Arquipelago - Life and Marine Sciences ISSN: 0873-4704

Elasmobranch landings in the Portuguese commercial fishery from 1986 to 2009

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Correia, J., F. Morgado, K. Erzini & A.M.V.M. Soares 2016. Elasmobranch landings in the Portuguese commercial fishery from 1986 to 2009. *Arquipelago*. Life and Marine Sciences 33: 81-109.

Portuguese commercial Elasmobranch landings were analysed for the period 1986 - 2009 and revealed that some species may be in danger of overfishing. Landings totalled 122,515 mt, with an average of 5,105 mt landed yearly, with captured sharks, skates and rays representing 8 orders, 14 families and 44 species. Annual landings for the fishery generally decreased over time, with a corresponding increase in price per kilogram. The most landed group, skates (*Raja* sp.), accounted for 33% of the landings, or 40,344 mt. They were followed by lesser spotted catsharks (*Scyliorhinus* sp.), Portuguese dogfish (*Centroscymnus coelolepis*), leafscale gulper sharks (*Centrophorus squamosus*), blue sharks (*Prionace glauca*) and gulper sharks (*Centrophorus granulosus*) (accounting for 12%, 11%, 10%, 9% and 8% of the landings, respectively). In the absence of CPUE data, comparative trends of landings and price over time were used as an indicator of the *status* of specific Elasmobranch species. *Centrophorus granulosus*, smoothounds (*Mustelus* sp.), torpedo rays (*Torpedo* sp.), requiem sharks (*Carcharhinus* sp.) and angel sharks (*Squatina* sp.) displayed indications of possible over-exploitation, with significantly decreasing landings and increasing prices over time, and merit the focus of future research. The pattern shown by fishing effort over time (i.e. number of fishing vessels over time) displayed a marked decrease, although this was substantially less than the decrease shown by landings of the species mentioned earlier. It is therefore unlikely that such a decrease in landings is justified solely by a decrease in number of fishing vessels. Similarly, the increase in price shown for all species was largely superior to the increase in inflation, which would suggest that the increase in inflation alone would not account for the increase in price. All results and data corroborate the notion that some species are, in fact, over-exploited and in need of immediate management and conservation measurements. These findings were substantiated by min/max auto-correlation factor analysis (MAFA), which shows that the most important trend is that of a decrease in landings of those species where overfishing in indicated.

Key words: European Union Common Fisheries Policy, misreporting, overfishing, finning ban, MAFA multivariate analysis.

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INTRODUCTION

A large number of authors have published results demonstrating that shark populations are facing serious threats all over the world. This drove the United Nations' Food and Agricultural Organization (FAO) and the International Council for the Exploration of the Sea (ICES) to call upon the scientific community to compile all available data on Elasmobranch landings and to put together local Shark Plans of Action (SPOAs). These compilations include classic reports such as Bonfil (1994), Shotton (1999), FAO Marine Resources Service (2000), Hareide et al. (2007), and Oceana (2007), among others. The European Shark Plan of Action had its first kick-off meeting in Brussels in March 2008 and was completed in 2009, although not all of its key aspects are in place at the time of publication.

With regards to finning, the European Union approved legislation to ban finning in European Waters (Reg. No. 1185 / 2003), with a proposal for amendment in 2011 (2011/0634), whereby fins were to be landed still attached to their respective body. This proposal was accepted in 2013. While this amendment was not approved, the regulation in place before it allowed vessels to land fins to a maximum fraction of 5% of the weight of the total catch. Many individuals from non-governmental organizations, as well as scientific authors, defended that the European legislation in place was too permissive. For example, authors including Baremore et al. (2005) and Cortés & Neer (2006) reported "5%" to be larger than the actual fin to total body weight ratio on a wide range of pelagic shark species. These findings mean that, while still under the law, fishermen could sell fins from shark carcasses that were not landed, specifically in those cases where the species involved have a fin to total body weight ratio that it's less than 5%. Other authors, such as Mejuto & García-Cortés (2004), Santos & Garcia (2005) and Santos et al. (2007) have measured fin to total body weight ratios above 5%. If that were the general case, then European Legislation would in fact be ensuring that no fins were landed without their respective carcass. These latter authors also defend that European fishermen were not targeting sharks for fins. However, one could retain only the fins of one shark and only the carcass of another and then claim that the two belonged together. This led the conservation community to strongly push for fins to be attached to each corresponding body upon landing.

Commercial fishermen, in turn, claim that landing sharks with fins attached promotes unsafe work conditions at sea, since frozen fins can easily severe a workman's limb should a carcass accidentally fall from storage. Despite the 2015 approval of "fins attached" legislation in the E.U., this discussion is still ongoing.

Shark Fishing in Portugal

Sharks and rays are abundant in Portuguese waters, both continental and insular (Azores and Madeira). Sanches (1986, *in* Correia & Smith 2004) recorded 46 shark and 31 ray species in local waters. Shark, skate and ray fisheries in Portugal accounted for approximately 2,5% of the global commercial fisheries landings (60.374 vs. 2.438.700 mt) between 1986 and 1996 (DGPA 1998). This proportion remained fairly constant in more recent years (e. g. 2,3% in 2001, 2,6% in 2002 and 2003 – DGPA 2003). See www.dgrm.mam.gov.pt for more information. Data on landings are compiled by a Governmental Institution (*Docapesca*) with delegations in all major fishing ports. Once the fishing vessels arrive to shore, animals caught are landed on the fishing docks in crates separated by species and size. The following parameters are automatically recorded when each crate is weighed and then sold in auction: date, time and location, name of fishing vessel, fishing license used, species, weight, size ("small", "medium" and "large"), freshness (on a scale of "1" to "4"), and price of sale. These values are automatically sent to a central database, compiled by the Docapesca headquarters in Lisbon, and subsequently sent to the local Fisheries Board (DGRM - *Direcção Geral de Recursos Naturais, Segurança e Serviços Marítimos*). This record keeping system was implemented in 1986 and all subsequent years therefore follow the same principle, the database covering all periods equally. The data are available for public use from the DGRM and the dataset for elasmobranch landings from 1986 to 2009 were used in the present study. Correia & Smith (2004) used the same information with the equivalent dataset from 1986 until 2001. Correia (2009) used the 1986 – 2006 dataset. The addition of the three most recent years (2007 – 2009) allowed for some unexpected conclusions, since 2007 was the year that a Total Allowable Catch (TAC) was established for 17 deep-sea shark species in Portugal.

Bioeconomics and misreporting in Portugal

Fishing is going through challenging times in Portugal, as in many other countries, particularly in the E.U. Nevertheless, informal observations show that the swordfish and black-scabbard fisheries seem to generate enough profit to sustain multiple vessels and crews, despite growing concern that these stocks are facing demise in the not too distant future. While preparing this report, numerous contacts with fishermen were conducted in an informal manner, which included participating in approximately one dozen fishing trips. Taking the swordfish industry in Portugal as an example, E.U. legislation assigns a quota of 6 mt per year per vessel. Swordfish is sold at approximately 6 - 10 € / kg, which means vessels are legally allowed to fish the equivalent of 36,000 € in swordfish per year. Maintenance of a typical surface longliner costs approximately 1,500 € per day. The combination of these two parameters allows the inference that surface longliners focusing exclusively on swordfish are allowed to fish 24 days per year (i.e. 36,000 € / 1,500 € / day). To find alternative income for the remaining time of the year, the vessels might fish other species, such as sharks (typically blue, shortfin mako, hammerheads, threshers and requiem sharks) or vessels overfish their swordfish quota, then being landed as "sharks". There is widespread unofficial knowledge that misreporting occurs throughout the fishing industry. Even FAO officials have unofficially admitted, in multiple conferences, that misreporting is generally assumed to be four fold, with this factor actually being incorporated in compilations of fisheries data from many countries. The contacts made for this study, however, revealed misreporting factors as high as 20 fold. Swordfish surface longliners commonly catch 7 to 8 mt per fishing trip. This number can go as high as 12 mt per trip during January, when stocks show higher abundance. Contracts are negotiated at sea and carcasses are landed on fishing docks away from the eyes of the authorities, frequently at night, and not all going through the official scales. Occasionally vessels are caught breaking the rules. One of the most common cases occurs when surface longliners are trying to land more than the limit of 10% of the total catch containing small swordfish (< 8 kg). When this occurs, vessels quickly communicate among each other and warn colleagues at sea that a particular fishing dock is under close supervision. Vessels at sea will then be heading for other fishing ports where vigilance is likely to be more flexible.

These facts suggest that legislating and establishing more stringent quotas may have potentially very little effect and perhaps the issue lays not so much in a "lack of fish" but, more in "excess of boats". This notion is rapidly becoming the focus of current conservation and awareness campaigns by non-governmental agencies, now focusing on decommissioning vessels and cutting down the size of fishing fleets. Interestingly, all fishermen we contacted for this study agreed that the fleet size should be cut down and the number of licences reduced drastically. Fishermen overfish their quota because their individual quotas are simply too low due to the fact that the E.U. has been consistently granting funds for fishing fleets to become safer at sea (legitimately so) but this ultimately led to a grossly oversized fleet.

MATERIAL AND METHODS

General descriptive statistics

The data set used consisted of 56,637 records, each record corresponding to landings of one species in one port in one month of a specific year. Descriptive statistics were performed on the data set, using Microsoft Excel™ pivot tables, consisting of the following sums: total landed weight (and its respective price) per year, then per species and finally per port. Combining the previous sums allowed for the calculation of: total landed weight (and its respective price) per species and per year; and then per species and per port. Note that "port" is not necessarily related to "catching site" but, rather, to the site where the catch was landed, which was a relevant distinction in the analysis.

Data processing per "taxa"

Whenever multiple species belonging to the same genus were predominantly landed as their respective genus, they were grouped as such, regardless of the fact that, on a small number of occasions, individual species were recorded. For example, *Raja* spp. (i.e. skates not identified to species level), such as *Raja brachyura*, *Raja circularis*, *Raja clavata*, *Raja montagui* and *Raja naevus* were analysed individually, but the complete set of *Raja* sp. was also analysed. This group, which encompasses all species from the genus *Raja* is referred to as a "taxa".

This method was also applied to the following species: *Carcharhinus* spp. (i.e. requiem sharks with no species identification) and *Carcharhinus longimanus*, *Carcharhinus plumbeus*, *Carcharhinus falciformis* and *Carcharhinus obscurus* were analysed individually, but the complete set of *Charcharhinus* sp. was also analysed; *Dasyatis* spp. (i.e. stingrays with no species identification) and *Dasyatis centroura* were analysed individually, but the complete set of *Dasyatis* sp. was also analysed; *Galeorhinus* spp. (i.e. school sharks with no species identification) and *Galeorhinus galeus* were analysed individually, but the complete set of *Galeorhinus* sp. was also analysed; *Mustelus* spp. (i.e. smoothhounds with no species identification), *Mustelus mustelus* and *Mustelus asterias* were analysed individually, but the complete set of *Mustelus* sp. was also analysed; *Scyliorhinus* spp. (i.e. catsharks with no species identification) and *Scyliorhinus stellaris* were analysed individually, but the complete set of *Scyliorhinus* sp. was also analysed; *Sphyrna* spp. (i.e. hammerhead sharks with no species identification) and *Sphyrna zygaena* were analysed individually, but the complete set of *Sphyrna* sp. was also analysed. Once these species were grouped in the aforementioned group the initial sums were recalculated as: total landed weight (and its respective price) per taxa and per year. By "taxa", again, we mean the complete set of data within each genus, such as *Raja* sp., *Carcharhinus* sp., and the remaining occurrences mentioned above.

Total landed weight, price per year and per port

Similar sums were calculated for each "taxa", consisting of: total landed weight (in kg) and price (in €) per "taxa" per year. The division of these corresponding values allowed for the calculation of average price (€ / kg) per "taxa" per year. This analysis was repeated in relation to port, where total landed weight (in kg) was calculated per taxa per port. The division of each of the previous records by 24 (i.e. the number of years in the data set from 1986 to 2009) allowed for the calculation of mean total landed weight per taxa, per year, per port. The division of the total landed weight per taxa per port, by the total landed weight per taxa in all ports allowed for the calculation of the percent landings per taxa per port.

Trends in landed weight and price over time

With the objective of analysing trends in weight and price over time linear regression was performed, using Microsoft Excel™, on the following 24 pairs of values: total landed weight (kg) vs. year and annual mean price (€ / kg) vs. year. Note these regressions were not calculated under the assumption that the relationship between these variables is linear. These regressions were calculated with the objective of analysing the *trend* of these relationships over time and using their respective slope as an *indicator* of this trend. As such, a positive slope was interpreted as an indicator that total landed weight, and/or price, was increasing with time. Inversely, a negative slope was interpreted as an indicator that total landed weight, and/or price, was decreasing with time. Slopes for both regressions from all "taxa" were compiled in a summary table, along with descriptive parameters such as n, r^2 and significance of F value. Regressions were assumed significant if the significance of the F value was under 0.05.

