Fisheries Research 230 (2020) 105648

Contents lists available at ScienceDirect

Fisheries Research

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

Assessment of trends in the Portuguese elasmobranch commercial landings over three decades (1986–2017)

Luís M.F. Alves[a,*], João P.S. Correia[a], Marco F.L. Lemos[a], Sara C. Novais[a], Henrique Cabral[b]

[a] *MARE – Marine and Environmental Sciences Centre, ESTM, Politécnico de Leiria, 2520-641, Peniche, Portugal*
[b] *INRAE, UR EABX, 50 Avenue de Verdun, 33612, Cestas, France*

ARTICLE INFO

Handled by: S Xavier Cadrin

Keywords:
Sharks
Commercial fisheries
Common fisheries policy
Bycatch
Misreporting

ABSTRACT

Portugal plays a major role in shark, skate and ray fisheries in the European Union. With the decline of these animals raising concerns amongst scientists all over the world, we set out to provide an updated assessment on elasmobranch landings in Portugal between 1986 and 2017. The dataset analysed in this study consisted of 15,521 records, each with information concerning the species (or higher taxonomic level), port, month, year, and weight of fish landed. A non-parametric change points assessment statistical technique was used to evaluate important changes in landings throughout the time series. Principal components analysis was also performed to mean values of landings per year for the most captured species, and similar analysis was conducted using fishing ports instead of year, for the same sub-set of species / taxa. According to the data, more than 143 thousand metric tons of elasmobranchs were landed in Portuguese ports between 1986 and 2017, divided by 58 taxa of sharks, skates and rays. The most landed taxa were demersal rays and skates (*Raja* spp.), followed by spotted dogfishes (*Scyliorhinus* spp.), blue shark (*Prionace glauca*), Portuguese dogfish (*Centroscymnus coelolepis)*, leafscale gulper shark (*Centrophorus squamosus),* gulper shark (*Centrophorus granulosus)* and shortfin mako (*Isurus oxyrinchus*). Together, these seven taxa accounted for more than 75% of all landings. Several cases of misreporting were identified and discussed. Overall, landings of elasmobranchs in Portugal show marked decreases and changes in composition, with deep-sea sharks being the most influential group during the studied period.

1. Introduction

There are over 1000 elasmobranch species in existence today, and sharks represent 35% of those species, with skates and rays further accounting for 13% and 52%, respectively (Weigmann, 2016). According to the International Union for Conservation of Nature (IUCN) Red List, a quarter of those species are estimated to be threatened with extinction (Dulvy et al., 2014). Shark meat consumption by humans is not a novelty, with records dating as back as the fourth century (Vannuccini, 1999). The global market for elasmobranch products has since vastly increased and diversified, with the food, pharmaceutical, and even clothing industries processing and selling meat, liver oil, cartilage, skin, and other shark related products (Dent and Clarke, 2015).

The demand for elasmobranch products has fuelled the overexploitation of these animals and numerous authors have already drawn attention for the steady decline affecting populations of sharks and their relatives all over the world (Davidson et al., 2016; Jacques, 2010; Roff et al., 2018; Worm et al., 2013). Data on elasmobranch fisheries are historically scarce and usually low quality, encumbering proper management (Barker and Schluessel, 2005; Oliver et al., 2015). Additionally, constant historical vilification of these animals by the media created a generalized lack of empathy from the general public, and has contributed to very weak conservation efforts by decision makers for many years (Evans, 2015; Friedrich et al., 2014).

This lack of concern must be averted as the decline shown by these animals can potentially affect entire ecosystems, with many elasmobranchs being top predators in their respective food webs (Bornatowski et al., 2014; Ferretti et al., 2010; Myers et al., 2007). Late maturation, long gestation and high longevity render the majority of elasmobranch species particularly susceptible to intensive fishing efforts, with overfishing generally considered to be the main driver for their decline (Myers and Worm, 2005; Stevens, 2000). Sharks and rays also suffer from high rates of bycatch, resulting in a staggering number of individuals caught every year. This phenomenon has been amply discussed by authors such as Worm and colleagues in 2013, who estimated between 63 and 273 million sharks killed in the year of 2010 alone.

With an Exclusive Economic Zone (EEZ) spanning over more than 1.7 million squared kilometres, fishing has been part of Portugal's identity

* Corresponding author.
E-mail address: luis.f.alves@ipleiria.pt (L.M.F. Alves).

https://doi.org/10.1016/j.fishres.2020.105648
Received 6 February 2020; Received in revised form 18 May 2020; Accepted 26 May 2020

and culture for many centuries. Although it represents a small percentage of the country's GDP, this industry and its associated activities are still the main source of income for many coastal communities (Alves, 2015; Estatística de, 2019). Statistics from 2014 reported 790 thousand tonnes (metric tonnes) of shark, skate and ray caught globally, with Portugal being one of Europe's highest ranked countries in this field (Dent and Clarke, 2015). Performing regular assessments of these stocks is difficult but essential. There are currently several different surveying projects operating in Portuguese waters collecting data using on-board observers, but this type of data collection is not practical and has limited reach. Boat owners and fishermen often oppose the obligation to take independent observers on their fishing trips, even if doing nothing wrong, for fear of unexpected fines and restrictions. The number of observers operating at any given moment is also limited, meaning that at any point in time a vast number of boats are fishing with no form of impartial recording. Nevertheless, efforts made in recent years to increase coverage in these observer-based programs are well worth it, as observer-derived catch data remains the best and sometimes only way of keeping record of by-catch and discards at sea. Additionally, it is important to keep reminding boat owners and fishermen that these programs are also important to collect evidence of stock recovery (Walsh et al., 2009), which can allow decision makers to increase fishing quotas in a sustainable way. To this day, fisheries-dependent data are still the preferred source of information used by decision makers to estimate the health of elasmobranch stocks (Barreto et al., 2016). Most fisheries of sharks and their relatives are understudied, and data collected from landings are often the only available information. Some countries, such as Portugal, have kept records that span several decades and provide for a way to keep track of catch trends. These numbers are often used to help make management decisions, but they have shortcomings that must be considered. Firstly, these data may be influenced by several factors other than fish population numbers. Changes in fishing capabilities, legislation, consumer preference and even climate have the potential to alter the intensity and the target of fishing efforts (Baum, 2003; Burgess et al., 2005; Correia et al., 2016a, 2016b; Gamito et al., 2016; Musick and Musick, 2011). Secondly, low priced fish such as elasmobranchs tend to be landed in generic agglomerated groups with low taxonomic resolution (Pauly and Zeller, 2016). This prevents proper assessment of trends for specific species. Thirdly, landing data do not represent the totality of all animals caught: animals discarded at sea and / or caught by recreational anglers are not included, and may represent considerable percentages of the total catch for a specific species (Dulvy et al., 2014; Gallagher et al., 2017).

Despite the ecological and economical importance of elasmobranchs, management of these animals is still a low priority when compared to other marine predators. While some of the most emblematic and endangered shark species remain vulnerable to overexploitation, other predators like dolphins and seals are targets of international protection (Dolman et al., 2016). Nevertheless, in recent years the European Union made considerable efforts to better regulate elasmobranch fisheries, introducing significant limitations. Such efforts include the regulations on the removal of fins of sharks aboard fishing vessels covered in Council Regulation (EU) No 605/2013 (2013), and fishing restrictions to some species of deep-sea covered in Council Regulation (EU) No 2015/2006 (2006), Council Regulation (EU) No 1359/2008 (2008) and Council Regulation (EU) No 1367/2014 (2014).

In this study, shark and ray landings in Portuguese fishing ports were analysed during the past three decades, with the objective of outlining trends and highlighting priorities for management.

