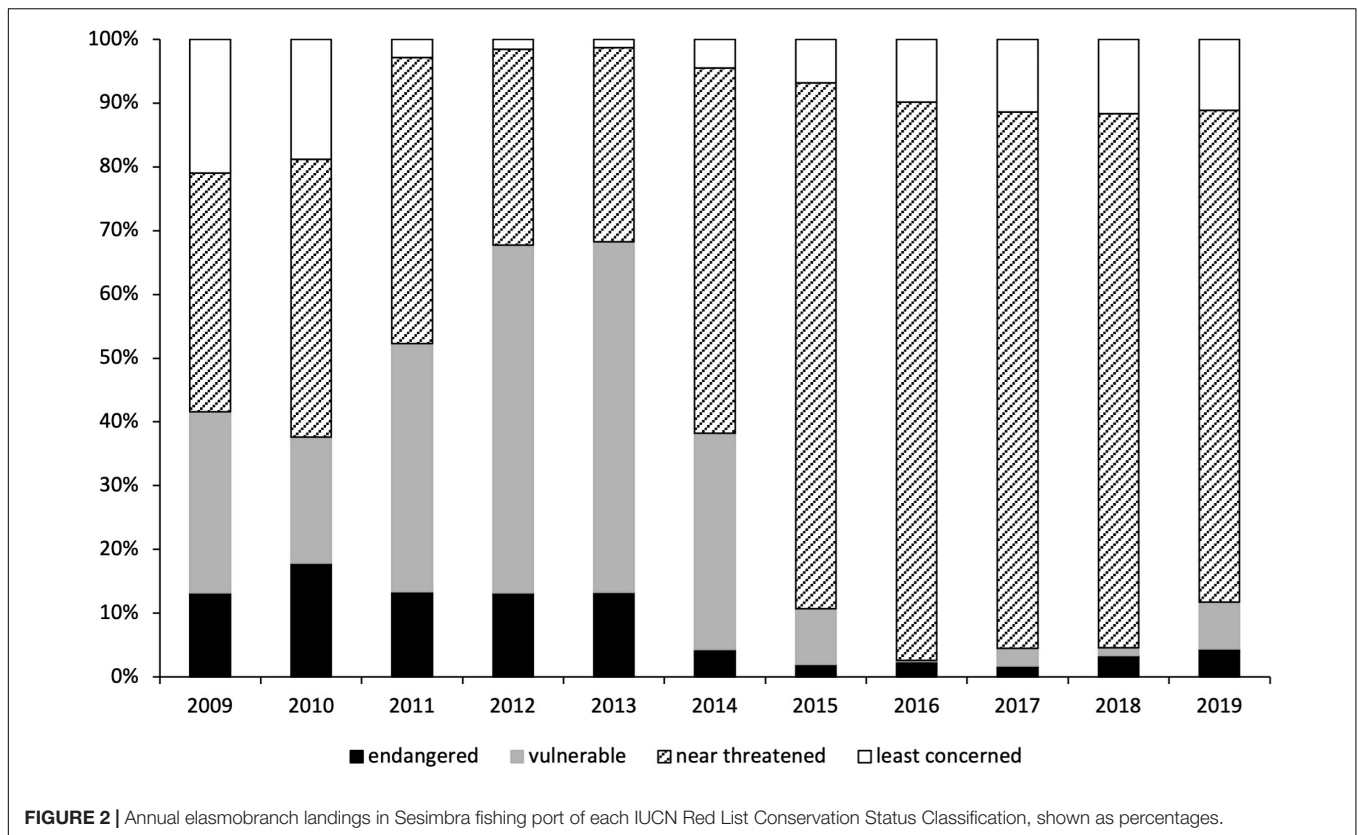
Fishers' identification of captured elasmobranchs through illustrations revealed that most captured species are *Galeorhinus galeus* (V), *Scyliorhinus* spp. (sharks) and *Torpedo marmorata*,

Leucoraja naevus, and *Myliobatis aquila* (rays). Comparing fishers' identification with official landing data, only *Scyliorhinus* spp. is common in both rankings. Additionally, fishers identified the following shark species as the less captured: *Centrophorus lusitanicus*, *Centroscymnus coelolepis*, *Isurus oxyrinchus*, *Squalus blainville*; and the following as less captured ray species: *Leucoraja circularis* and *Dipturus oxyrinchus*. Again, fishers answers and landings data did not match.