Estimation of total landed weight

Once trends for total landed weight over time were calculated, it was investigated whether those trends were a reflection of decreasing, or increasing, stock numbers or a reflection of a shift in gear utilization. As such, observed annual weights were compared to estimated annual weights. The calculation of estimated weights was conducted with the objective of investigating if the percent variation in total landed weight, from year *N-1* to year *N*, was analogous to the variation in number of licenses – involved in each respective type of fishing activity - issued from year *N-1* to year *N*. This analysis included the following steps:

1) A table with the number of licenses issued per fishing gear per year was compiled from data supplied by the DGRM. Each license corresponds to an operating fishing vessel. This table was compiled from 1993 to 2009, as no data were available (in electronic format) prior to 1993. The percent variation in gear type from year *N-1* to year *N* was also calculated (Table 1).

2) The sum of total landed weight per "taxa", per gear, was calculated as landed from one of three gear types: trawl, seine and multigear. These values were converted to a percentage of gear used per taxa.
3) Estimated total landed weight over time was calculated using the percentages calculated in the 2) point above as a weighting factor for each year. This process included the following steps:

a) Using *Raja* sp. as an example, where 22.7% of the landings were caught by trawling, 0.3% by seine and 77.0% by multigear vessels;

b) These weighting factors (i.e. 22.7% | 0.3% | 77.0%) were applied to the variation in trawl | seine | multigear licenses issued per year to recalculate the total number of licenses issued per year. For example, the variation from 1993 to 1994 in licenses issued for trawling was +0.8%, -18.6% for seine, -4.1% for multigear. *Estimated* landings in 1994 for *Raja* sp. were therefore the observed landings in 1993 x (1,0 + 22.7% x 0.8% + 0.3% x (-18.6%) + 77.0% x (-4.1%)).

This process was repeated from 1995 through 2009 and these annual estimates of total weight landed were compared to their respective observed total weight landed using Student's t-test for paired samples. These tests allowed to infer whether landings estimated through the variation in gear type were higher, or lower, than observed landings over time.

Table 1. Number of licenses issued annually per type of fishing gear in Portugal from 1933 to 2009. Each license corresponds to one fishing vessel.

	No. Licenses / vessels			**% annual variation**		
Year	**Trawl**	**Seine**	**Multigear**	**Trawl**	**Seine**	**Multigear**
1993	122	199	6.665	- - -	- - -	- - -
1994	123	162	6.393	0,8%	-18,6%	-4,1%
1995	115	142	6.107	-6,5%	-12,3%	-4,5%
1996	112	143	5.952	-2,6%	0,7%	-2,5%
1997	104	137	5.701	-7,1%	-4,2%	-4,2%
1998	103	137	5.611	-1,0%	0,0%	-1,6%
1999	105	137	5.071	1,9%	0,0%	-9,6%
2000	105	136	4.846	0,0%	-0,7%	-4,4%
2001	108	137	4.815	2,9%	0,7%	-0,6%
2002	107	128	4.622	-0,9%	-6,6%	-4,0%
2003	108	120	4.534	0,9%	-6,3%	-1,9%
2004	106	114	4.463	-1,9%	-5,0%	-1,6%
2005	104	112	4.370	-1,9%	-1,8%	-2,1%
2006	94	112	4.096	-9,6%	0,0%	-6,3%
2007	91	98	4.013	-3,2%	-12,5%	-2,0%
2008	92	91	3.908	1,1%	-7,1%	-2,6%
2009	92	88	3.836	0,0%	-3,3%	-1,8%

ESTIMATION OF PRICE

Estimating mean annual price per kg per taxa followed a rationale similar to the one used for estimating total landed weight, with one important distinction: landing estimates were calculated using the number of licenses per fishing gear as a weighting factor while estimated prices used Portugal's annual economic inflation index as a factor. The objective of this analysis was to investigate whether the variation in price per kg, from year *N-1* to year *N*, was analogous to the variation in the country's official inflation rate during the same time interval. In other words, was price being influenced by external economic factors alone or were other factors, such as "supply and demand", driving prices above, or below, the country's overall fluctuation in prices, which is translated annually as inflation. The analysis therefore began with the compilation of a table with Portugal's official annual inflation figures, supplied by the Portuguese Institute of Statistics (*Instituto Nacional de Estatística*) www.ine.pt. The numbers are given in Table 2.

Table 2. Annual official index of economic inflation in Portugal from 1986 to 2009.

Year	Inflation (%)
1983	25.5%
1984	29.3%
1985	19.3%
1986	11.7%
1987	9.3%
1988	9.7%
1989	12.6%
1990	13.4%
1991	11.4%
1992	8.9%
1993	6.5%
1994	5.2%
1995	4.1%
1996	3.1%
1997	2.3%
1998	2.8%
1999	2.3%
2000	2.9%
2001	4.4%
2002	3.6%
2003	3.3%
2004	2.4%
2005	2.3%
2006	3.1%
2007	2.5%
2008	2.6%
2009	-0.8%

Estimated annual prices for year *N* were calculated by adding the inflation of year *N-1* to the annual mean price in year *N-1*. Observed and their respective estimated mean annual prices were compared with Student's t-test for paired samples with the objective of determining whether elasmobranch prices experienced variations, with time, similar to those manifested by inflation.

Min/Max autocorrelation factor analysis

MAFA analyses were performed to validate those trends suggested by analyzing landings and price trends over time (Table 3).

Response and explanatory variables

Annual landings of the 16 elasmobranch "taxa" with the highest landings in Portugal, from 1986 until 2009, were used as response variables. The analyses focused on three groups of species: pelagic, deep-sea and demersal. Pelagics included *Prionace glauca*, *Isurus oxyrinchus*, *Carcharhinus* sp. and *Alopias vulpinus*. Deep-sea included *Centroscymnus coelolepis*, *Centrophorus squamosus* and *Centrophorus granulosus*. Demersal included *Raja* sp., *Scyliorhinus* sp., *Dalatias licha*, *Mustelus* sp., *Torpedo* sp., *Galeorhinus* sp., *Galeus melastomus*, *Myliobatis aquila* and *Squatina* sp. Two types of explanatory variables were used: environmental and fisheries related. Environmental variables were the North Atlantic Oscillation (NAO) and Sea Surface Temperature (SST). The NAO index numbers used corresponded to winter (i.e. December through March), and this index is based on the normalized difference in atmospheric pressure between Lisbon (Portugal) and Stykkisholmur/Reykjavik (Iceland). Traditionally, a high NAO index means strong Westerly winds, while a low NAO index means weak Westerly winds. These numbers were retrieved from www.cgd.ucar.edu/cas/jhurrell/indices.html. SST values during the cold season of the year (November through May) were retrieved from COADS (Comprehensive Oceanic-Atmosphere Data Set; www.cdc.noaa.gov/coads/) for the geographic position of 38°N and 9°W, which corresponds to the 1 x 1 degrees square directly off Lisbon, which is the mid-point in Portugal's continental shore. Panoply for Windows™ was used to retrieve the data from the COADS database.

Fisheries related explanatory variables were the annual number of fishing licenses issued per fishing gear, which are the same that were used for estimating total landed weight based on the variation of fishing licenses over time. The numbers were available only from 1993 onwards. Explanatory variables are given in table 3. Landings statistics were associated to one of three types of fishing gear (i.e. trawl, seine or multigear), category multigear was broken down in multiple sub-categories by the license issuing bureau of the DGRM: "< 12 m", "> 12 m" and "international".

Table 3. Explanatory variables used in MAFA analysis of annual commercial landings of Elasmobranchs in Portugal from 1986 to 2009. NAO – North Atlantic Oscillation index; SST – Sea Surface Temperature; trawl – vessels operating trawling nets; seine – vessels operating seine nets; < 12 m – vessels under 12 meters long operating non-disclosed fishing gear; > 12 m vessels over 12 meters long operating non-disclosed fishing gear; international – vessels with licenses issued to operate in international waters and operating non-disclosed fishing gear.

					Multigear		
Year	**NAO**	**SST**	**trawl**	**seine**	**< 12 m**	**> 12 m**	**international**
1986	0,50	15,3	NA	NA	NA	NA	NA
1987	-0,75	15,8	NA	NA	NA	NA	NA
1988	0,72	15,8	NA	NA	NA	NA	NA
1989	5,08	16,1	NA	NA	NA	NA	NA
1990	3,96	16,3	NA	NA	NA	NA	NA
1991	1,03	15,2	NA	NA	NA	NA	NA
1992	3,28	15,4	NA	NA	NA	NA	NA
1993	2,67	15,6	122	199	6.000	603	62
1994	3,03	14,9	123	162	5.765	567	61
1995	3,96	16,2	115	142	5.545	508	54
1996	-3,78	16,4	112	143	5.372	530	50
1997	-0,17	16,2	104	137	5.155	505	41
1998	0,72	16,4	103	137	5.064	508	39
1999	1,70	15,9	105	137	4.570	466	35
2000	2,80	15,8	105	136	4.368	441	37
2001	-1,90	15,8	108	137	4.352	429	34
2002	0,76	16,0	107	128	4.158	427	37
2003	0,20	15,8	108	120	4.097	398	39
2004	-0,07	15,4	106	114	4.036	391	36
2005	0,13	15,8	104	112	3.951	383	36
2006	-1,09	16,1	94	112	3.697	366	33
2007	2,80	16,7	91	98	3.625	354	34
2008	2,10	16,6	92	91	3.525	351	32
2009	-0,40	15,5	92	88	3.452	350	34

MAFA ANALYSIS

Min/max autocorrelation factor analyses (MAFA) is a method that can be used to extract trends from multiple time series, estimate functions and indexes and also smooth data (Solow 1994; Zuur et al., 2007). Cross-correlations between the significant MAFA axes and the species can be used to infer which species are related to the main trends. Cross correlations between the MAFA axes and explanatory variables also allow identification of significant relationships between trends and explanatory variables. The analyses was conducted on standardized data using the Brodgar™ (www.brodgar.com) software package.

RESULTS AND DISCUSSION - GENERAL

Based on 56,637 records supplied by the *DGRM*, between 1986 and 2009 122.5 thousand mt of elasmobranchs were landed in Portuguese ports, corresponding to 167.9 million euros. This corresponds to mean annual landings of 5.1 thousand mt per year (n = 26). Figure 1 shows how these landings are distributed per year, with a slight decrease in numbers over time, particularly since 1988 (maximum = 6,165 mt). Landings mostly remained under 5,000 mt after 1998.

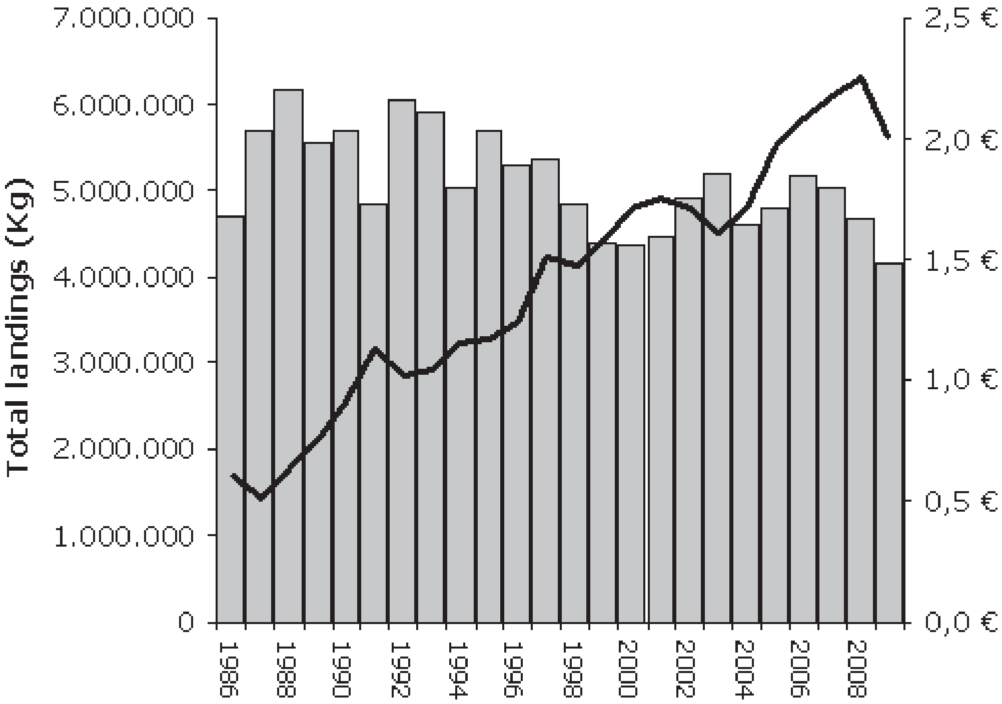


Fig 1. Annual total landed weight (bars), and mean price (line), of elasmobranchs in Portugal from 1986 to 2009.