2. Methods

2.1. Data collection

To assess Portuguese elasmobranch fisheries, data from commercial landings were analysed for a period of 32 years, from 1986 to 2017. In Portugal, data concerning landings are collected and compiled by Docapesca, a public company with delegations in all major Portuguese fishing ports. When a fishing vessel docks and lands its catch, date, time and port name are registered, as well as the name and type of fishing license of the vessel. Additionally, the total weight and price of each landed taxon are recorded. These values are then automatically sent to the *Direcção Geral de Recursos Naturais, Segurança e Serviços Marítimos* (DGRM), the National Fisheries Board. The dataset analysed in this study consisted of 15,521 records, each consisting of species (or higher taxonomic level), port, month and year, and weight of fish landed. Taxonomic resolution and misclassification of elasmobranch species was a major constraint and varied throughout the 32 years of data that were analysed. Species clustering under a broad designation, such as 'shark', was a common procedure in more remote years, but it gradually gave place to identification to genus or species level. Taking the aforementioned facts into account, landings trend analyses for some species were made at a higher taxonomic resolution than species, in order to maintain coherence throughout the dataset. Ecological groups, obtained from Fishbase (Froese and Pauly, 2019) (i.e. demersal, pelagic, bathydemersal and benthopelagic), were assigned to each species / taxon present in fisheries landings.

2.2. Data analyses

In order to evaluate changes in landings throughout the time series for the species / taxa with highest catches, a non-parametric change points assessment statistical technique was used and implemented with the "changepoint" package in R (Killick and Eckley, 2014). The algorithm used (PELT - pruned exact linear time; Killick et al., 2012) evaluated the sequence of values in the data series and set segments (corresponding to periods of the data series) that presented different characteristics in terms of their statistical properties (mean and / or variance). In addition to total landings of elasmobranchs, seven taxa representing approximately 80 % of landings were used in these analyses: demersal rays and skates (*Raja / Leucoraja* spp.) – group comprising all species of the genus *Raja* and *Leucoraja*; spotted dogfishes (*Scyliorhinus* spp.) – group integrating both lesser spotted dogfish (*Scyliorhinus canicular*) and nursehound (*Scyliorhinus stellaris*), although both literature (Correia and Smith, 2003; Correia et al., 2016a, 2016b) and field observations indicate that landings of this group consist predominantly of *S. canicula*; blue shark (*Prionace glauca*); Portuguese dogfish (*Centroscymnus coelolepis*); leafscale gulper shark (*Centrophorus squamosus*); gulper shark (*Centrophorus granulosus*); and shortfin mako (*Isurus oxyrinchus*). Principal components analysis was conducted to mean values of landings per year for most captured species (17 taxa with overall mean annual landings higher than 20 tonnes). The purpose of this analysis was to explore temporal patterns in landings in order to evaluate their trends in the past three decades, while also identifying those taxa most related with these patterns. These statistical analyses were performed with R software (R Core Team, 2018).

3. Results

Between 1986 and 2017, 58 taxa of sharks, skates and rays were identified in Portuguese fisheries landings (Table 1). Total annual mean landings varied between 2229 and 4504 tonnes, and the change points methodology identified three distinct and progressively lower landing periods (Fig. 1). Sharks landings were higher compared to skates and rays throughout the time series analysed, except from 1986 to 1989 and from 2014 onwards (Fig. 2). With regards to main ecological groups, demersal rays and skates were the dominant group throughout the time series analysed. Landings of bathydemersal sharks remained high until 2008, after which a marked decrease was noticed. Pelagic sharks displayed an opposite trend compared to this latter group, being landed in higher quantities from 2004 until 2013. Demersal sharks' landings remained fairly constant throughout the years (between 400 and 800 tonnes per year). Benthopelagic sharks' landings were low.

Table 1
Species or taxa of sharks, skates and rays landed in Portuguese fishing ports, between 1986 and 2017, and their annual mean landed values.

Species / Taxa	Common name	Ecological group	Mean annual landings (tonnes)
Raja spp.	Rays	Demersal	1122.83
Scyliorhinus spp.	Lesser spotted dogfish	Demersal	599.77
Prionace glauca (Linnaeus. 1758)	Blue shark	Pelagic	442.73
Centroscymnus coelolepis (Barbosa du Bocage & de Brito Capello, 1864)	Portuguese dogfish	Bathydemersal	420.71
Centrophorus squamosus (Bonnaterre, 1788)	Leafscale gulper shark	Bathydemersal	399.30
Centrophorus granulosus (Bloch & Schneider, 1801)	Gulper shark	Bathydemersal	323.66
Raja clavata (Linnaeus, 1758)	Thornback ray	Demersal	269.94
Isurus oxyrinchus (Rafinesque, 1810)	Shortfin mako	Pelagic	179.90
Raja brachyura (Lafont, 1871)	Blonde ray	Demersal	119.77
Centrophorus lusitanicus (Barbosa du Bocage & de Brito Capello, 1864)	Lowfin gulper shark	Bathydemersal	97.93
Dalatias licha (Bonnaterre, 1788)	Kitefin shark	Bathydemersal	96.56
Mustelus spp.	Smooth-hounds	Demersal	78.98
Torpedo spp.	Torpedos	Demersal	62.08
Oxynotus centrina (Linnaeus, 1758)	Angular roughshark	Bathydemersal	56.21
Euselachii	Sharks	–	52.57
Galeorhinus galeus (Linnaeus, 1758)	Tope shark	Benthopelagic	38.00
Carcharhinus spp.	Sharks	Pelagic	37.11
Raja montagui (Fowler, 1910)	Spotted ray	Demersal	35.57
Galeus melastomus (Rafinesque, 1810)	Blackmouth catshark	Demersal	24.46
Deania calcea (Lowe, 1839)	Birdbeak dogfish	Bathydemersal	23.39
Mustelus mustelus (Linnaeus, 1758)	Smooth-hound	Demersal	23.18
Leucoraja circularis (Couch, 1838)	Sandy ray	Demersal	22.92
Alopias vulpinus (Bonnaterre, 1788)	Thresher shark	Pelagic	21.14
Myliobatis aquila (Linnaeus, 1758)	Common eagle ray	Benthopelagic	17.08
Scymnodon ringens (Barbosa du Bocage & de Brito Capello, 1864)	Knifetooth dogfish	Bathypelagic	12.43
Squatina spp.	Angelsharks	Demersal	8.32
Sphyrna spp.	Hammerheads sharks	Pelagic	7.17
Gymnura altavela (Linnaeus, 1758)	Spiny butterfly ray	Demersal	5.34
Mustelus asterias (Cloquet, 1819)	Starry smooth-hound	Demersal	4.99
Leucoraja naevus (Müller & Henle, 1841)	Cuckoo ray	Demersal	4.94
Squalus acanthias Linnaeus. 1758	Picked dogfish	Benthopelagic	4.33
Centroscymnus crepidater (Barbosa du Bocage & de Brito Capello, 1864)	Longnose velvet dogfish	Bathydemersal	3.26
Dipturus oxyrinchus (Linnaeus, 1758)	Longnosed skate	Bathydemersal	3.26
Dasyatis spp.	Stingrays	Demersal	2.66
Hexanchus griseus (Bonnaterre, 1788)	Bluntnose sixgill shark	Bathydemersal	2.20
Raja undulata Lacepède. 1802	Undulate ray	Demersal	1.80
Raja microocellata (Montagu, 1818)	Small-eyed ray	Demersal	1.45
Lamna nasus (Bonnaterre, 1788)	Porbeagle	Pelagic	1.38
Somniosus microcephalus (Bloch & Schneider, 1801)	Greenland shark	Benthopelagic	0.77
Rhinobatos spp.	Guitarfishs	Demersal	0.65
Sphyrna zygaena (Linnaeus, 1758)	Smooth hammerhead shark	Pelagic	0.64
Cetorhinus maximus (Gunnerus, 1765)	Basking shark	Pelagic	0.48
Echinorhinus brucus (Bonnaterre, 1788)	Bramble shark	Bathydemersal	0.32
Deania hystricosa (Garman, 1906)	Rough longnose dogfish	Bathydemersal	0.18
Dasyatis pastinaca (Linnaeus, 1758)	Common stingray	Demersal	0.15
Centroscymnus owstonii (Garman, 1906)	Roughskin dogfish	Bathydemersal	0.09
Deania profundorum (Smith & Radcliffe, 1912)	Arrowhead dogfish	Bathydemersal	0.08
Etmopterus spp.	Lanternshark	Bathydemersal	0.08
Heptranchias perlo (Bonnaterre, 1788)	Sharpnose sevengill shark	Bathydemersal	0.07
Bathytoshia centroura (Mitchill, 1815)	Roughtail stingray	Demersal	0.05
Alopias superciliosus (Lowe, 1841)	Bigeye thresher shark	Pelagic	0.02
Carcharhinus longimanus (Poey, 1861)	Oceanic whitetip shark	Pelagic	0.01
Raja miraletus (Linnaeus, 1758)	Brown ray	Demersal	0.01
Carcharhinus plumbeus (Nardo, 1827*)*	Sandbar shark	Benthopelagic	0.01
Carcharhinus falciformis (Müller & Henle, 1839)	Silky shark	Benthopelagic	0.01
Pseudocarcharias kamoharai (Matsubara, 1936)	Crocodile shark	Pelagic	< 0.01
Carcharhinus obscurus (Lesueur, 1818)	Dusky shark	Benthopelagic	< 0.01
Centroscyllium fabricii (Reinhardt, 1825)	Black dogfish	Bathydemersal	< 0.01