Fishers' Knowledge About Elasmobranchs' Biology and Ecology

Fishers reported to find elasmobranchs from the coast until around 1,000 meters depth, mostly in sandy bottom. When asked about areas of highest elasmobranchs catches, fishers were not able to indicate any specific location. There was no unanimous answer regarding a specific season of highest catches, though the winter season seems to be when more catches occur, with 25% of fishers indicating this season as the most important. Fishers also didn't seem to know areas and/or seasons of juveniles catches.

Elasmobranch catches may have different destinations: sale at fish auction, discarded (mostly in the case of rays during the closed season) or for crew consumption (in case they were already dead during closed season). Over the years, contrary to landing data, most fishers had the perception that elasmobranch population increased, and that elasmobranch catches have also been increasing (39% of replies), with fishers stating that "there are more and more". The reasons fishers presented for this increasing trend were mainly management measures (55%), especially the imposed closed season for rays, less fishing effort (due to the reduction of fishing vessels number) or because sharks were not a targeted group of the fleet. Only a few fishers were



of the opinion that elasmobranchs have been reducing due to fishery, pollution and lack of management measures.

There is a consensus amongst fishers that elasmobranchs feed mainly of fishes (61%) and crustaceans (57%) (Figure 3A). Fishers admitted that the reproduction season, mainly for sharks, remains unknown (68%) to them. For rays, most fishers pointed out Spring (54%) mainly during May, as the reproduction season (Figure 3B). Most fishers answered that elasmobranchs reproduce through eggs (50%) or born alive (viviparous) (21%). Nonetheless there was still a considerable part that stated to have no knowledge about their reproduction (36%) (Figure 3C).

Fishers identified only two reasons for elasmobranchs mortality: pollution (43%) and the fishing activity (32%). Fishers did not consider that elasmobranchs were threatened (64%) not feeling the need to protect them (54%). Measures like closed season during reproduction (“study reproduction season and prohibit fishing during that time”), minimum landing size and reduced fishing effort were suggested by some fishers, however most of them (36%) could not suggest a measure to be implemented, either because they did not find it necessary or because they had no suggestions (“I don’t know about those subjects”) (Table 1).

DISCUSSION

A recent and comprehensive analysis of Portuguese elasmobranch fisheries showed that in the past decades,

landings of sharks, skates and rays in Portuguese fishing ports have been decreasing (Alves et al., 2020). In the present study, Sesimbra official landing data corroborated the previous analysis, showing a considerable reduction especially of shark landings in this fishing port over the past decade. This tendency replicates reports from several countries since more than 60% of world’s countries catching elasmobranchs reported a reduction in their landings (Davidson et al., 2016). Also, the prior analysis (Alves et al., 2020) identified *Raja* spp. and *Scyliorhinus* spp. as the most landed taxa over the 32 years period, which match the official landings considered in the present study.

During the analyzed period, several management measures were introduced for elasmobranch fisheries in order to control their exploitation: rays’ TACs have been decreasing, the EU banned the capture of some ray species, the Portuguese government implemented both a closed season and landing size for some rays, and the EU prohibited targeting fishing for sharks. All these measures may have been highly responsible for the reduction in landings. Nonetheless, fishers who took part in the survey had the perception that elasmobranch catches have been increasing, which may be related to the fact that the fishing effort has decreased therefore each fisher has been capturing a larger number of individuals. It is important to notice that official landing data is based on fish sold at auction. Most sharks are discarded, dead or injured, therefore not being accounted for official statistics (Coelho et al., 2005). This means that fishers may catch sharks which were never landed, leading to an underestimation in