Landings by taxa are given in Figure 2, which shows that the ten most landed taxa were *Raja* sp., *Scyliorhinus* sp., *Centroscymnus coelolepis*, *Centrophorus squamosus*, *Prionace glauca*, *Centrophorus granulosus*, *Isurus oxyrinchus*, *Dalatias licha*, *Mustelus* sp., and *Pleurotremata*. These taxa accounted for 112.8 thousand mt, i.e. 92.1% of captures in weight.

Landings were recorded in 118 ports, given in Figure 3. The cumulative landings for the top 10 ports were 93.7 thousand mt, i.e. 76.5% of captures in weight.

Breaking down landings of each species per license of fishing gear revealed higher values of trawling for bottom dwelling species, such as *Raja* sp. and *Scyliorhinus* sp., and higher multi-gear values for both demersal and pelagic species. These include surface and bottom longline, as well as gillnets, trammel nets and traps (Table 4).

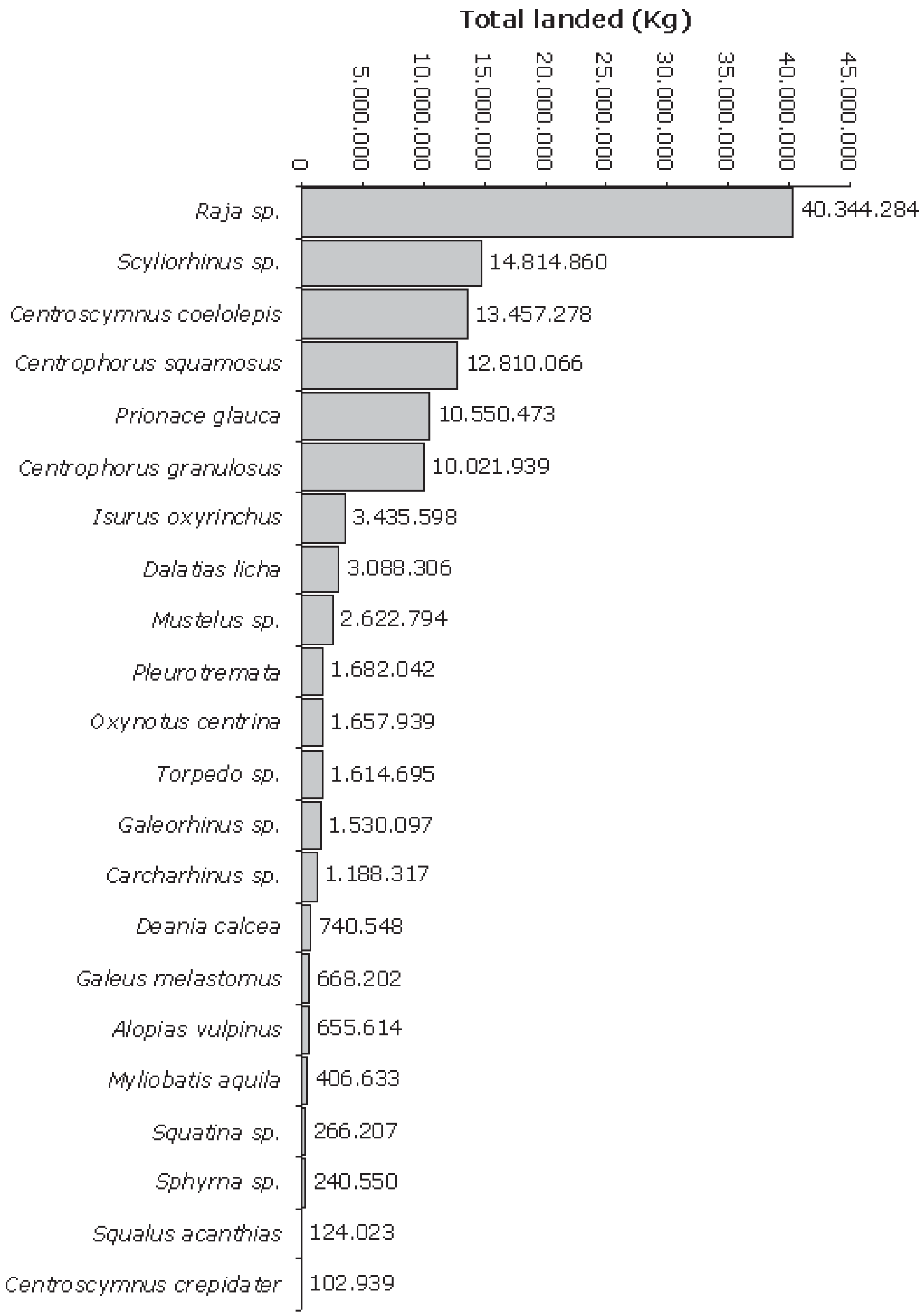


Fig. 2. Total landed weight, by taxa, of elasmobranchs in Portugal from 1986 to 2009. Only taxa with values above 100 mt are represented.

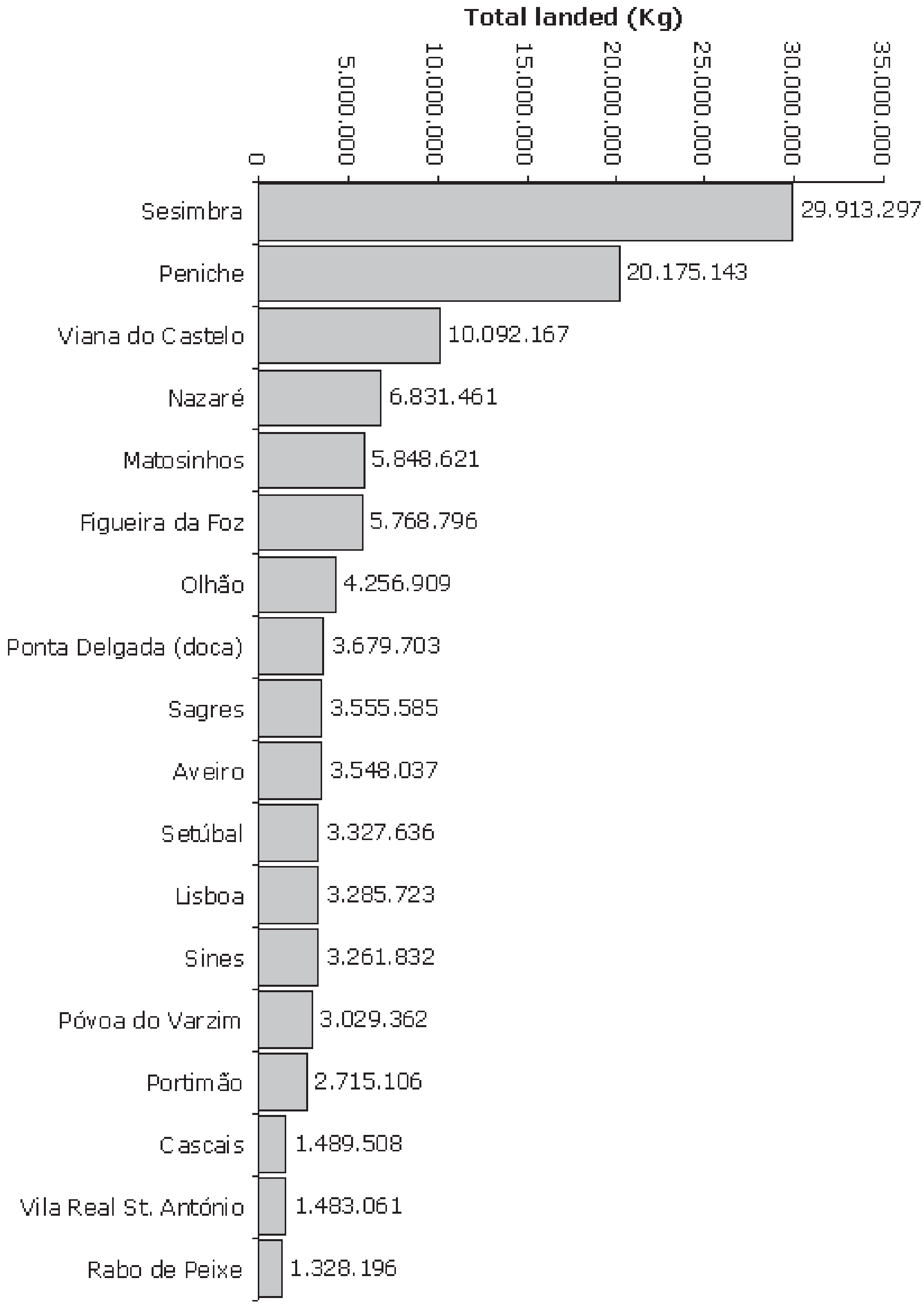


Fig. 3. Total landed weight, by port, of elasmobranchs in Portugal from 1986 to 2009. Only ports with values above 1.000 mt are represented.

Table 4. Total landed weight of elasmobranchs in Portugal from 1986 to 2009 by taxa for the three main gear types and the total weight landed by each gear type in percent.

	1986 to 2009						
	Total landed weight per gear type (Kg)			Total landed weight per gear type (%)			Total landed weight
Taxa	Trawl	Seine	Multigear	Trawl	Seine	Multigear	(Kg)
Raja sp.	9.149.476	117.766	31.077.043	22,7%	0,3%	77,0%	40.344.284
Scyliorhinus sp.	8.223.362	29.631	6.561.866	55,5%	0,2%	44,3%	14.814.860
Centroscymnus coelolepis	5.777	900	13.450.601	0,0%	0,0%	100,0%	13.457.278
Centrophorus squamosus + C. lusitanicus	3.134	13.894	12.793.039	0,0%	0,1%	99,9%	12.810.066
Prionace glauca	53.095	111.776	10.385.602	0,5%	1,1%	98,4%	10.550.473
Centrophorus granulosus	72.503	8.453	9.940.983	0,7%	0,1%	99,2%	10.021.939
Isurus oxyrinchus	2.322	8.054	3.425.222	0,1%	0,2%	99,7%	3.435.598
Dalatias licha	285.969	1.311	2.801.025	9,3%	0,0%	90,7%	3.088.306
Mustelus sp.	199.771	3.726	2.419.298	7,6%	0,1%	92,2%	2.622.794
Pleurotremata	44.244	925	1.636.873	2,6%	0,1%	97,3%	1.682.042
Oxynotus centrina	143.595	465.860	1.048.484	8,7%	28,1%	63,2%	1.657.939
Torpedo sp.	115.096	7.809	1.491.789	7,1%	0,5%	92,4%	1.614.695
Galeorhinus sp.	0	0	1.530.097	0,0%	0,0%	100,0%	1.530.097
Carcharhinus sp.	73	0	1.188.244	0,0%	0,0%	100,0%	1.188.317
Deania calcea	9.008	7	731.533	1,2%	0,0%	98,8%	740.548
Galeus melastomus	93.494	3.648	571.060	14,0%	0,5%	85,5%	668.202
Alopias vulpinus	4.145	4.519	646.949	0,6%	0,7%	98,7%	655.614
Myliobatis aquila	62.555	25.890	318.188	15,4%	6,4%	78,2%	406.633
Squatina sp.	8.233	2.286	255.688	3,1%	0,9%	96,0%	266.207
Sphyrna sp.	207	1.408	238.935	0,1%	0,6%	99,3%	240.550
Squalus acanthias	20.049	37	103.937	16,2%	0,0%	83,8%	124.023
Centroscymnus crepidater	3.145	0	99.793	3,1%	0,0%	96,9%	102.939
Oils	0	0	99.800	0,0%	0,0%	100,0%	99.800
Gymnura altavela	27.362	326	66.971	28,9%	0,3%	70,7%	94.660
Dasyatis sp.	10.194	22.021	51.710	12,1%	26,2%	61,6%	83.924
Hexanchus griseus	18.511	1.175	49.125	26,9%	1,7%	71,4%	68.811
Livers	0	0	52.115	0,0%	0,0%	100,0%	52.115
Lamna nasus	2.009	1.106	38.066	4,9%	2,7%	92,4%	41.182
Somniosus microcephalus	1.472	128	22.993	6,0%	0,5%	93,5%	24.593
Cetorhinus maximus	1.019	0	12.688	7,4%	0,0%	92,6%	13.708
Echinorhinus brucus	505	18	8.564	5,6%	0,2%	94,2%	9.087
Etmopterus sp.	441	0	2.075	17,5%	0,0%	82,5%	2.516
Heptranchias perlo	0	0	859	0,0%	0,0%	100,0%	859
Alopias superciliosus	0	0	426	0,0%	0,0%	100,0%	426
Euselachii	0	0	96	0,0%	0,0%	100,0%	96

RESULTS AND DISCUSSION PER TAXA

Results for the analysis conducted for each of the taxa with the heaviest landings are summarized in Table 5 and represented in Figures 4 through 15.