The majority of landings consisted of multigear fishing fleet, operating with both gill and trammel nets, as well as surface and bottom longlines (ca. 80 %). Trawl fleet landings represented 19 % of the total and those relative to seiners less than 1%. Landings in ports located in mainland Portugal accounted for 92 % of the total, with landings in Azores and Madeira consisting of 7% and 1%, respectively. Landings were concentrated in only five ports (out of 122) (i.e. Sesimbra, Peniche, Nazaré, Figueira da Foz, and Matosinhos), that globally accounted for 60 % of all landings.

Only seven species / taxa accounted for more than 75 % of all landings (i.e. *Raja* spp. / *Leucoraja* spp., *Scyliorhinus* spp., *P. glauca*, *C. coelolepis*, *C. squamosus*, *C. granulosus* and *I. oxyrinchus*). The time series analyses conducted for these species revealed different trends (Fig. 3). For *Raja* spp. / *Leucoraja* spp. a decreasing trend was noticed, with five distinct periods regarding the change points methodology (Fig. 3A). Landings of these species totalized more than 2000 tonnes / year (t / y) in the late 1980s, while in the last years the amount landed per year was lower than 1000 tonnes. *Scyliorhinus* spp. landings varied between 440 and 780 t / y, with the highest values in the late 1990s and early 2000s (Fig. 3B). For *P. glauca*, three main periods were identified: one with increasing landings values from 1986 to 1997, another between 2000 and 2012, with a high variability but with the highest values registered throughout the times series (peak values higher than 600 t / y), and finally a third period, from 2013 onwards, showing low landings

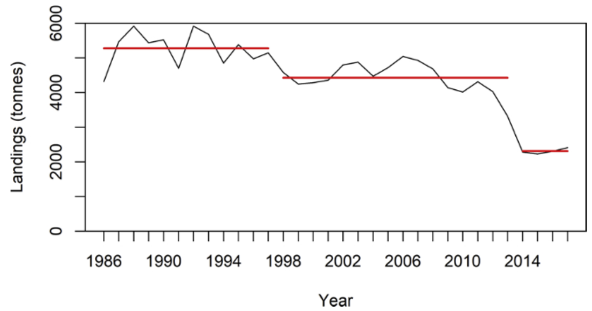

Fig. 1. Total landings of elasmobranchs in Portuguese fishing ports, between 1986 and 2017. Red lines are relative to periods that differ in terms of mean and variance that resulted of the non-parametric change points assessment.

values (overall mean similar to the one for the first period) (Fig. 3C). Trends of the three bathydemersal sharks, *C. coelolepis*, *C. squamosus* and *C. granulosus*, were partially concordant, with a marked decreasing trend over time, although the periods and intensity of landings drops were different (Figs. 3D, 3E and 3 F). *C. coelolepis* and *C. squamosus* landings were approximately 500 t / y in the beginning of the series, and in both cases there was a dramatic decrease in landings during the mid 2000s (Figs. 3D and 3E). *C. granulosus* landings varied between 700 and 1200 t / y until 1993, after which a huge decrease was noticed, with no records since 2012 (Fig. 3F). Finally, *I. oxyrinchus'* time series analysis identified three distinct periods: one with stable landings of ca. 60 t / y, between 1986–2002; a second one corresponding to high values of landings (approximately 500 t / y), from 2005 to 2013, and a third one relative to the last 4 years of the series, with values near 30 t / y (Fig. 3G).

The principal components analysis performed using data of the most captured species / taxa (landings values per year higher than 20 tonnes), displayed a clear temporal pattern, roughly segregating decades: late 1980s and early 1990s were collectively associated with higher landings of *C. granulosus*; late 1990s and 2000s were associated with higher landings of *Raja* spp. and several species of bathydemersal sharks (*C. squamosus* and *C. coelolepis*); and the last period, from 2009 until 2017, corresponded to both reduced landings of rays and bathydemersal sharks, and also to higher values of some species of pelagic sharks (Fig. 4).

4. Discussion

Elasmobranch science is a relatively new topic in Portugal, with most references being dated after 1990, particularly after 1997, when a non-profit organization focused on elasmobranch conservation (APECE) was created. Before then, the most relevant works consisted of either ICES or ICCAT technical reports, the most relevant being Melo de (1987); Silva da (1983, 1987, 1988) and Silva and Pereira (1998). At the time of submission, this study represents the most recent and comprehensive analysis of Portuguese elasmobranch fisheries and provides insight on their dynamics over a 32 years period. The numbers in this study show that between 1986 and 2017, landings of sharks, skates and rays in Portuguese ports have been decreasing. This tendency is not exclusive to Portugal. According to the United Nations Food and Agriculture Organization (FAO), more than half of the world's countries catch elasmobranchs. Of those, roughly 60 % reported reductions in landings of these animals (Davidson et al., 2016). However, the same report mentions that the eastern central and south-west Atlantic show the biggest landings increase of all FAO fishing areas. This contrasting trend is probably due to the action of the Spanish fleet, which reported increases of 20,065 tonnes between 2003 and 2013.

Despite reporting almost 60 taxa, Portuguese fisheries seem to be focused on less than 10, with *Raja* spp. / *Leucoraja* spp. dominating the top spot in elasmobranch landings over the past 32 years. From almost 20 species of skates described for Portuguese waters, less than half are landed frequently. All of them were landed as *Raja* spp. for the majority of the last three decades, something already observed in previous works (Correia and Smith, 2003; Correia et al., 2016a, 2016b). The non-parametric change points assessment (Fig. 3A) showed that during the first two thirds of the period, landings of this taxon remained stable. Stable landing trends like the ones observed seem to be the norm for this group of fishes in other parts of the world, but some considerations should be taken into account as these steady but agglomerated numbers may be hiding declines in particular species (Stevens, 2000). Like most elasmobranchs, skates are slow growing and don't deal well with elevated fishing pressures (Agnew et al., 2000). These animals reproduce by laying eggs, with yearly numbers ranging from a few dozen to more than a hundred (Clark, 1922; Holden et al., 1971). While this may sound like a good fecundity rate, it is actually very low when compared with most non cartilaginous fish. These animals tend to be found in groups, making them very susceptible to the action of directed artisanal fisheries and also larger commercial bottom trawlers (McCully et al.,