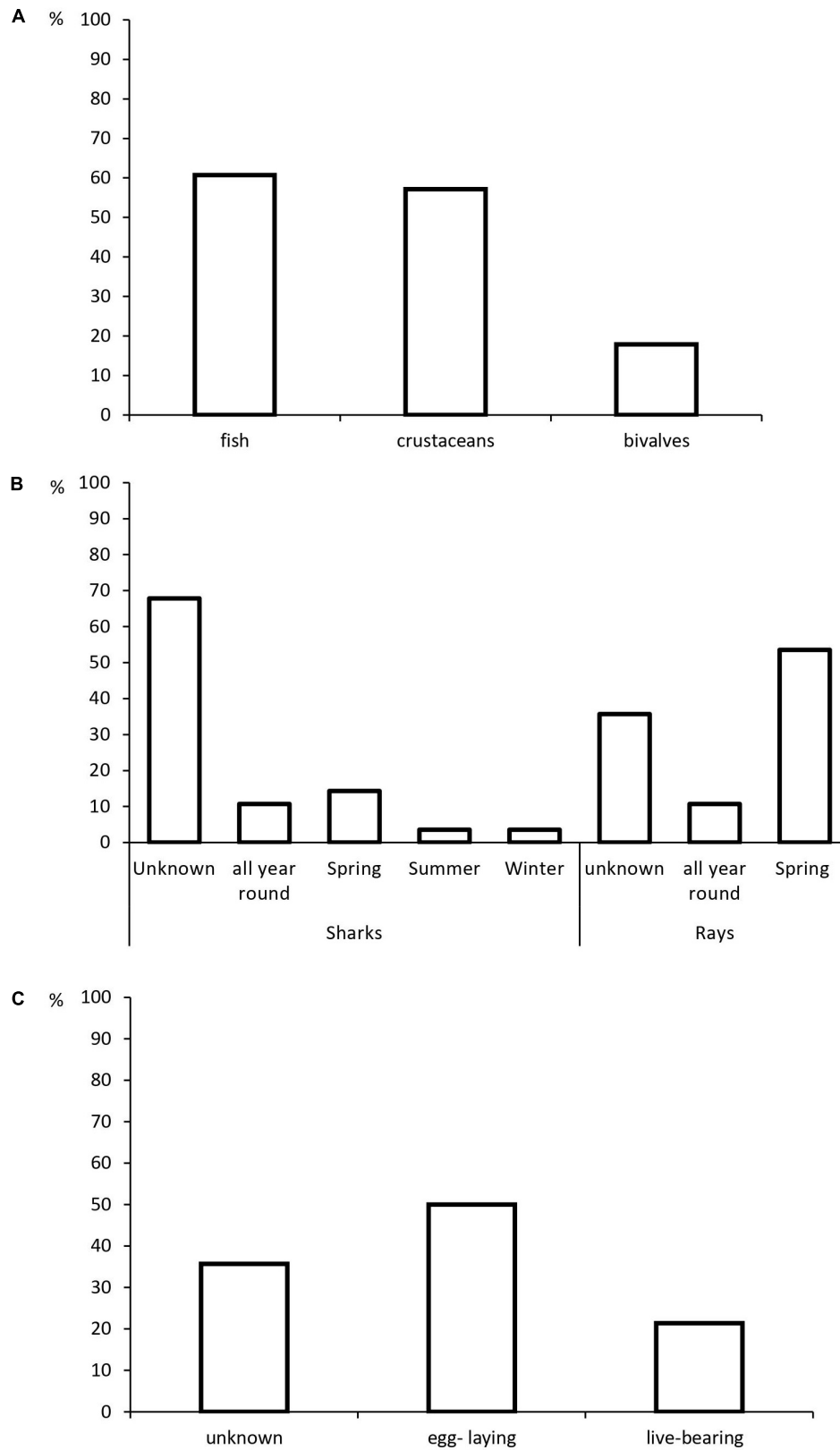


FIGURE 3 | Fishers' knowledge about elasmobranch feeding habits (A), reproduction season (B) and method (C). Answers were presented as percentages. Some fishers selected more than one option in (A,B) as such values add-up to more than 100%.

TABLE 1 | Fishers' perception about the reasons for elasmobranch mortality, threatening state, need of protection and suggested management measures to protect them.

| Fishers' perception about elasmobranchs | |
|--|----|
| Reasons for elasmobranchs' mortality (%)* | |
| Pollution | 43 |
| Fishery' activity | 32 |
| No suggestion | 29 |
| Elasmobranchs' threat state (%) | |
| Fishers who perceive elasmobranchs to be threaten (%) | 32 |
| Fishers who feel the need to protect elasmobranchs (%) | 36 |
| Management measures (%) | |
| Reduction of fishing effort | 21 |
| Implementation of a minimum landing size | 18 |
| Implementation of a biological closure | 24 |
| No suggestion | 36 |

*Some fishers selected more than one option, and as such values sum more than 100%.

official data. Another point in question is the fact that several fishers admitted off-the-record to skin the rays (already dead) aboard before landing, which impairs species identification, and thus avoiding the penalties for capturing prohibited species. Thus, official landings are likely to be an underestimation of the real catches of elasmobranchs, because not all catches are landed (some are discarded, some skinned aboard). This has been observed in other locations, with Tiralongo et al. (2018) noting that fishers' choice to retain or discard catches relates to local traditions and market demand, so differences could be found not only between countries, but also between regions.

IUCN Red List of Endangered Species is a valuable tool to assess and monitor the biodiversity status of sharks over time and to help setting priorities for conservation action. During the consultation of elasmobranchs category, it has been noticed that no recent assessment was available for several species. The cost of maintaining the Red List up-to-date nowadays overcame the total budget, which is likely to cause outdated assessments. It was anticipated that by 2025, 83% of assessments would be outdated and the average age of assessments would be above 30 years. This lack of assessment can lead to an unacceptable risk of delaying conservation responses (Rondinini et al., 2014). Thus, the present consideration of IUCN conservation status should be seen as a basis of elasmobranchs situation but taking into account that their situation may be even worse.