Raja **sp.**

Most skates landed in Portugal are referred simply as "skates" (i.e. *Raja* sp.), although there are sixteen species listed in Portuguese waters according to Sanches (1986). The following species are recorded with their correct name: *Raja clavata*, *Raja brachyura*, *Raja montagui*, *Raja circularis*, *Leucoraja naevus*, and *Raja naevus*, but these specific denominations correspond to only 53.2%, 3.83%, 1.37%, 1.21%, 0.21% and 0.03% of *Raja* sp. landings, respectively. The percentages for the first two species are approximately double those percentages reported by Correia (2009), while analysing the same data set from 1986 to 2006, and this increase was interpreted as fishing port employees becoming better at properly identifying these species, rather than simply using the generic term "skate".

In 2001 Machado et al. (2004) developed a sampling program in the fishing docks of Matosinhos and Peniche, showing that *Raja brachyura* and *Raja clavata* were the highest landed *Raja* sp. species in Peniche (44% and 23%, respectively) and Matosinhos (18% and 37%, respectively). These authors also mention how *Raja miraletus* was the least abundant species in all samplings. But the most significant aspect of this study is the fact that multiple recommendations for the local Fisheries Authority (DGRM) were issued and the fruits of that effort are already visible, as the official landings of the previously mentioned species correspond to recent years.

Table 5. Summary table of analyses performed on elasmobranchs landed in Portugal from 1986 to 2009. Bold pairs of "Trend landings" and "Trend prices" correspond to "Category I" taxa, i.e. those that show a trend of decreasing landed weight and inc reasing price over time; bold p values are greater than 0.05, i.e. there is no significant difference between observed and estimated values; bold MAFA values are greater than 0.40, or lesser than, -0.40, i.e. the trend detected in the analysis is significant.

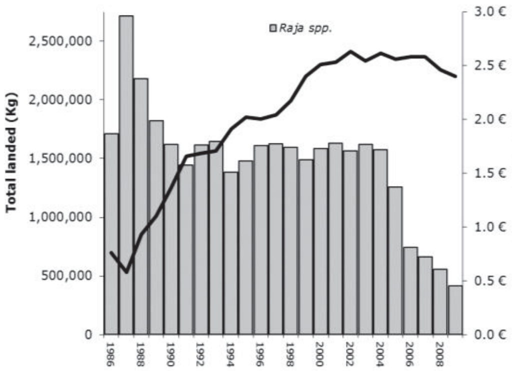
		Trend Landings				Trend Price					Estimated vs. observed values						MAFA analysis Correlation	
Category	Taxa	Kg / year	n	r^2	F	€/Kg / year	n	r^2	F	Category	Kg / year obs	Kg / yeast est	P	€/kg / year obs	€/Kg / ano est	P	MAFA 1	MAFA 2
pelagic	*Prionace glauca*	17.637	24	0,52	0,00	€ 0,05	24	0,79	0,00	II	501.561	329.025	0,00	€ 0,76	€ 0,38	0,00	**0,63**	0,39
pelagic	*Isurus oxyrinchus*	16.709	24	0,51	0,00	€ 0,16	24	0,79	0,00	II	178.509	35.761	0,00	€ 3,03	€ 2,41	0,02	**0,99**	0,17
pelagic	*Carcharhinus sp.*																-0,31	**0,89**
pelagic	*Alopias vulpinus*																**0,44**	-0,09
deep-sea	*Centroscymnus coelolepis*	-6.663	24	0,05	0,28	€ 0,04	24	0,74	0,00	III	579.297	467.439	0,03	€ 0,99	€ 1,26	0,00	**0,40**	**-0,89**
deep-sea	*Centrophorus squamosus + lusitanicus*	6.585	24	0,24	0,02	€ 0,06	24	0,74	0,00	II	545.198	264.565	0,00	€ 1,47	€ 1,36	**0,21**	0,04	**0,85**
deep-sea	*Centrophorus granulosus*	**-47.992**	24	0,74	0,00	**€ 0,09**	24	0,56	0,00	I	202.408	664.921	0,00	€ 1,71	€ 1,26	0,01	**-0,89**	-0,46
demersal	*Raja* sp.	**-15.449**	24	0,17	0,04	**€ 0,08**	24	0,81	0,00	I	1.602.404	1.273.533	0,00	€ 1,96	€ 1,71	**0,06**	**0,54**	-0,09
demersal	*Scyliorhinus sp.*	5.213	24	0,17	0,04	€ 0,03	24	0,92	0,00	II	649.436	451.403	0,00	€ 0,53	€ 0,44	0,04	**-0,83**	0,23
demersal	*Dalatias licha*	**-11.964**	24	0,18	0,04	**€ 0,02**	24	0,26	0,01	I	103.461	462.142	0,00	€ 0,46	€ 1,00	0,00	0,29	**0,45**
demersal	*Mustelus* sp.	**-8.840**	24	0,68	0,00	**€ 0,13**	24	0,92	0,00	I	78.219	116.421	0,00	€ 2,02	€ 1,59	0,02	**0,79**	0,35
demersal	*Torpedo* sp.	**-3.628**	24	0,66	0,00	**€ 0,06**	24	0,68	0,00	I	50.654	80.664	0,00	€ 1,51	€ 0,99	0,00	**0,95**	0,14
demersal	*Galeorhinus sp.*	**-5.191**	18	0,58	0,00	**€ 0,03**	18	0,33	0,01	I	85.136	87.462	**0,41**	€ 1,43	€ 1,03	0,00	-0,05	**0,88**
demersal	*Galeus melastomus*																**-0,65**	0,12
demersal	*Myliobatis aquila*																0,20	**0,51**
demersal	*Squatina* sp.	**-1.780**	24	0,36	0,00	**€ 0,06**	24	0,62	0,00	I	1.069	1.922	**0,36**	€ 1,12	€ 1,07	0,01	**0,70**	0,03

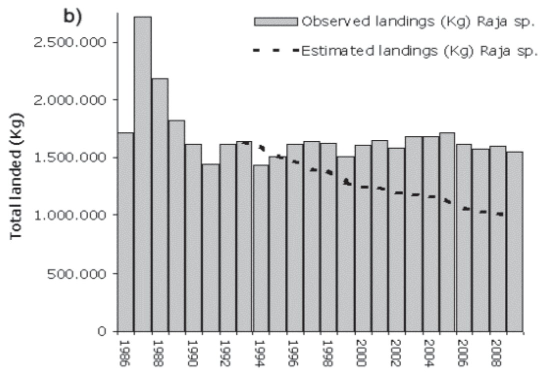
This differentiation is so obvious that the general landings of *Raja* spp. show a marked decrease in 2005 and 2006, precisely because a lot of those are being recorded to the species level (Fig. 4a).

Regression analysis of observed landings over time (Table 5) shows a significant ($r^2 = 0.17$; $p < 0.05$) mean decrease of 15 mt per year, while Correia and Smith (2004) showed a decrease of 47 mt per year when working on data from 1986 to 2001 and Correia (2009) showed a non-significant decrease of 18 mt per year when processing data from 1986 to 2006. It seems, therefore, that the 2002 to 2009 segment of data brought some stability, which is particularly visible when looking at Figure 4a, which shows very stable landings since 1988. Fishing gear used for *Raja* sp. consisted of 22.7% trawling, 0.3% seining and 77.0% multigear (Table 4). The annual variations of these types of fishing gear licenses (Table 1) were used to estimate a weighted annual variation of landings starting in 1993, as this information was not available for previous years.

Results are given in Figure 4b. Observed landings are significantly higher than estimated ($p < 0.00$), which most likely means that there is an active interest in harvesting, and selling, these species. Estimated annual prices, based on inflation, are given in Figure 4c. This figure shows how observed prices are higher than estimated values (although not significantly, $p > 0.06$), which suggests that there is demand for these products and catches are unlikely to be purely accidental.

a)





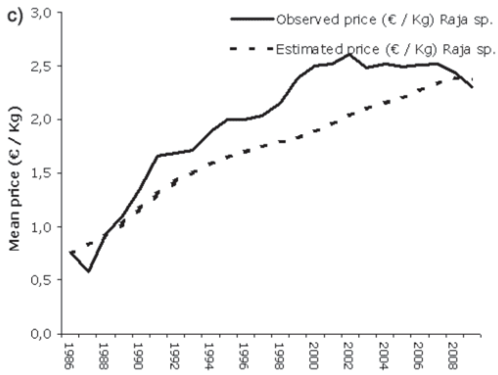


Fig. 4. a) Annual total landed weight (bars) and mean price (line) of *Raja* spp.; b) Observed (bars) and estimated (dashed line) annual total landed weight of *Raja* sp.; c) Observed (solid line) and estimated (dashed line) annual mean price of *Raja* sp. in Portugal from 1986 to 2009.

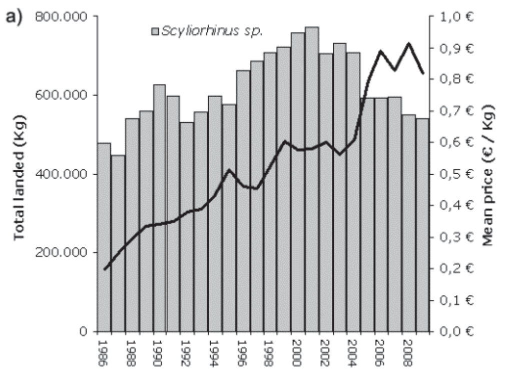
Scyliorhinus canicula

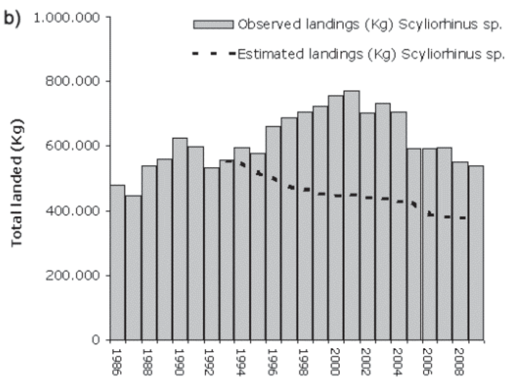
Two species of catsharks are known to occur in Portuguese waters according to Sanches (1986): *Scyliorhinus canicula* and *Scyliorhinus stellaris*. Informal contacts in multiple fishing docks corroborate that *S. canicula* is the most abundant species, with *Scyliorhinus stellaris* accounting for only 15.2% of all *Scyliorhinus* landings. Similarly to *Raja* sp., recent landings of the genus *Scyliorhinus* have suffered a decrease but this is mostly due to an increase in specific identification of *Scyliorhinus stellaris*. Overall, however, this genus shows relatively stable landings, with regression analysis of observed landings over time yielding a significant ($r^2 = 0.17$; $p < 0.05$) increase of 5 mt per year.

Research surveys conducted by the R/V "Noruega", from the Portuguese Marine Research Institute (IPMA) reveal that these species are more abundant between 200 and 400 m depth, mostly along flat and sandy bottoms (Figueiredo et al. 1996; Machado 1996).

Fishing gear used for *Scyliorhinus* sp. were 55.5% for trawling, 0.2% for seining and 44.3% for multigeaar (Table 4). The results of the annual variations of these types of fishing gear license (Table 1) are given in Figure 5b. Observed landings are significantly higher ($p < 0.00$) than estimated, which most likely means that there is an active interest in harvesting, and selling, these species.

Estimated annual prices, based on inflation are given in Figure 5c. This figure shows how observed prices are also significantly higher ($p < 0.04$) than estimated values, which supports the previous assumption that there is an active demand for these products and catches are therefore likely to be targeted.





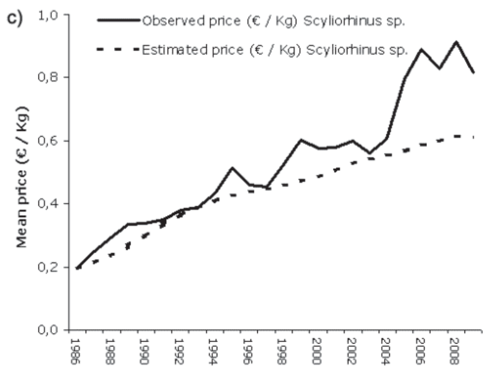


Fig 5. a) Annual total landed weight (bars) and mean price (line) of *Scyliorhinus* sp.; b) Observed (bars) and estimated (dashed line) annual total landed weight of *Scyliorhinus* sp.; c) Observed (solid line) and estimated (dashed line) annual mean price of *Scyliorhinus* sp. in Portugal from 1986 to 2009.

Centroscymnus coelolepis

Portuguese dogfish (*Centroscymnus coelolepis*) landings given in Figure 6 show decreasing values in recent years. Regression analysis of observed landings over time (Table 5) shows a non-significant ($r^2 = 0.05$; $p > 0.05$) mean decrease of 6.6 mt per year, while Correia and Smith (2004) showed a non-significant increase of 25 mt per year when working data from 1986 to 2001, whereas Correia (2009) showed a non-significant increase of 5.6 mt per year when processing data from 1986 to 2006. It seems, therefore, that the 2002 to 2009 segment of data brought a downward trend, which is particularly visible when looking at Figure 6a, which shows decreasing landings since 1999.