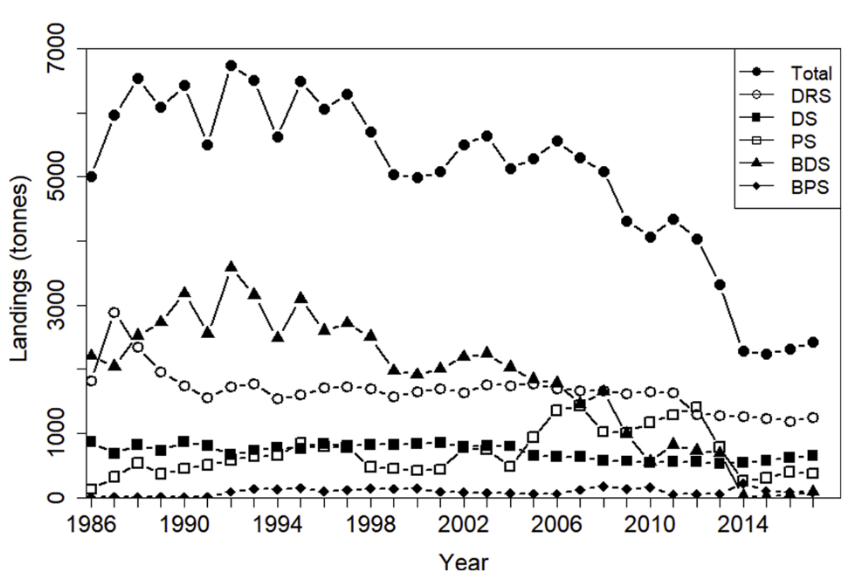

Fig. 2. Total landings of rays, skates and sharks in Portuguese fishing ports, between 1986 and 2017. Landings relative to main ecological groups are also presented (DRS – demersal rays and skates; DS – demersal sharks; PS – pelagic sharks; BDS – bathydemersal sharks; BPS – benthopelagic sharks).

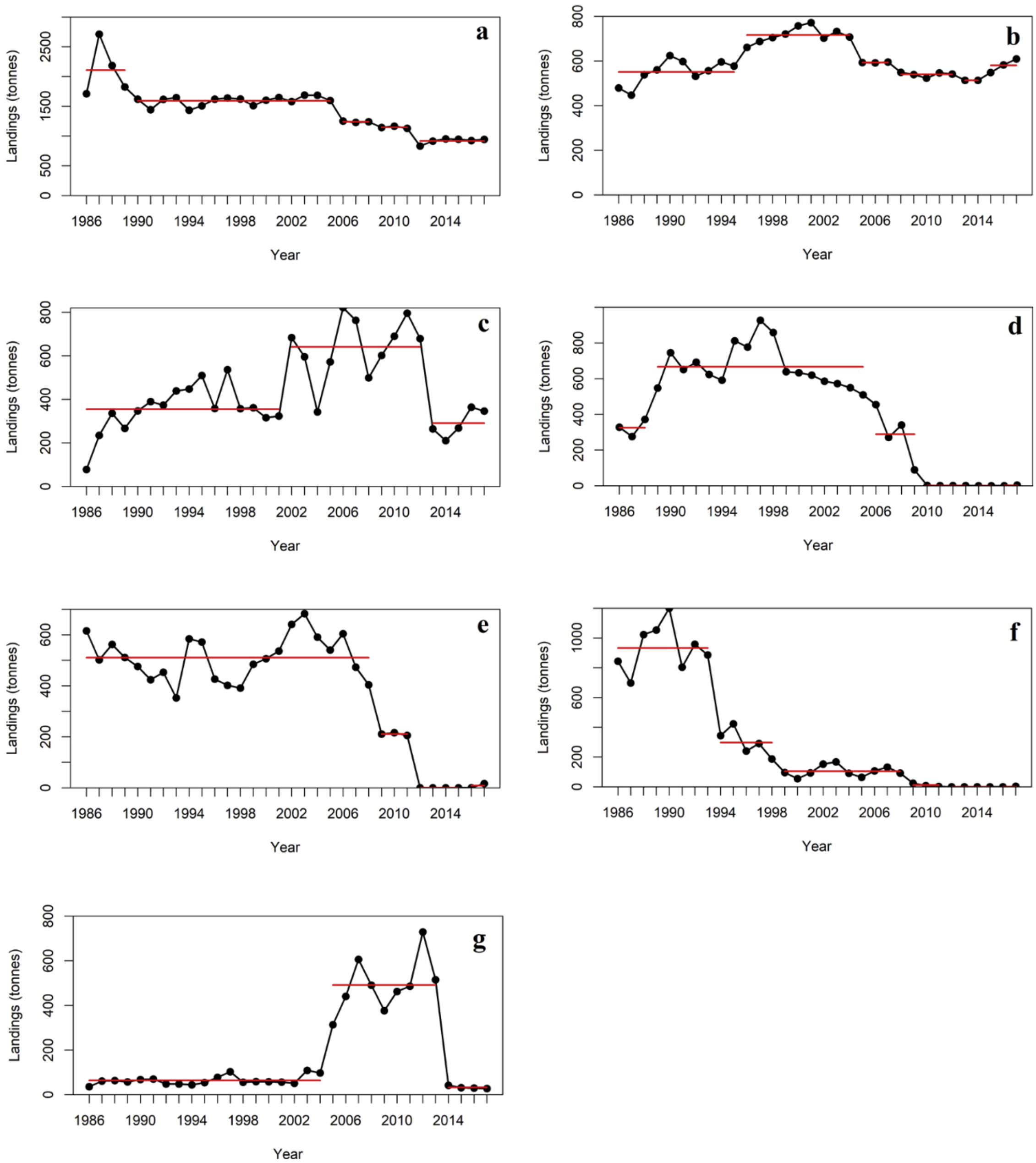

Fig. 3. Landings of the seven most landed taxa of elasmobranchs in Portuguese fishing ports, between 1986 and 2017. Red lines are relative to periods that differ in terms of mean and variance that resulted of the non-parametric change points assessment. a) rays (*Raja* spp. and *Leucoraja* spp.), b) spotted dogfishes (*Scyliorhinus*spp.), c) blue shark (*Prionace glauca*), d) Portuguese dogfish (*Centroscymnus coelolepis*), e) leafscale gulper shark (*Centrophorus squamosus*), f) gulper shark (*Centrophorus granulosus*), and g) shortfin mako (*Isurus oxyrinchus*).

2012). Trawlers, in particular, present a serious problem to the correct assessment of the numbers of fish caught, as they have high rates of dead animals discarded at sea, especially those too small to sell. Landings of this group progressively decreased over the last decade and in the end averaged half the landed weight registered in the first years of the period analysed. The decrease observed for landings of miscellaneous skates is partially explained by the adoption of increasingly lower TAC for skates in the EU and by the implementation of specific legislation by the Portuguese government (ICES, 2018).

Scyliorhinus spp. was the second most landed taxon, corresponding to 13% of all elasmobranch landings over the 32 years period. According to Sanches (1986), *S. stellaris* and *S. canicula* are the only two species of catsharks found in Portuguese waters. However, *S. canicula* is far more common than *S. stellaris*, and is believed to represent the vast majority of landings for this genus (Correia and Smith, 2003; Correia et al., 2016a, 2016b). Proper species identification should be implemented for this group, as these two species possess different ecological characteristics that may warrant different management approaches.