Our results provided insights into the perceptions of local fishers, revealing a lack of awareness about the state of shark and ray populations, and also about some aspects of their biology and ecology. In the present study we were also able to perceive some difficulty regarding elasmobranch species identification. Even though our findings are based on a limited sample, this case study provided enough information to trigger the understanding of elasmobranch fishery from the perspective of Portuguese fishers and to determine important issues which may be addressed by management authorities in the future,

filling the existing gap in knowledge. As in a previous study, we suggest that fishers should be trained on proper identification of elasmobranch species, as similar species possess different ecological characteristics that could require different approaches (Alves et al., 2020).

Fishers' answers regarding elasmobranch feeding habits coincide with scientific description (e.g., Wetherbee and Cortés, 2004) and the same was shown about reproduction methods, with all elasmobranchs categorized as oviparous (egg-laying) and viviparous (or ovoviviparous) (live-bearing) (e.g., Carrier et al., 2004). Considering sharks' reproduction seasons, fishers admitted a lack of knowledge about this topic, while they seemed to be more knowledgeable about rays' reproduction season, mostly associating their reproduction season with the imposed closed season. A specific study along the Portuguese mainland coast for *Raja clavata*, the most important species for the local small-scale fleet and subsequently the most studied, indicated an extended reproductive peak season from December to May (Serra-Pereira et al., 2015). However, despite the economic importance of rajids in the North-east Atlantic, their reproductive behavior remains poorly known (Baeta et al., 2010). The generalized lack of knowledge of some aspects of this group of species (sharks or rays) is a motive for concern due to the diversity of species and different life histories, threatened status and conservation needs for each one.

Fishers may have the perception that catch information could eventually be used as a tool against them to place restrictions and regulations (Jabado et al., 2015) which may be related to the demonstration of lack of concern regarding sharks' exploitation status and protection needs.

Regarding management measures, fishers demonstrated a higher preference for closed season. Closed seasons are a commonly used management tool and often used to control effort. However, it does not usually reduce effort as much as anticipated and effort become more temporally concentrated in the remaining open season (Fulton et al., 2011). This is particularly relevant in the case of rays, whose concentrated fishing effort before or after the closed season was commented by some fishers.

Despite the growing concern about the state of elasmobranch populations, few mitigation actions have been established and there are still no clear guidelines about which would be effective. Bycatch mortality must be mitigated by managers and fishers. Some of the solutions presented to this effect were technological changes in gear and fishing practices (Cosandey-Godin and Morgan, 2011). Yet, even with all the measures that could be applied and seen as effective, it is crucial that managers recognize that the most effective piece for a successful management plan to mitigate elasmobranch mortality would be fishers' cooperation and commitment (Fulton et al., 2011). The development of management plans with the collaboration of fishers could prevent excessive exploitation of elasmobranchs (Tiralongo et al., 2018). During the decision-making process, there is the need to pay much more attention to the motivation and behavior of stakeholders, especially resource users (Fulton et al., 2011). In fact, the inclusion of human motivation as part of the

management system had been suggested for many years (Ludwig et al., 1993), but is still not being addressed or prioritized.

Previous studies have already highlighted the importance of the involvement of fishers, focused on their knowledge to assess shark population trends and to provide valuable guidance on the conservation status of local shark populations (Leduc et al., 2021). Others have reported fishing communities awareness about population declines of several shark species, but that they rarely take action to avoid capture of sharks (Martins et al., 2018). A study conducted in Portugal assessing fishers' knowledge about fishing resources, concluded that fishers only seem to have a moderate knowledge about the biology and ecology of the resources they exploit (Silva et al., 2019).

Given our results and the previous work on sharks' vulnerability to overfishing, it is imperative that robust strategies for shark management and conservation be designed (Worm et al., 2013). Our study contributed with new information regarding fishers' knowledge (or lack of it) about elasmobranch life cycle, highlighting the need to fill in this existing gap in knowledge through the transfer of scientific knowledge and sharing of management responsibilities. Also, we demonstrate the necessity for awareness and education activities within fishing communities, not only to increase their knowledge about these resources but also to change their perception about the conservation needs they face.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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AUTHOR CONTRIBUTIONS

PS carried out all data analysis and wrote the manuscript. CT provided guidance on analysis and provided edits for the manuscript. HC, SF, and CP contributed to the design of this work. All the authors contributed to manuscript revision, read, and approved the submitted version.

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