Fishing gear used for *Centroscymnus coelolepis* were 100.0% for multigear (Table 4). The annual variations of these types of fishing gear license (Table 1) were used to estimate a weighted annual variation of landings starting in 1993, as this information was not available for previous years. Results are given in Figure 6b. Observed landings are significantly higher than estimated ($p < 0.03$), which most likely means that there is an active interest in harvesting, and selling, these species.

Estimated annual prices, based on inflation, are given in Figure 6c. This figure shows how observed prices are actually significantly lower than estimated values (p < 0.00), which contradicts the previous assumption that there is an active demand for these products and catches are therefore likely to be purely accidental in recent years.

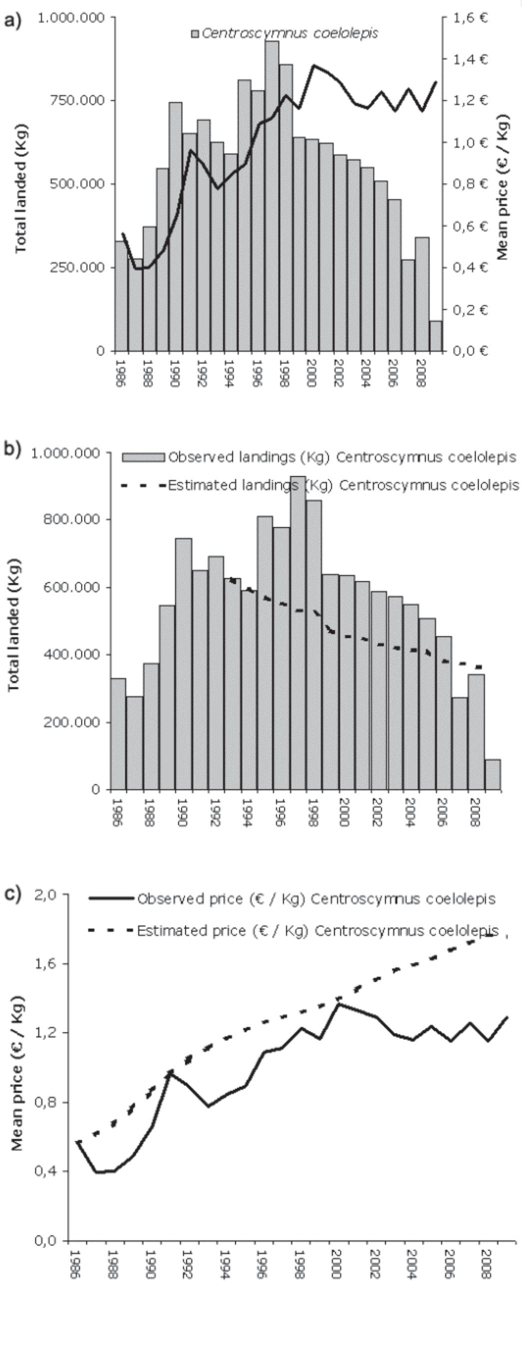


Fig. 6. a) Annual total landed weight (bars) and mean price (line) of *Centroscymnus coelolepis*; b) Observed (bars) and estimated (dashed line) annual total landed weight of *Centroscymnus coelolepis*; c) Observed (solid line) and estimated (dashed line) annual mean price of *Centroscymnus coelolepis* in Portugal from 1986 to 2009.

Centrophorus squamosus

Leafscale gulper shark (*Centrophorus squamosus*) landings are given in Figure 7a and generally show increasing landings, with linear regression yielding a non-significant ($r^2 = 0.24$; $p > 0.05$) positive slope of 6.6 mt per year. *C. squamosus* landings show a marked decrease since 2007, but this is easily explained by the landings of *Centrophorus lusitanicus* (Fig. 7b), which had never been reported in Portuguese landings before 2007. Commencement of reporting in 2007 is most likely a consequence of the TAC enforced by the EU Council of Fisheries Ministers (in January 2007) which imposed severe restrictions on landings of deep-sea sharks.

Centrophorus lusitanicus was included in Sanches' 1986 publication on elasmobranchs occurring in Portuguese waters but its distinction from *Centrophorus squamosus* remained a subject of debate and both species have been historically landed as *Centrophorus squamosus*. The establishment of a TAC for deep-sea sharks, in 2007, drove fishermen to land all deep-sea elasmobranch catches as *Centrophorus lusitanicus*, since this species was not included in the list of TAC regulated species. This case of misreporting has had a very negative effect on the data, with *Centrophorus lusitanicus* now replacing records that most likely should be *Centrophorus squamosus* and possibly even other deep-sea species, such as *Centroscymnus coelolepis* and *Centrophorus granulosus*.

Centrophorus squamosus landings are concentrated in ports with a long tradition of bottom longline fishing, such as Sesimbra (67%), Viana do Castelo (8%), Funchal and Câmara de Lobos, the latter two in the Madeira islands (6 and 5%, respectively). This was to be expected, as the black-scabbard bottom longline fishery originated in Madeira, and did not become common in mainland Portugal until the early 1980s (Melo 1987).

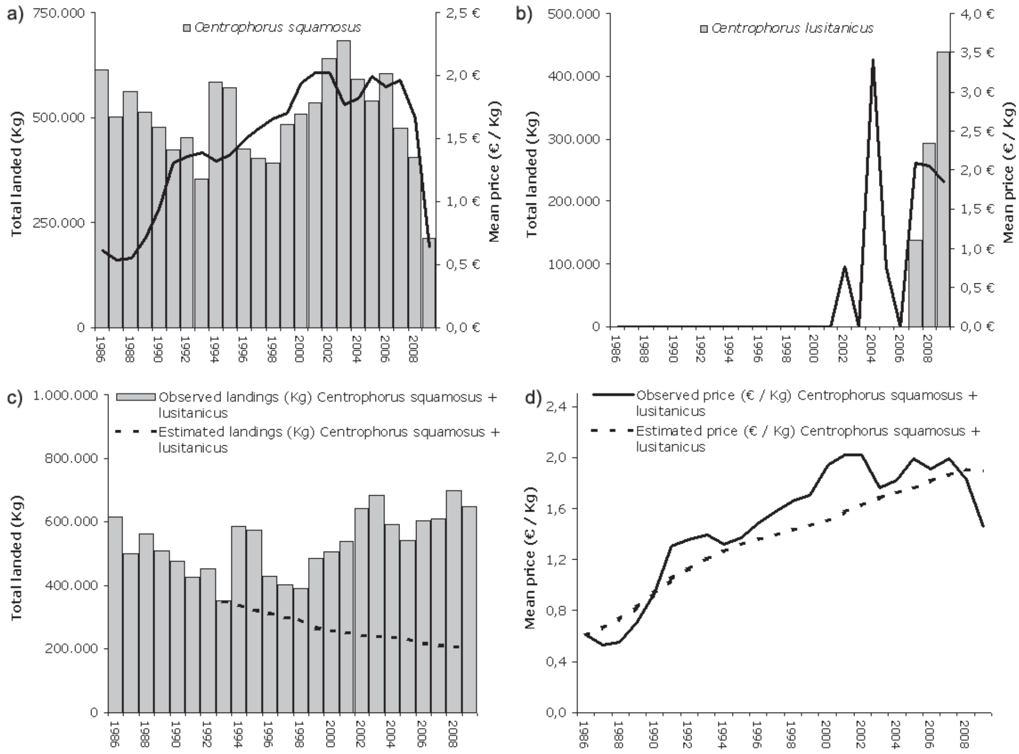


Fig. 7. a) Annual total landed weight (bars) and mean price (line) of *Centrophorus squamosus*; b) Annual total landed weight (bars) and mean price (line) of *Centrophorus lusitanicus*; c) Observed (bars) and estimated (dashed line) annual total landed weight of *Centrophorus squamosus* and *Centrophorus lusitanicus* in Portugal from 1986 to 2009; d) Observed (solid line) and estimated (dashed line) annual mean price of *Centrophorus squamosus* and *Centrophorus lusitanicus* in Portugal from 1986 to 2009.

These findings support the earlier suggestion, corroborated by multiple trips to fishing ports where bottom longliners traditionally land their catch, that this species is a bycatch of the black-scabbard fishery.

Queiroz (2004) determined 96 cm to be the mean length at maturity. Severino (2004) suggested that there is a strong effect of seasonality in the distribution of this species, which had been previously advanced by Veríssimo et al. (2003) for *Centroscymnus coelolepis*. Severino also states that, to date, only four gravid females of *Centrophorus squamosus* have been observed worldwide, which supports the hypothesis that reproduction is taking place in a location where fishing does not occur.

Fishing gear used for *Centrophorus squamosus* were 0.1% for seine and 99.9% for multigear (Table 4). The annual variations of these types of fishing gear license (Table 1) were used to estimate a weighted annual variation of landings starting in 1993. Results are given in Figure 7c. Observed landings are significantly higher than estimated ($p < 0.00$), which most likely means that there is an active interest in harvesting, and selling, these species.

Estimated annual prices, based on inflation are given in Figure 7d. This figure shows how observed prices are slightly higher, and not significantly ($p > 0.21$), than estimated values ($p < 0.00$), which contradicts the previous assumption that there is an active demand for these products and catches are therefore likely to be purely accidental in recent years.

Centrophorus granulosus

Gulper shark (*Centrophorus granulosus)* landings are given in Figure 8a and show a decreasing pattern in landings, with linear regression yielding a significant ($r^2 = 0.74$; $p < 0.05$) negative slope of 48.0 mt per year.

Fishing gear used for *Centrophorus granulosus* were 99.2 % by multigear, 0.7% for trawling and 0.1% for seining (Table 4), as this species is also mostly caught as bycatch of the black-scabbard fish bottom longline fishery. Estimated landings using the weighted variation of fishing gear license per year are given in Figure 8b and show a marked difference between landings, with observed values being significantly lower ($p < 0.00$) than the observed.

This suggests a very high interest in this species. This assumption is entirely corroborated by price analyses, with observed values being significantly higher than estimated values ($p < 0.01$), especially since the late 1990s (Fig. 8c). Such a pattern raises serious concerns, which has been noted by Correia & Smith (2004) when analysing similar data from 1986 to 2001 only, and by Correia (2009) which included the years 1986 to 2006. Landings of this species should therefore be monitored closely.

Similar to *Centroscymnus coelolepis*, and *Centrophorus squamosus*, landings of *Centrophorus granulosus* are closely tied to the black-scabbard fish longline fishery, although multiple contacts with local fishermen revealed how this species was caught by trawling off the North African coast back in the 1980s. The cessation of this fishery was agreed between Morocco and the EU (in 1993) and could explain, if partially, the severe decrease shown in landings since 1994.

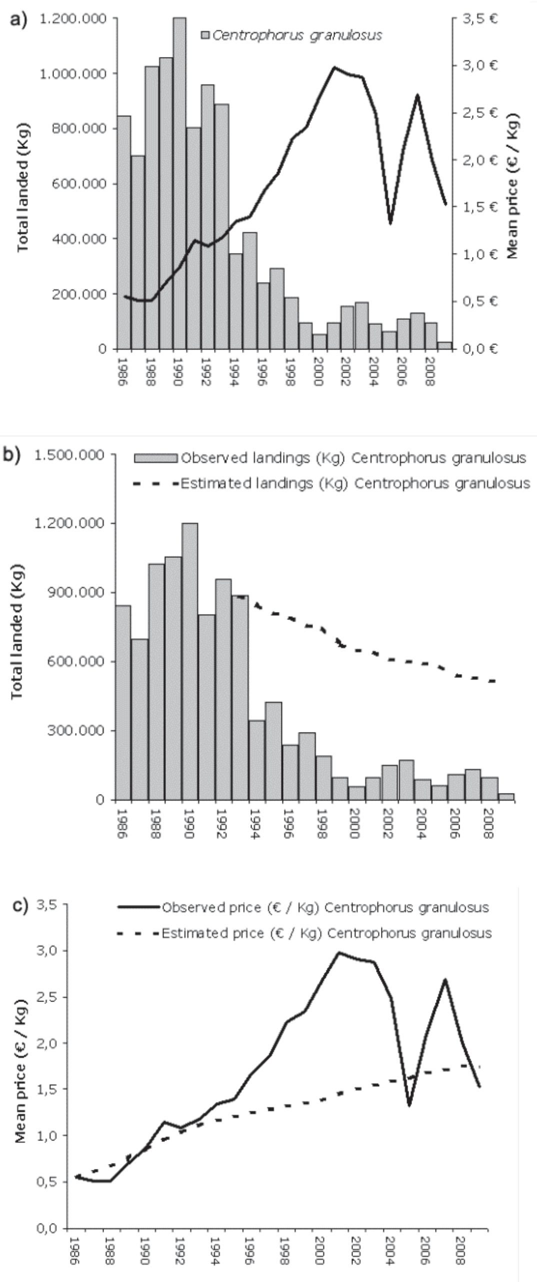


Fig. 8. a) Annual total landed weight (bars) and mean price (line) of *Centrophorus granulosus*; b) Observed (bars) and estimated (dashed line) annual total landed weight of *C. granulosus*; c) Observed (solid line) and estimated (dashed line) annual mean price of *C. granulosus* in Portugal from 1986 to 2009.