Taking the number one spot on the list of pelagic shark landings in Portugal and being the third most landed taxon during the 32 year period of this study, *P. glauca* landings show a rather erratic pattern, divided in three main periods (Fig. 3C). Blue sharks are currently classified as 'Near Threatened' by the IUCN Red List, and this species of shark is one of the most frequently caught all over the world. Keeping an accurate register of landed numbers of this species in Portugal is particularly important, as Portuguese waters seem to play an important role for the Atlantic blue shark population. Adult males are often found off the Portuguese coast and there is recent evidence of a nursery in the Azores (Queiroz et al., 2012; Vandeperre et al., 2014). Landings of this

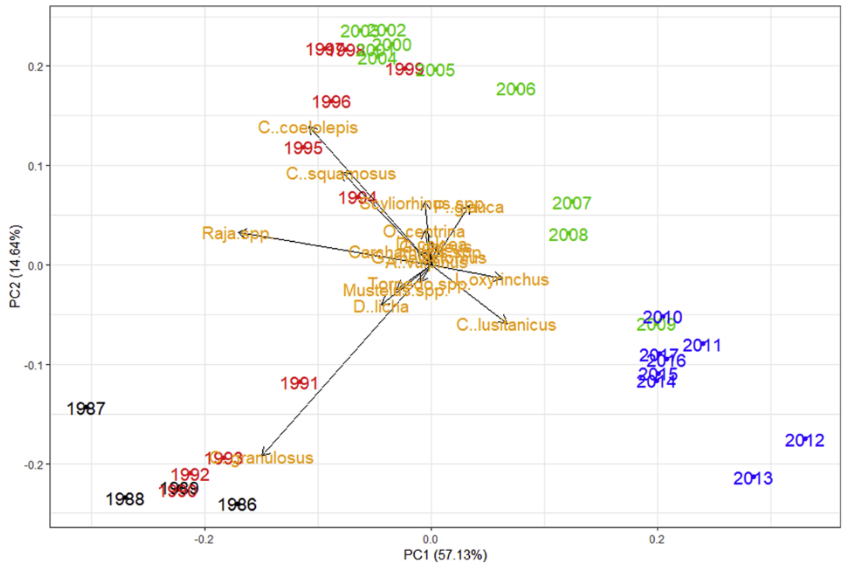

Fig. 4. Principal components analysis performed to landings data per year for the most captured species / taxa of sharks, skates and rays. Colour code: yellow - taxa; black - 1980s; red - 1990s; green - 2000s; blue - 2010s.

species showed higher numbers between 2002 and 2012 and remaining below 400 tonnes ever since. The erratic behaviour displayed by *P. glauca* landings may be partially explained by anecdotal reports suggesting that often swordfish (*Xiphias gladius*) are in fact labelled as *P. glauca* when landed, given *X. gladius'* very tight Individual Quota, i.e. the Total Allowable Catch per vessel. This was previously reported by Correia et al. (2016a, 2016b).

The fourth, fifth and sixth most landed taxon belong to the group of bathydemersal sharks, highlighting this group's historical importance to the country's elasmobranch fisheries. Both *C. coelolepis* and *C. squamosus* exhibited their higher landings until 2006, and for both the dramatic decrease in landings was in the mid 2000s (Figs. 3D and 3E). Overall, landings of most deep-sea sharks exhibited notorious declines after 2006. These declines coincided with the introduction of progressively lower quotas on deep-sea shark species, as per Council Regulation (EC) No. 2015/2006. The EU maintained its efforts to protect this group of sharks with Council Regulation (EC) No. 1359/2008, increasing the number of species on the restricted list and further lowering the quota for 2009, finally setting a 0 quota for deep-sea shark species in 2010. Landings of *C. granulosus* were higher than the ones for the previous two mentioned species until 1993, after which a huge decrease was noticed (Fig. 3F). In Portuguese waters, this species was traditionally caught as bycatch of the black scabbard fish (*Aphanopus carbo*) longline fishery, but the main contributions to such high numbers are believed to have come from Portuguese trawlers operating off the coast of northern Africa (Correia et al., 2016a, 2016b). The pronounced decline in landings of this species is attributed to the end of the fisheries agreements between the European Union and northern African countries where these animals used to be caught (Garrido, 2018).

Finally, landings of *I. oxyrinchus*, the seventh most landed taxon in the dataset, showed three distinct periods (Fig. 3G), similar to those identified for *P. glauca*. This is to be expected, as *I. oxyrinchus* usually share the same distribution as *P. glauca*, and are often caught by the same vessels, albeit in considerably lower numbers. The meat from this mostly epipelagic species is more valuable than blue sharks' (Compagno et al., 2005). Our data show mean annual landings of 59 tonnes for *I. oxyrinchus* from 1986 until 2002, showing a marked increase to mean 420 tonnes between 2003 and 2013. In 2014, landings suffered an extremely sharp decrease, with 2017 registering the lowest value recorded during the 32 years period (i.e. 27 tonnes). Decreases in landing numbers do not necessarily mean a reduction in abundance, and shark fisheries are notorious for being dubious in this aspect (Worm et al., 2013). Nevertheless, North Atlantic reported catches are believed to be severely underestimated (Byrne et al., 2017), and this species' conservation status on the IUCN Red List has been recently updated to "Endangered" (Rigby et al., 2019). The dramatic decline in landings observed in the final four years of this study should not be depreciated as, like many other pelagic sharks, numbers of these animals are most likely declining (Baum, 2003). While discussing our results, in an effort to better understand trends observed with *P. glauca* and *I. oxyrinchus* landings, data on *X. gladius* was also obtained from DGRM, since landings of these sharks are mostly a bycatch from the *X. gladius* fishery. However, there are no common patterns between landings of these two species and landings of *X. gladius* throughout these 32 years. Further efforts should be made to collect accurate capture and landing numbers for both *P. glauca* and *I. oxyrinchus,* as understanding the complicated relationship between their landings and those from *X. gladius* might be the key to ensuring proper management policies. As previously mentioned, other studies have hypothesised that landings of these two species of shark are sometimes used to mask landings of *X. gladius* if quotas are low (Correia et al., 2016a, 2016b; Roxo et al., 2017). This explanation was given to us by some commercial fishermen as well, which seemed doubtful, considering values for shark meat are much lower than cost per kilo for swordfish. We have, therefore, pursued well informed agents from the industry and were able to get a new answer, despite off the record. In Portugal, smaller commercial fishing vessels, which are not subject to quotas for swordfish, can catch this species in an amount that corresponds to a small percentage of their total landings. Allegedly, these boats may sometimes declare "ghost" landings of *P. glauca* and / or *I. oxyrinchus* (which have no limits). This way, these boats can possibly increase significantly the amount of swordfish they can legally land, but this remains to be officially confirmed.

Throughout these 32 years, total landings of elasmobranchs in Portugal suffered changes not only in volume, but also in composition. Historically, deep-sea shark species were the main driver behind Portugal's shark fisheries (Correia and Smith, 2003; Correia et al., 2016a, 2016b), and that is clearly visible here. The principal components analysis presented in this work evidenced three distinct periods where the main taxon varied (Fig. 4). Bathydemersal sharks seemed to exert the most influence in overall landings, when compared with the remaining groups. The last period, from 2009 until 2017, is the most noteworthy and was characterized by higher values of some species of pelagic sharks, but mainly by a reduction in landings of, not just skates and rays, but also bathydemersal sharks. There is an exception to the decrease observed on the latter group, which is lowfin gulper shark (*Centrophorus lusitanicus*). *C. lusitanicus* was not included in the original list of restricted deep-sea shark species, and the commercial fishing industry was quick to adapt. In 2007, when the first restrictions were implemented, this species saw an abrupt increase in landings that kept rising during the 7 years following the implementation of deep-sea shark restrictions. Field observations confirmed that, during that time, *C. lusitanicus* became a proxy to all other deep-sea shark species, masking landings of traditionally landed species (Correia et al., 2016a, 2016b). This finally ended in 2014 when Council Regulation (EU) No 1367/2014 added the whole *Centrophorus* genus to the list of deep-sea sharks with a '0' quota policy.

Relying solely on landings data can be problematic and has generated much debate throughout the years, which does not mean this information is not important (Pauly et al., 2013). Reported landings can fluctuate due to multiple factors and researchers should take them into consideration when trying to infer about fish populations. Despite the alleged episodes of over reporting we came across while conducting this study, the vast majority of fisheries seems to suffer from under-reporting, with authors describing an almost 20 fold difference in some cases (Newton et al., 2007). As if this was not enough, these records are often not very specific, leading to several species being landed in generic agglomerated groups. This was particularly visible for skates and rays in our study, a group known for its vulnerability to exploitation (Dulvy et al., 2000). These agglomerations with low taxonomic resolution are an impediment to accurate assessments of each species landing trends and may give a false sense of stability to populations of these animals. A recent study by Cashion et al. (2019) has drawn attention to the negative impacts of this practice in areas under serious need of proper management. Nevertheless, although low taxonomic resolution of reported landings is visible in some taxa within our data, identification practices have been improving and our most recent records of landings already exhibit that. Improvement in identification practices are welcomed and although they usually do not affect total numbers of landed elasmobranchs they will inevitably lead to the decrease of some landings and the sudden appearance and increase of others. If taken at face value, these changes can lead to wrong conclusions (Jensen et al., 2012).

The implementation of landing restrictions in national waters and the end of fishing agreements between countries can also drastically change regional elasmobranch landings, and the impacts such decisions had on deep-sea shark landings in Portugal are a good example. Changes in fleet structure and socioeconomic factors can also play an important role in explaining the variability of reported catches (Bishop, 2006; Garrido, 2018). Previous authors have alerted to the oversized dimension of the Portuguese fishing fleet when compared to the available resources (Correia et al., 2016a, 2016b). Informal contacts made with fishing vessel owners confirmed the notion that fish have become harder to find and that boats need to travel longer and further than before, increasing operational costs. At the same time, fishermen complained that fish selling prices did not follow the rise in fuel cost. In recent years, some authors have stressed the lack of economic insight in fisheries dependent analysis, and the importance of considering the effects of inflation on the evolution of fish prices (Goulart et al., 2018).

The future of elasmobranch conservation is uncertain. If we are to make improvements on measures currently in place, an interdisciplinary approach is advised (Horodysky et al., 2016). Efforts must be made to create strategies that deal with the complex and data-poor nature of most elasmobranch fisheries (Niella et al., 2017; Smith et al., 2009). Despite all the inherent difficulties, there is evidence that sharks can be fished sustainably (Simpfendorfer and Dulvy, 2017; Walker, 1998). For decades the set of biological traits possessed by sharks, skates and rays have made it almost impossible to properly assess and manage their fisheries, but these restrains are today less severe than they ever were. On one hand, technological advancements have made it possible to track fish and boats in places traditionally out of reach (Letessier et al., 2017). On the other hand, the increasing library of scientific data has made it impossible for decision makers to hide behind ignorance. There are currently no regulations (e.g. minimum size) for some of the most landed species of sharks in Portugal, such as *P. glauca* and *I. oxyrinchus* sharks. The latter species in particular has been raising serious concerns all over the world amongst the scientific community (Sims et al., 2018). Pre-emptive measures and careful monitoring should be applied, as landing bans - like the ones implemented for the deep-sea species analysed in this work - can be counterproductive under certain circumstances (Tolotti et al., 2015). In fact, the lack of surveillance and the fact many species are caught as bycatch mean that banning landings will probably not stop catches and mortality at sea. Investment must be made to increase the range and coverage of observer programs. Given the fact that most concerning situations occur outside each country's national waters, the creation of a cooperative entity, similar to the North Atlantic Treaty Organization (NATO) but focused on the enforcement of marine fisheries policies, could be the answer.

No-catch / seasonal closure periods and Marine Protective Areas (MPAs) have proven to be effective measures in the protection of overfished species (Rodríguez-Cabello et al., 2008; Weigel et al., 2014; White et al., 2015). Commercial fishermen themselves told us they believe these to be the only effective solutions to the problems faced by these animals, but monetary compensations, in the form of subsidies, should be given to allow for the survival of the fleet during fishing ban periods. This is something already done in Portugal in other fisheries, the sardine being the most notorious example.

Finally, there is a need to change the general public – including fishermen's - perception of elasmobranchs. Sharks rarely elicit empathy from humans, instead awakening primal instincts that are usually reinforced by sensationalist media coverage (Nosal et al., 2016). Recent studies have shown that this general lack of interest is present even in communities that can closely see the decline of these animals (Martins et al., 2018). Changing everyone's perception on these animals, may prove essential to their conservation, as public opinion can be a powerful tool when pressuring decision makers (McKinley and Fletcher, 2010).

CRediT authorship contribution statement

Luís M.F. Alves: Conceptualization, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Funding acquisition. **João P.S. Correia:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Marco F.L. Lemos:** Investigation, Writing - review & editing, Funding acquisition. **Sara C. Novais:** Writing - review & editing, Funding acquisition. **Henrique Cabral:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

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

Acknowledgements

This study was supported by Fundação para a Ciência e a Tecnologia (FCT) and FEDER through the project BLUESHARKER (PTDC/CTA-AMB/29136/2017) and the Strategic Project UID/MAR/04292/2019. The project was also funded by the Integrated Programme of SR&TD "SmartBioR" (Centro-01-0145-FEDER-000018) cofunded by Centro 2020 program, Portugal2020, European Union, through the European Regional Development Fund. Luís M.F. Alves also wishes to acknowledge the financial support given by FCT (SFRH/BD/122082/2016). This study was also supported by Oceanário de Lisboa and Oceano Azul Foundation through the project Shark Attract, winner of the first edition of the Ocean's Conservation Fund.

References

Agnew, D.J., Nolan, C.P., Beddington, J.R., Baranowski, R., 2000. Approaches to the assessment and management of multispecies skate and ray fisheries using the Falkland Islands fishery as an example. Can. J. Fish. Aquat. Sci. 57, 429–440. https://doi.org/10.1139/f99-264.

Alves, A.L., 2015. A Economia do Mar em Portugal: a estratégia e a realidade, num retrato doméstico e comunitário. E.E.F. Mercados Financ. 35–45.

Barker, M.J., Schluessel, V., 2005. Managing global shark fisheries: suggestions for prioritizing management strategies. Aquat. Conserv. Mar. Freshw. Ecosyst. 15, 325–347. https://doi.org/10.1002/aqc.660.

Barreto, R., Ferretti, F., Flemming, J.M., Amorim, A., Andrade, H., Worm, B., Lessa, R., 2016. Trends in the exploitation of South Atlantic shark populations. Conserv. Biol. 30, 792–804. https://doi.org/10.1111/cobi.12663.

Baum, J.K., 2003. Collapse and conservation of shark populations in the Northwest Atlantic. Science 299, 389–392. https://doi.org/10.1126/science.1079777.

Bishop, J., 2006. Standardizing fishery-dependent catch and effort data in complex fisheries with technology change. Rev. Fish Biol. Fish. 16, 21–38. https://doi.org/10.1007/s11160-006-0004-9.

Bornatowski, H., Navia, A.F., Braga, R.R., Abilhoa, V., Corrêa, M.F.M., 2014. Ecological importance of sharks and rays in a structural foodweb analysis in southern Brazil. ICES J. Mar. Sci. 71, 1586–1592. https://doi.org/10.1093/icesjms/fsu025.

Burgess, G.H., Beerkircher, L.R., Cailliet, G.M., Carlson, J.K., Cortés, E., Goldman, K.J., Grubbs, R.D., Musick, J.A., Musyl, M.K., Simpfendorfer, C.A., 2005. Is the collapse of shark populations in the Northwest Atlantic Ocean and Gulf of Mexico real? Fisheries 30, 19–26. https://doi.org/10.1577/1548-8446(2005)30[19:ITCOSP]2.0.CO;2.

Byrne, M.E., Cortés, E., Vaudo, J.J., Harvey, G.C.M., Sampson, M., Wetherbee, B.M., Shivji, M., 2017. Satellite telemetry reveals higher fishing mortality rates than previously estimated, suggesting overfishing of an apex marine predator. Proc. R. Soc. B Biol. Sci. 284https://doi.org/10.1098/rspb.2017.0658. 20170658.

Cashion, M.S., Bailly, N., Pauly, D., 2019. Official catch data underrepresent shark and ray taxa caught in Mediterranean and Black Sea fisheries. Mar. Policy 105, 1–9. https://doi.org/10.1016/j.marpol.2019.02.041.

Clark, R.S., 1922. Rays and skates (raiæ) No. 1.—egg-capsules and young. J. Mar. Biolog. Assoc. U.K. 12, 578–643. https://doi.org/10.1017/S002531540000967X.