Prionace glauca

Blue shark (*Prionace glauca*) landings are given in Figure 9a and show a relatively stable pattern, with occasional higher spikes in 2002, 2003, 2006 and 2007. Linear regression yielded a significant ($r^2 = 0.52$; $p < 0.05$) positive slope of 17.6 mt per year.

Blue shark landings data are hard to analyse because there is a vast, and unknown, proportion of it that is not corresponding to blue shark but to swordfish, *Xiphias gladius*. This is due to the fact that swordfish quotas are limited to 6 mt per boat, per year and are surpassed by surface longline fishermen commonly in one trip only. During subsequent trips swordfish are therefore often landed under the denomination of “blue shark”.

Fishing gear used for *Prionace glauca* were 98.4% for multigear, 0.5% for trawling and 1.1% for seining (Table 4), as this species is largely caught as bycatch of the swordfish surface long-line fishery. Estimated landings using the weighted variation of fishing gear license per year are given in Figure 9b and show a marked significant difference between landings ($p < 0.00$), with observed values being much higher than estimated, especially in recent years. This suggests a high interest in this species. This assumption is entirely corroborated by the analysis of price, with observed values being substantially, and significantly ($p < 0.00$), higher than estimated values (Fig. 9c).

Blue sharks have long been regarded as an exceptionally abundant species, particularly in the Atlantic Ocean, and as not being seriously threatened. This species is the main bycatch of the swordfish fishery, which has been demonstrated frequently in the literature and in many parts of the world, e.g. Santos et al. (2002) while analysing logbooks from Portuguese longliners operating in the Atlantic; Stevens (2005) and Mejuto et al. (2006, 2007) also based in the Atlantic; Hazin et al. (2007) and Mourato et al. (2007a, 2007b) in Brazil; Matsunaga (2007a, b) in Japan.

Recent studies have shown a marked decrease in worldwide catches of this species, which is also heavily targeted by the finning industry (Tudela et al. 2005). Additional references on the widespread diminishing numbers of blue shark landings include De Metrio et al. (1984) and Megalofonou et al. (2005).

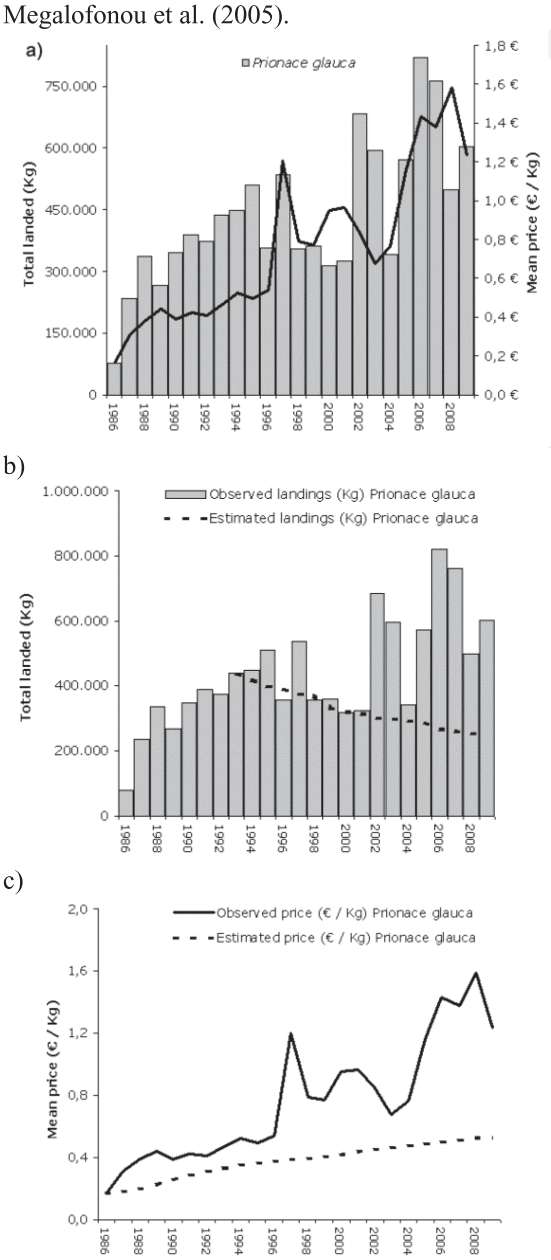


Fig. 9. a) Annual total landed weight (bars) and mean price (line) of *Prionace glauca*; b) Observed (bars) and estimated (dashed line) annual total landed weight of *P. glauca*; c) Observed (solid line) and estimated (dashed line) annual mean price of *P. glauca* in Portugal from 1986 to 2009.

***Mustelus* sp.**

The vast majority of smoothhound landings include landings of animals simply identified as "smoothhound" (i.e. *Mustelus* sp.), with 5.6% and 3.5% of total smoothhound landings being relative to *Mustelus mustelus* and *Mustelus asterias*, respectively. The combined total of *Mustelus* sp. landings is given in Figure 10a and shows a decreasing pattern, evocative of the pattern shown by *Centrophorus granulosus*, with linear regression yielding a significant (r^2 = 0.68; $p < 0.05$) negative slope of 8.8 mt per year. Much like the case for *Raja* sp. and *Scyliorhinus* sp., Docapesca officials are increasing their efforts to record smoothounds with their correct species name, therefore decreasing the amount of landings of unidentified species. This process, however, is still not as advanced as for *Raja* sp. and *Scyliorhinus* sp.

Fishing gear used for *Mustelus* sp. were 92.2% for multigear, 7.6% for trawling and 0.1% for seining (Table 4), as this species is predominantly caught by gill-nets targeting demersal species. Estimated landings using the weighted variation of fishing gear license per year are given in Figure 10b and show a marked difference between landings, with observed values being much significantly lower ($p < 0.00$) than estimated, suggesting a not particularly high interest in this species, which is supported by the analysis of price, where observed values are identical to estimated ones, using inflation, in early years, although they become significantly higher ($p < 0.02$) in recent years (Fig. 10c).

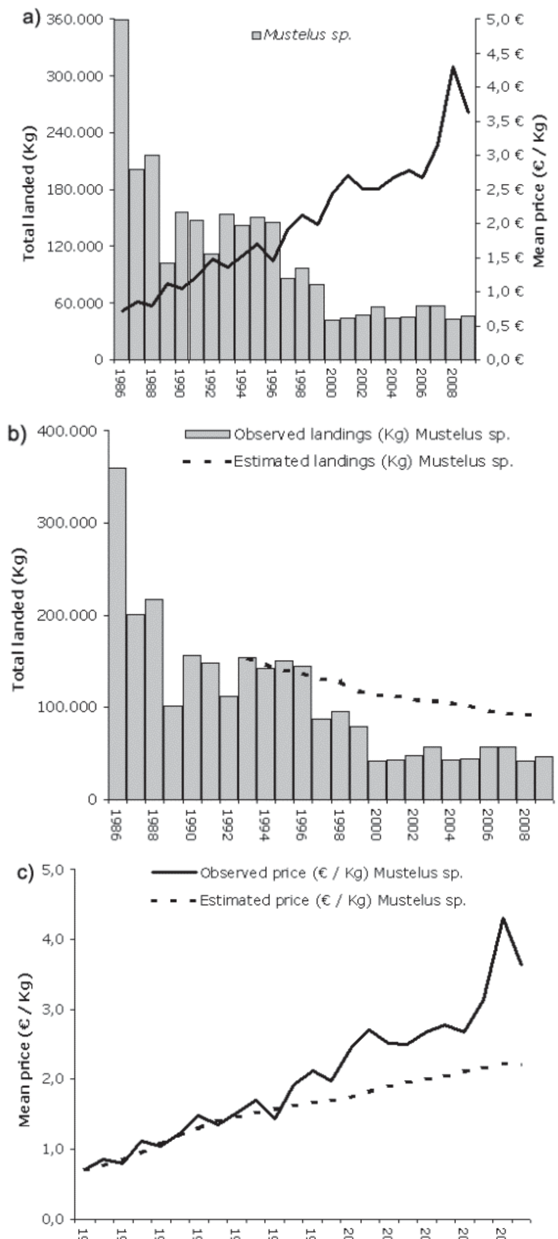


Fig 10. a) Annual total landed weight (bars) and mean price (line) of *Mustelus* sp.; b) Observed (bars) and estimated (dashed line) annual total landed weight of *Mustelus* sp.; c) Observed (solid line) and estimated (dashed line) annual mean price of *Mustelus* sp. in Portugal from 1986 to 2009.

Isurus oxyrinchus

Shortfin mako sharks (*Isurus oxyrinchus*) show relatively stable and almost constant landings until 2005 (Fig. 11a), when a sharp increase was observed. These spikes are more than likely associated with misreporting of the swordfish industry, as was described for blue sharks. Linear regression shows an overall significant ($r^2 = 0.51$, $p < 0.05$) increasing slope of 16.7 mt per year, which is mostly due to the unusually large reported landings from 2005 onwards, which, in turn, are mostly correspondent to swordfish, although the correct proportion is unknown.

Fishing gear used for *Isurus oxyrinchus* were 99.7% for multigear, 0.1% for trawling and 0.2% for seining (Table 4), as this species is mostly caught by surface longliners targeting swordfish. Estimated landings using the weighted variation of fishing gear license per year are given in Figure 11b and show that observed values are significantly ($p < 0.00$) and overwhelmingly higher than landings estimated from fishing licenses, during the aforementioned recent years of 2005 to 2009. This suggests shortfin mako sharks are a traditional bycatch species, which is also substantiated by the analysis of price, with observed values not being particularly different than estimated values through inflation (Fig. 11c), although they are significantly higher ($p < 0.02$).

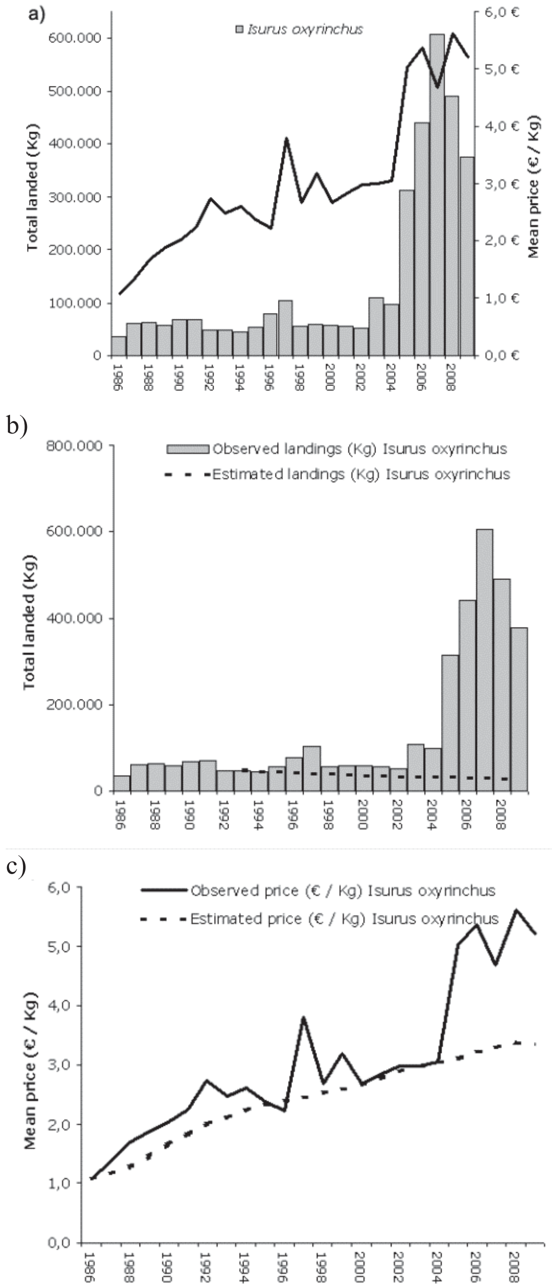


Fig. 11. a) Annual total landed weight (bars) and mean price (line) of *Isurus oxyrinchus*; b) Observed (bars) and estimated (dashed line) annual total landed weight of *I. oxyrinchus*; c) Observed (solid line) and estimated (dashed line) annual mean price of *I. oxyrinchus* in Portugal from 1986 to 2009.

***Torpedo* sp.**

Torpedo rays in Portuguese waters include species *Torpedo marmorata*, *Torpedo nobiliana* and *Torpedo torpedo* (Sanches 1986). However, these individuals are not easily distinguishable and are landed simply as "Torpedo ray", i.e. *Torpedo* spp. Landings are given in Figure 12a and show decreasing trends coupled with an increase in price, much like what was described for *Centrophorus granulosus* and *Mustelus* sp. Torpedo ray landings displayed a significant ($r^2 = 0.66$; $p < 0.05$) decreasing slope of 3.6 mt per year, with numbers stabilizing around 40 mt per year since 1999.