Compagno, L.J.V., Dando, M., Fowler, S., 2005. Sharks of the World, 2005th paper edition. Princeton University Press.

Correia, J.P., Smith, C.M., 2003. Elasmobranch landings for the Portuguese commercial fishery from 1986–2001. Mar. Fish. Rev. 65, 32–40.

Correia, J.P.S., Morgado, F., Erzini, K., Soares, A.M.V.M., 2016a. Elasmobranch landings for the Portuguese commercial fishery from 1986 to 2009. Arquipel. Life Mar. Sci. 81–109.

Correia, J.P.S., Morgado, F., Erzini, K., Soares, A.M.V.M., 2016b. Elasmobranch landings for the Portuguese commercial fishery from 1986 to 2009. Arquipel. Life Mar. Sci. 81–109.

Council Regulation (EC) No 2015/2006 of 19 December 2006 fixing for 2007 and 2008 the fishing opportunities for Community fishing vessels for certain deep-sea fish stocks. Off. J. Eur. Union 28–37.

Council Regulation (EC) No 1359/2008 of 28 November 2008 fixing for 2009 and 2010 the fishing opportunities for Community fishing vessels for certain deep-sea fish stocks. Off. J. Eur. Union.

Council Regulation (EU) No 1367/2014 of 15 December 2014 fixing for 2015 and 2016 the fishing opportunities for Union fishing vessels for certain deep-sea fish stocks. Off. J. Eur. Union. https://doi.org/10.4324/9780429494512-9.

Davidson, L.N.K., Krawchuk, Ma., Dulvy, N.K., 2016. Why have global shark and ray landings declined: improved management or overfishing? Fish Fish. 17, 438–458. https://doi.org/10.1111/faf.12119.

Dent, F., Clarke, S., 2015. State of the global market for shark products. FAO Fish. Aquac. Tech. Pap. No. 590. pp. 187.

Dolman, S.J., Green, M., Gregerson, S., Weir, C.R., 2016. Fulfilling EU laws to ensure Marine mammal protection during Marine renewable construction operations in Scotland. In: Popper, A.N., Hawkins, A. (Eds.), The Effects of Noise on Aquatic Life II, Advances in Experimental Medicine and Biology. Springer, New York, New York, NY, pp. 223–230. https://doi.org/10.1007/978-1-4939-2981-8_26.

Dulvy, N.K., Metcalfe, J.D., Glanville, J., Pawson, M.G., Reynolds, J.D., 2000. Fishery stability, local extinctions, and shifts in community structure in skates. Conserv. Biol. 14, 283–293. https://doi.org/10.1046/j.1523-1739.2000.98540.x.

Dulvy, N.K., Fowler, S.L., Musick, J.A., Cavanagh, R.D., Kyne, P.M., Harrison, L.R., Carlson, J.K., Davidson, L.N.K., Fordham, S.V., Francis, M.P., Pollock, C.M., Simpfendorfer, Ca., Burgess, G.H., Carpenter, K.E., Compagno, L.J.V., Ebert, Da., Gibson, C., Heupel, M.R., Livingstone, S.R., Sanciangco, J.C., Stevens, J.D., Valenti, S., White, W.T., 2014. Extinction risk and conservation of the world's sharks and rays. Elife 2014, 1–34. https://doi.org/10.7554/eLife.00590.001.

Estatística de, I.N., 2019. Estatísticas da Pesca 2018 Editor, 2019th edition. Lisboa.

Regulation (EU) No 605/2013 of the European Parliament and of the Council of 12 June 2013 Amending Council Regulation (EC) No 1185/2003 on the Removal of Fins of Sharks on Board Vessels.

Evans, S., 2015. Shark week and the rise of infotainment in science documentaries. Commun. Res. Rep. 32, 265–271. https://doi.org/10.1080/08824096.2015.1052903.

Ferretti, F., Worm, B., Britten, G.L., Heithaus, M.R., Lotze, H.K., 2010. Patterns and ecosystem consequences of shark declines in the ocean. Ecol. Lett. 13. https://doi.org/10.1111/j.1461-0248.2010.01489.x.

Friedrich, La., Jefferson, R., Glegg, G., 2014. Public perceptions of sharks: gathering support for shark conservation. Mar. Policy 47, 1–7. https://doi.org/10.1016/j.marpol.2014.02.003.

Froese, R., Pauly, D. (Eds.), 2019. FishBase. World Wide Web Electronic Publication (12/2019). www.fishbase.org.

Gallagher, A.J., Hammerschlag, N., Danylchuk, A.J., Cooke, S.J., 2017. Shark recreational fisheries: status, challenges, and research needs. Ambio 46, 385–398. https://doi.org/10.1007/s13280-016-0856-8.

Gamito, R., Pita, C., Teixeira, C., Costa, M.J., Cabral, H.N., 2016. Trends in landings and vulnerability to climate change in different fleet components in the Portuguese coast. Fish. Res. 181, 93–101. https://doi.org/10.1016/j.fishres.2016.04.008.

Garrido, Á., 2018. As pescas em portugal, Ensaios da Fundação. Fundação Francisco Manuel dos Santos.

Goulart, P., Veiga, F.J., Grilo, C., 2018. The evolution of fisheries in Portugal: a methodological reappraisal with insights from economics. Fish. Res. 199, 76–80. https://doi.org/10.1016/j.fishres.2017.11.022.

Holden, M.J., Rout, D.W., Humphreys, C.N., 1971. The rate of egg laying by three species of ray. ICES J. Mar. Sci. 33, 335–339. https://doi.org/10.1093/icesjms/33.3.335.

Horodysky, A.Z., Cooke, S.J., Graves, J.E., Brill, R.W., 2016. Fisheries conservation on the high seas: linking conservation physiology and fisheries ecology for the management of large pelagic fishes. Conserv. Physiol. 4https://doi.org/10.1093/conphys/cov059. cov059.

ICES, 2018. Report of the Working Group on Elasmobranch Fishes (WGEF), 19–28 June 2018, Lisbon, Portugal.

Jacques, P.J., 2010. The social oceanography of top oceanic predators and the decline of sharks: a call for a new field. Prog. Oceanogr. 86, 192–203. https://doi.org/10.1016/j.pocean.2010.04.001.

Jensen, O.P., Branch, Ta., Hilborn, R., 2012. Marine fisheries as ecological experiments. Theor. Ecol. 5, 3–22. https://doi.org/10.1007/s12080-011-0146-9.

Killick, R., Eckley, I.A., 2014. Changepoint : an R package for changepoint analysis. J. Stat. Softw. 58, 1–19. https://doi.org/10.18637/jss.v058.i03.

Killick, R., Fearnhead, P., Eckley, I.A., 2012. Optimal detection of changepoints with a linear computational cost. J. Am. Stat. Assoc. 107, 1590–1598. https://doi.org/10.1080/01621459.2012.737745.

Letessier, T.B., Bouchet, P.J., Meeuwig, J.J., 2017. Sampling mobile oceanic fishes and sharks: implications for fisheries and conservation planning. Biol. Rev. 92, 627–646. https://doi.org/10.1111/brv.12246.

Martins, A.P.B., Feitosa, L.M., Lessa, R.P., Almeida, Z.S., Heupel, M., Silva, W.M., Tchaicka, L., Nunes, J.L.S., 2018. Analysis of the supply chain and conservation status of sharks (*Elasmobranchii*: superorder Selachimorpha) based on fisher knowledge. PLoS One 13, e0193969. https://doi.org/10.1371/journal.pone.0193969.

McCully, S.R., Scott, F., Ellis, J.R., 2012. Lengths at maturity and conversion factors for skates (*Rajidae*) around the British Isles, with an analysis of data in the literature. ICES J. Mar. Sci. 69, 1812–1822. https://doi.org/10.1093/icesjms/fss150.

McKinley, E., Fletcher, S., 2010. Individual responsibility for the oceans? An evaluation of marine citizenship by UK marine practitioners. Ocean Coast. Manag. 53, 379–384. https://doi.org/10.1016/j.ocecoaman.2010.04.012.