Fishing gear used for *Torpedo* sp. were 92.4% for multigear, 7.1% for trawling and 0.5% for seining (Table 4), with this species being mostly caught by trammel nets targeting demersal and benthic species. Estimated landings using the weighted variation of fishing gear license per year are given in Figure 12b and show that observed values are, in fact, much lower (significantly, $p < 0.00$) than those estimated from boat licenses, strongly suggesting that these species suffered a marked decline in recent years. This is also supported by the analysis of price, with observed values being significantly higher ($p < 0.00$) than estimated values through inflation (Fig. 12c), suggesting that there is a demand for such products. This pattern is similar to the one reported above for *Raja* sp., *Centrophorus squamosus* and *Mustelus* sp.

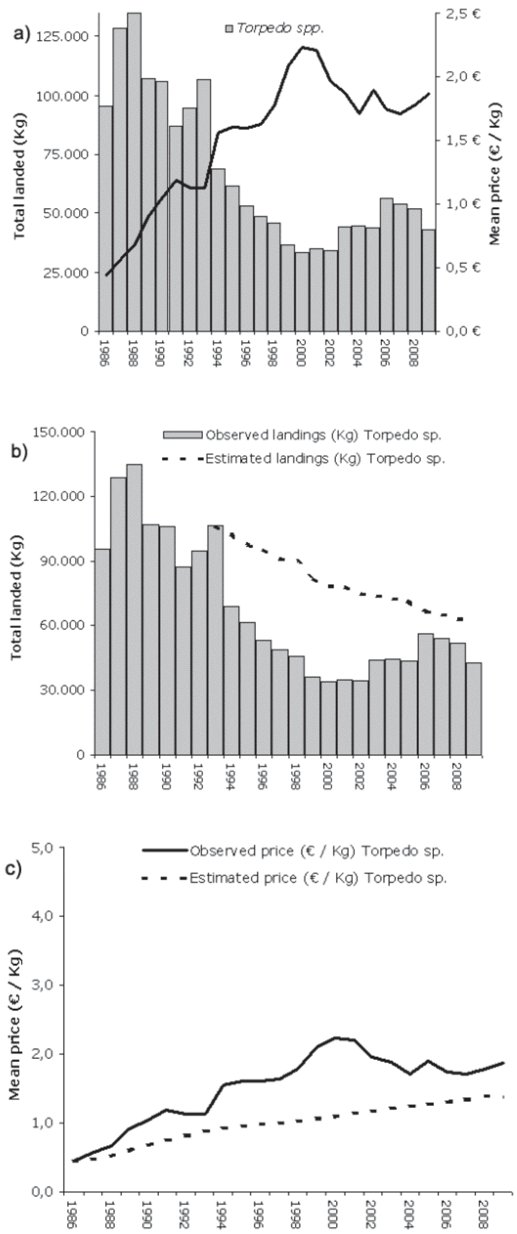


Fig. 12. a) Annual total landed weight (bars) and mean price (line) of *Torpedo* sp.; b) Observed (bars) and estimated (dashed line) annual total landed weight of *Torpedo* sp.; c) Observed (solid line) and estimated (dashed line) annual mean price of *Torpedo* sp. in Portugal from 1986 to 2009.

Dalatias licha

Kitefin shark (*Dalatias licha*) landings are given in Figure 13a and show a very abrupt decline after 1996, with a significant ($r^2 = 0.18$; $p < 0.05$) mean decreasing slope of 12.0 mt per year, and low numbers (averaging 22.5 mt per year) since.

Estimated values of both landings and price are substantially (and significantly, $p < 0.00$) higher than observed values, which may suggest that demand for this product is not met by supply. The landings discrepancy echoes the results for *Raja* sp., *Centrophorus squamosus*, *Mustelus* sp. and *Torpedo* sp. The low price of kitefin sharks, however, suggests demand for this species is low in recent years.

This is most likely due to the fact that this species was landed heavily, mostly in the Azores, during the early 1990s, as their livers were shipped to the Asian market for processing in the cosmetic industry. However, with the advent of synthetic raw materials, market prices decreased for this particular use, and landings decreased accordingly.

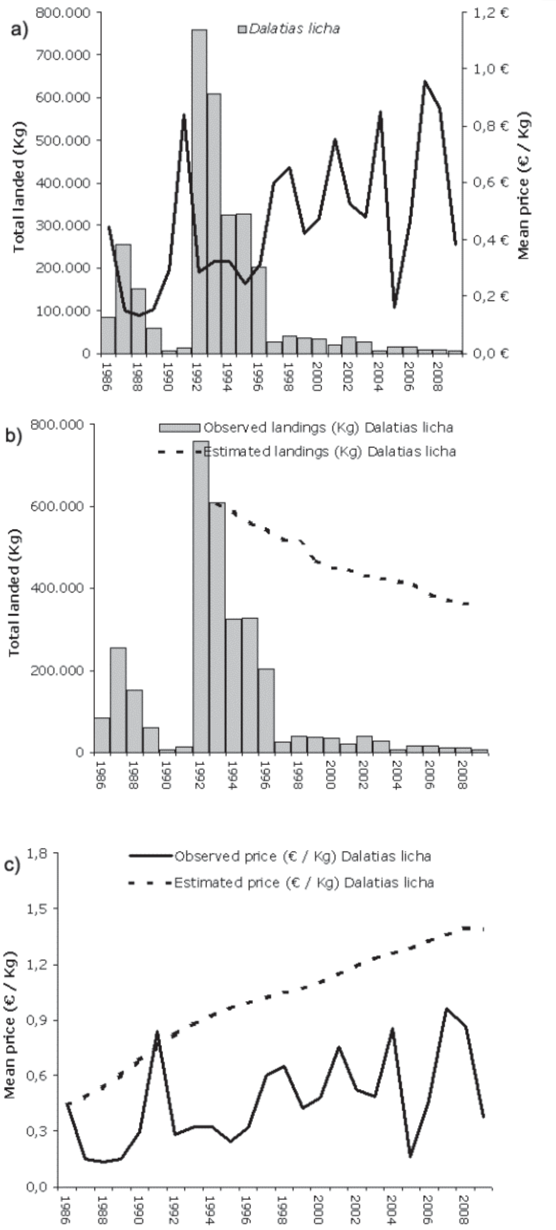


Fig. 13. a) Annual total landed weight (bars) and mean price (line) of *Dalatias licha*; b) Observed (bars) and estimated (dashed line) annual total landed weight of *D. licha*; c) Observed (solid line) and estimated (dashed line) annual mean price of *D. licha* in Portugal from 1986 to 2009.

Galeorhinus galeus

Galeorhinus galeus is the only species of this genus to occur in Portuguese waters (Sanches 1986) and its landings are given in Figure 14a and show a marked decline after 2000, with a significant ($r^2 = 0.58$; $p < 0.05$) mean decreasing slope of 5,1 mt per year.

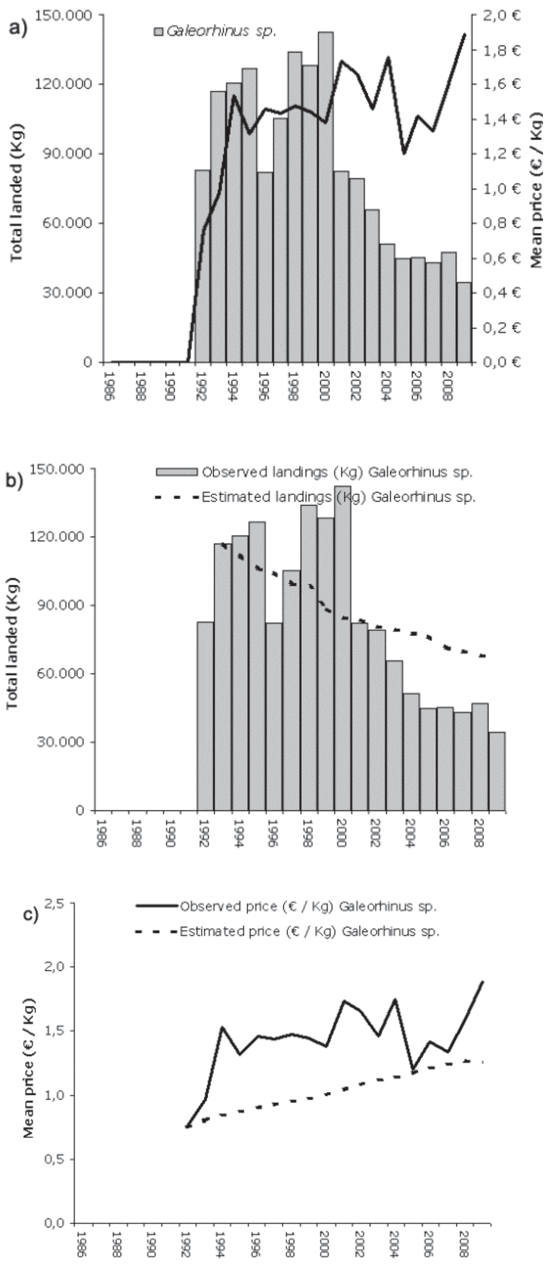


Fig. 14. a) Annual total landed weight (bars) and mean price (line) of *Galeorhinus galeus*; b) Observed (bars) and estimated (dashed line) annual total landed weight of *G. galeus*; c) Observed (solid line) and estimated (dashed line) annual mean price of *G. galeus* in Portugal from 1986 to 2009.

Estimated values of landings are not significantly different ($p < 0.41$) from observed values, but observed values are nonetheless lower than estimated ones. Also, observed prices are significantly higher than estimated ones ($p < 0.00$), which is the pattern described for *Raja* sp., *Centrophorus granulosus*, *Mustelus* sp. and *Torpedo* sp. as well.

Squatina squatina

Squatina squatina is the only species of angel shark described in Portuguese waters (Sanches 1986). Landings are given in Figure 15a and show a very abrupt decrease after 1991, with a significant ($r^2 = 0.36$; $p < 0.05$) mean decreasing slope of 1.8 mt per year, and numbers stabilizing around 600 kg mt per year since 1996.

Fishing gear used for *Squatina* sp. were 96.0% for multigear, 3.1% for trawling and 0.9% for seining (Table 4), with this species being mostly caught by gill-nets targeting demersal and benthic species. However, numerous contacts with local fishermen have indicated a very specific explanation for the abrupt decrease in the early 1990's, which is related to the fact that these species were mostly caught in North Africa, namely in Morocco. As fisheries trade agreements between the European Union and Morocco ceased, landings decreased quite substantially. These species have been the subject of much attention from the conservationist community and are listed as "critically endangered" in Cavanagh and Gibson's publication (2007) on the status of Mediterranean species. Estimated landings given in Figure 15b and show that estimated values are substantially higher than observed values (although not significantly, $p > 0.36$), which is explained by the fact that the ceasing of the fisheries agreement drove landings to be much lower than its respective fleet size. The analysis of price displays observed prices fluctuating above and below estimated values through inflation (Fig. 15c), albeit significantly higher ($p < 0.01$), suggesting that there is an occasional demand for such products.

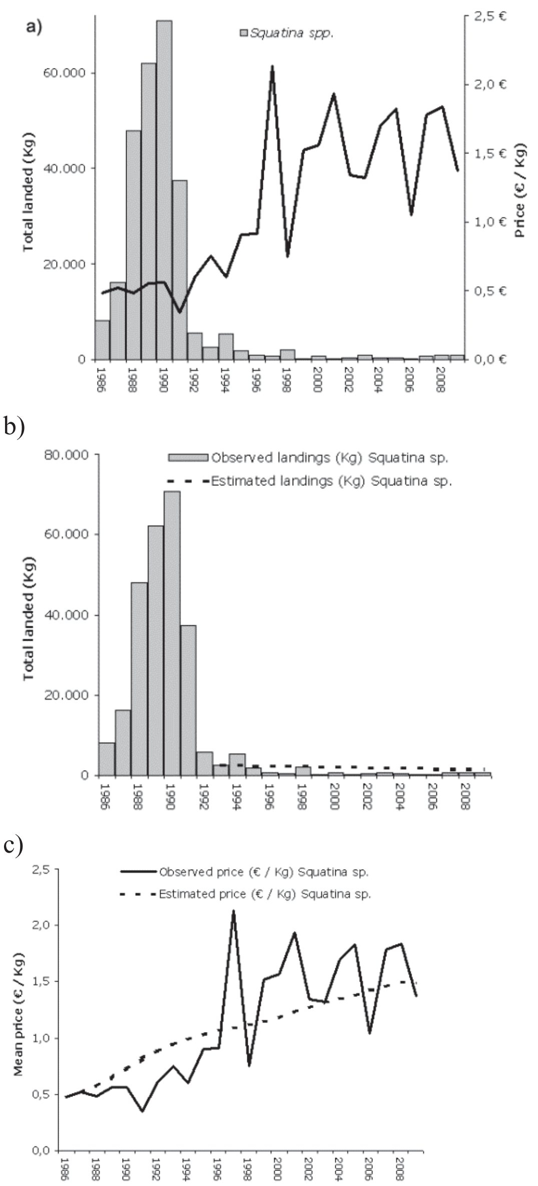


Figure 15. a) Annual total landed weight (bars) and mean price (line) of *Squatina* sp.; b) Observed (bars) and estimated (dashed line) annual total landed weight of *Squatina* sp.; c) Observed (solid line) and estimated (dashed line) annual mean price of *Squatina* sp. in Portugal from 1986 to 2009.