Melo de, A.Á., 1987. Tubarões de profundidade. Algumas notas acerca da pescaria dos tubarões de profundidade. Inst. Nacional de Invest. das Pescas, Lisboa, pp. 37.

Musick, J.A., Musick, S., 2011. Sharks. FAO fish. Aquac. Rev. Stud. 13.

Myers, Ra., Worm, B., 2005. Extinction, survival or recovery of large predatory fishes. Philos. Trans. R. Soc. B Biol. Sci. 360, 13–20. https://doi.org/10.1098/rstb.2004.1573.

Myers, R.A., Baum, J.K., Shepherd, T.D., Powers, S.P., Peterson, C.H., 2007. Cascading effects of the loss of apex predatory sharks from a Coastal Ocean. Science 315, 1846–1850. https://doi.org/10.1126/science.1138657.

Newton, K., Côté, I.M., Pilling, G.M., Jennings, S., Dulvy, N.K., 2007. Current and future sustainability of island coral reef fisheries. Curr. Biol. 17, 655–658. https://doi.org/10.1016/j.cub.2007.02.054.

Niella, Y.V., Hazin, F.H.V., Afonso, A.S., 2017. Detecting multispecific patterns in the catch composition of a fisheries-independent longline survey. Mar. Coast. Fish. 9, 388–395. https://doi.org/10.1080/19425120.2017.1347115.

Nosal, A.P., Keenan, Ea., Hastings, Pa., Gneezy, A., 2016. The effect of background music in shark documentaries on viewers' perceptions of sharks. PLoS One 11, e0159279. https://doi.org/10.1371/journal.pone.0159279.

Oliver, S., Braccini, M., Newman, S.J., Harvey, E.S., 2015. Global patterns in the bycatch of sharks and rays. Mar. Policy 54, 86–97. https://doi.org/10.1016/j.marpol.2014.12.017.

Pauly, D., Hilborn, R., Branch, T.A., 2013. Fisheries: does catch reflect abundance? Nature 494, 303.

Pauly, D., Zeller, D., 2016. Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. Nat. Commun. 7, 10244. https://doi.org/10.1038/ncomms10244.

Queiroz, N., Humphries, N.E., Noble, L.R., Santos, A.M., Sims, D.W., 2012. Spatial dynamics and expanded vertical niche of blue sharks in oceanographic fronts reveal habitat targets for conservation. PLoS One 7, e32374. https://doi.org/10.1371/journal.pone.0032374.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Jabado, R.W., Liu, K.M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B., Winker, H., 2019. *Isurus Oxyrinchus*, Shortfin Mako Assessment. IUCN Red List Threat. Species™ 8235https://doi.org/10.2305/IUCN.UK.2019-1.RLTS.T39341A2903170.en.

Rodríguez-Cabello, C., Sánchez, F., Serrano, A., Olaso, I., 2008. Effects of closed trawl fishery areas on some elasmobranch species in the Cantabrian Sea. J. Mar. Syst. 72, 418–428. https://doi.org/10.1016/j.jmarsys.2007.09.010.

Roff, G., Brown, C.J., Priest, M.A., Mumby, P.J., 2018. Decline of coastal apex shark populations over the past half century. Commun. Biol. 1, 223. https://doi.org/10.1038/s42003-018-0233-1.

Roxo, A., Mendes, S., Correia, J., 2017. Portuguese commercial fisheries of swordfish, *Xiphias gladius*. Rev. Fish. Sci. Aquac. 25, 150–157. https://doi.org/10.1080/23308249.2016.1251879.

Sanches, J.G., 1986. Nomenclatura e diagnose dos principais peixes marinhos de Portugal: Ciclóstomos, Seláceos e Holocéfalos, 9th edition. Publicações avulsas do I.N.I.P. Instituto Nacional de Investigação das Pescas, Lisbon.

da Silva, H.M., 1987. An Assessment of the Azorean Stock of Kitefin Shark, *Dalatias Licha* (Bonn, 1788) 1987. I.C.E.S. C.M., pp. 10 (G:66).

Silva, A.A., Pereira, J.G., 1998. Catch Rates for Pelagic Sharks Taken by the Portuguese Swordfish Fishery in the Waters Around the Azores, 1993–1997. ICCAT Working Document. SCRS/98/168, pp. 12.

Silva da, H.M., 1983. Preliminary Studies of the Exploited Stock of Kitefin Shark *Scymnorhinus Licha* (Bonnaterre, 1788) in the Azores 1983. I.C.E.S. C.M., pp. 13 (G:18).

Silva da, H.M., 1988. Growth and Reproduction of Kitefin Shark *Dalatias Licha* (Bonn, 1788) in Azorean Waters 1988. I.C.E.S. C.M., pp. 15 (G:21).

Simpfendorfer, C.A., Dulvy, N.K., 2017. Supplemental Information: bright spots of sustainable shark fishing. Curr. Biol. 27.

Sims, D.W., Mucientes, G., Queiroz, N., 2018. Shortfin mako sharks threatened by inaction. Science 359https://doi.org/10.1126/science.aat0315. 1342.1-1342.

Smith, D., Punt, A., Dowling, N., Smith, A., Tuck, G., Knuckey, I., 2009. Reconciling approaches to the assessment and management of data-poor species and fisheries with Australia's harvest strategy policy. Mar. Coast. Fish. 1, 244–254. https://doi.org/10.1577/C08-041.1.

Stevens, J., 2000. The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. ICES J. Mar. Sci. 57, 476–494. https://doi.org/10.1006/jmsc.2000.0724.

Tolotti, M.T., Filmalter, J.D., Bach, P., Travassos, P., Seret, B., Dagorn, L., 2015. Banning is not enough: the complexities of oceanic shark management by tuna regional fisheries management organizations. Glob. Ecol. Conserv. 4, 1–7. https://doi.org/10.1016/j.gecco.2015.05.003.

Vandeperre, F., Aires-da-Silva, A., Fontes, J., Santos, M., Serrão Santos, R., Afonso, P., 2014. Movements of blue sharks (*Prionace glauca*) across their life history. PLoS One 9, e103538. https://doi.org/10.1371/journal.pone.0103538.

Vannuccini, S., 1999. Shark Utilization, Marketing and Trade.

Walker, T.I., 1998. A question revisited with a review of shark fisheries. Mar. Freshw. Res. 49, 553–572.

Walsh, W.A., Bigelow, K.A., Sender, K.L., 2009. Decreases in shark catches and mortality in the Hawaii-based longline fishery as documented by fishery observers. Mar. Coast. Fish. 1, 270–282. https://doi.org/10.1577/C09-003.1.

Weigel, J.-Y., Mannle, K.O., Bennett, N.J., Carter, E., Westlund, L., Burgener, V., Hoffman, Z., Simão Da Silva, A., Kane, E.A., Sanders, J., Piante, C., Wagiman, S., Hellman, A., 2014. Marine protected areas and fisheries: bridging the divide. Aquat. Conserv. Mar. Freshw. Ecosyst. 24, 199–215. https://doi.org/10.1002/aqc.2514.

Weigmann, S., 2016. Annotated checklist of the living sharks, batoids and chimaeras (*Chondrichthyes*) of the world, with a focus on biogeographical diversity. J. Fish Biol. 88, 837–1037. https://doi.org/10.1111/jfb.12874.

White, E.R., Myers, M.C., Flemming, J.M., Baum, J.K., 2015. Shifting elasmobranch community assemblage at Cocos Island-an isolated marine protected area. Conserv. Biol. 29, 1186–1197. https://doi.org/10.1111/cobi.12478.

Worm, B., Davis, B., Kettemer, L., Ward-Paige, Ca., Chapman, D., Heithaus, M.R., Kessel, S.T., Gruber, S.H., 2013. Global catches, exploitation rates, and rebuilding options for sharks. Mar. Policy 40, 194–204. https://doi.org/10.1016/j.marpol.2012.12.034.