SUMMARY OF RESULTS AND DISCUSSION PER TAXA

The previous analyses allowed for the distinction of three categories for the analysed taxa, similarly to the analyses conducted by Correia & Smith (2004) and Correia (2009): category I species show a significant decreasing trend of landings, with an increasing trend of price over time; category II species show a significant increasing trend of landings with time; and category III species do not show any significant trends in landings and/or price with time. The category assigned to each taxa is described in Table 5, with category I taxa being the most vulnerable to overfishing: *Raja* sp., *Centrophorus granulosus*, *Dalatias licha*, *Mustelus* sp., *Torpedo* sp., *Galeorhinus* sp. and *Squatina* sp. The analyses conducted in the present study also revealed that “Category I” taxa all show, except for *Raja* sp. and *Dalatias* sp., observed landings that are significantly lower than those estimated by the number of licences and observed prices that are significantly higher than those estimated by inflation.

RESULTS AND DISCUSSION FOR MAFA ANALYSES

MAFA analysis for **pelagic sharks** revealed two very significant trends, MAFA 1 and MAFA 2 axes (p = 0.000 and p = 0.001, respectively), with high autocorrelation factors (0.909 and 0.652, respectively). The first trend (MAFA 1 axis) shows relatively stable landings over time with a pronounced peak around 2007 while MAFA 2 shows a peak in 1995, quickly followed by a decline and second, lower, peaks in 2003 and 2007 (Figure 16).

Landings of *Prionace glauca* and *Isurus oxyrinchus* were significantly correlated to MAFA 1 (0.63 and 0.99, respectively), while *Alopias vulpinus* was almost significantly correlated (0.44; cutoff for significance = 0.5). These results are in

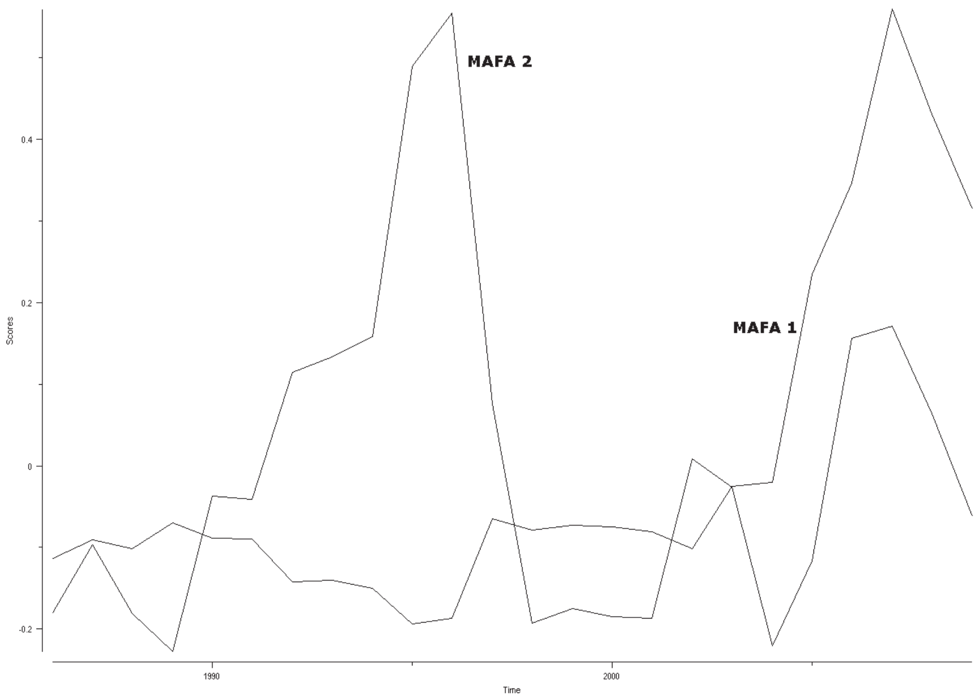


Figure 16. MAFA 1 and MAFA 2 trends for pelagic sharks landed in Portugal from 1986 to 2009.

agreement with the trends in landings of these three species, which show marked increases in recent years. Only *Carcharhinus* sp. was significantly correlated with MAFA 2 (0.89), where landings peaked around 1995 and decreased thereafter. Canonical correlations between explanatory variables and MAFA 1 and MAFA 2 axes revealed a significant relationship between "international" landings and MAFA 2. These results are in accordance with empirical knowledge, since multiple fisheries trade agreements between Europe and other countries ceased in the 90s, therefore significantly decreasing landings in foreign countries.

MAFA analysis for **deep-sea sharks** revealed two very significant trends, MAFA 1 and MAFA 2 ($p = 0.000$ and $p = 0.000$, respectively), with high autocorrelation factors (0.925 and 0.834, respectively). The first trend shows a steady increase until 1997 and a slow decrease since. MAFA 2 shows oscillating landings until 1997 and then a steady increase until 2009 (Fig. 17).

Canonical correlations for MAFA 1 were close to being significant for *Centroscymnus coelolepis* (0.40), again echoing landings results, which showed an increase with time and a decrease in recent years, particularly after the establishment of the TAC for deep-sea sharks in 2007. Canonical correlations for MAFA 2 were very significant for *Centrophorus squamosus* (0.85), also echoing landings results, which revealed steadily increasing values since the early 1990s. Canonical correlations between explanatory variables and MAFA 1 and MAFA 2 revealed significant negative relationships between all fisheries related explanatory variables and MAFA 2, which is in agreement with the aforementioned decrease in fishing licenses over time.

MAFA analysis for **demersal sharks** revealed two very significant trends, MAFA 1 and MAFA 2 ($p = 0.000$ and $p = 0.000$, respectively), with high autocorrelation factors (0.965 and 0.926, respectively). The first trend shows a steady decline until 2001 and a slow increase since. MAFA 2 increases until it peaks in 1995 and then declines (Fig. 18).

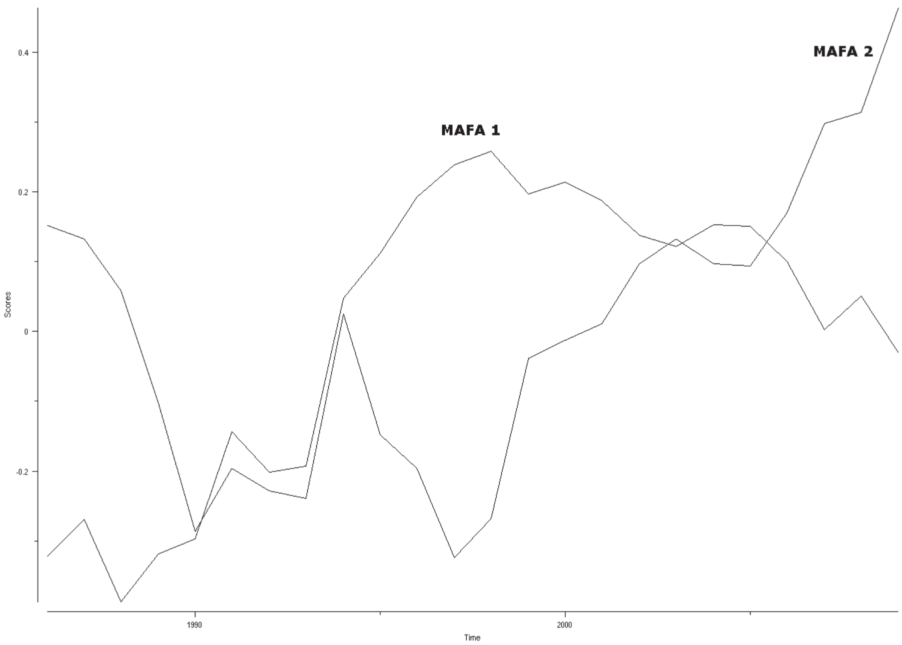


Fig. 17. MAFA 1 and MAFA 2 trends for deep-sea sharks landed in Portugal from 1986 to 2009.

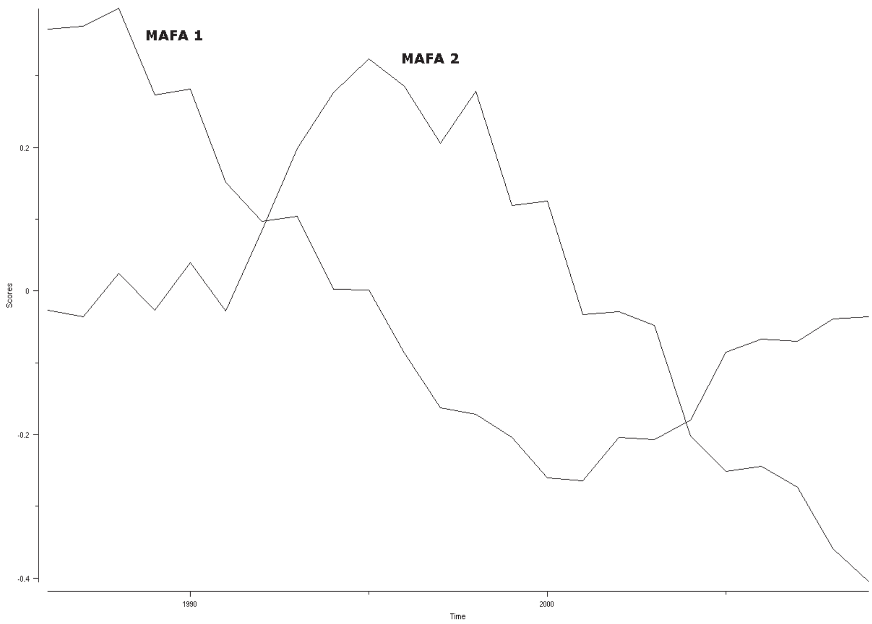


Fig. 18. MAFA 1 and MAFA 2 trends for demersal sharks landed in Portugal from 1986 to 2009.

Canonical correlations for MAFA 1 were significant for *Raja* sp. (0.54), *Mustelus* sp. (0.79), *Torpedo* sp (0.95) and *Squatina* sp. (0.70). These are very interesting results, since *all* of these four taxa were placed in "Category 1" when observed landings and price were compared to their estimated values. These highly significant canonical correlations with the decreasing trend depicted by MAFA 1 support the need for protective measures. Canonical correlations for MAFA 2 (Table 5) were significant for *Dalatias licha* (0.45) and *Myliobatis aquila* (0.51) but *highly* significant for *Galeorhinus* sp. (0.88), also echoing landings results, which revealed steadily decreasing values since the 1990s.

It should be noted that pelagic, deep-sea and demersal sharks all revealed an absence of significant correlation between MAFA 1, MAFA 2 and environmental explanatory variables, suggesting these factors have very little influence on elasmobranch fisheries. However, while canonical correlations between pelagic / deep-sea sharks and fisheries related explanatory variables were not significant, these correlations were highly significant between demersal sharks and fisheries related explanatory variables. This suggests the decrease in fleet size might be playing a relevant role in the decrease of demersal shark landings.

CONCLUSIONS

The first aspect that becomes obvious by looking at the summary table (Table 5) is the fact that "category I" species are the same appointed by Correia & Smith (2004), who analysed similar data corresponding to a time series between 1986 and 2001. They are again the same species categorized by Correia (2009), who analysed similar data from 1986 to 2006. The expansion of the data set to 2009, and inclusion of MAFA analysis, correlated the same species to a decreasing trend. There is, hence, consistency in the assumption that these species have been under heavy commercial exploitation over the years and merit closer monitoring. Observed landings of "category I" species were all substantially lower than landings estimated by variation in fishing gear, in addition, observed prices for these species were higher than prices estimated through inflation. In conclusion, we show that three different methods (1 estimated vs. observed landings, 2 estimated vs. observed prices, and 3 MAFA) corroborate each other by strongly suggesting the same species to be under heavy commercial exploitation. These species are *Raja* sp., *Centrophorus granulosus, Mustelus* sp., *Torpedo* sp., and *Squatina* sp.

ACKNOWLEDGMENTS

The authors would like to acknowledge the DGRM for providing the data, the students from the superior School of Tourism and Sea Technology, who assisted with the trips on board fishing boats, and the fishermen who kindly donated their time and information. We would also like to thank Drs. Julia Spät and Helen Rost Martins for their valuable suggestions to the manuscript.

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Received 22 Feb 2016. Accepted 20 Sep 2016, Published online 28 Oct 2016.