Elasmobranch Landings for the Portuguese Commercial Fishery From 1986 to 2001

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Introduction

Fishing has been important to the livelihood of the Portuguese for centuries. Some coastal communities are almost totally dependent on fishing or related activities (DGPA, 1998). The nation's fishing grounds are delineated by an EEZ (Exclusive Economic Zone) of 1,700,000 km^2, encompassing both continental Portugal (with a coastline of 942 km) and two large insular regions surrounding the Azores and Madeira (DGPA, 1998).

Historically, fisheries have targeted elasmobranchs to supply the liver-oil or "squalene" market (Holts, 1988; Last and Stevens, 1994). Elasmobranchs have also been landed, and in many cases discarded, as the bycatch of other fisheries (Berkeley and Campos, 1988; Stevens, 1992). More recently, however, elasmobranchs have been targeted specifically to provide a source of protein in the form of meat and fins (Cailliet and Bedford, 1983; Holts, 1988).

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ABSTRACT—Portuguese commercial elasmobranch landings were analyzed for the period 1986–2001. An average of 5,169 (± 795 t) were landed yearly, representing 18 families, 29 genera, and 34 confirmed species. However, annual landings for the fishery generally decreased over time, with a corresponding increase in price per kilogram. The most important group, Raja *spp., accounted for 33% of the landings or 26,916 t. They were followed by* Centroscymnus coelolepis, Scyliorhinus *spp.,* Centrophorus granulosus, *and* Centrophorus squamosus *(accounting for 12%, 12%, 11%, and 9% of the landings, respectively). In the absence of CPUE data, the comparative trends of landings and price were employed as an indicator of the "status" of specific elasmobranch species.* Raja *spp.,* Centrophorus granulosus, Mustelus *spp.,* Torpedo *spp., and Squatinidae displayed indications of possible overexploitation, and they merit the focus of future research.*

The life history of elasmobranchs is characterized by slow growth rates, late maturity, long gestation periods, and the production of a small number of offspring (Holden, 1973; Pratt and Casey, 1990). These characteristics are customarily coupled with a distinctive predatory behavior (Gruber, 1982). Elasmobranchs therefore frequently represent an important "apex" role within their respective food web, and the depletion of their stocks could potentially cause a rapid and profound negative impact upon the ecosystem from which they are drawn (Gruber, 1982).

In addition, the nature of their life history frequently subjects elasmobranchs to a "high risk" of overfishing (Holden, 1973, 1974, 1977). Many publications highlight the inability of elasmobranchs to sustain strong fishing pressure for any extended period, as overfishing often translates into a rapid decline of population numbers (Pratt and Casey, 1990; Pepperell, 1992; Stevens, 1992; Musick et al., 1993; Sminkey and Musick, 1995). The delicate nature of elasmobranch populations emphasizes the need for effective conservation and management measures for this important taxonomic group.

In 1983, the Portuguese elasmobranch fishery expanded rapidly due to an increasing demand for shark by-products (i.e. oil, liver, etc.) and as the bycatch of an accelerated deep-sea teleost fishery (Nunes et al.[1]). In 1985, the demand for shark by-products peaked (oil prices reached US$4.00 ~ US$5.00 per liter) and then declined from 1987 to 1999 (oil prices decreasing to less than US$1.00 per liter) (Nunes et al.[1]). During the same period, the demand for elasmobranch flesh steadily increased, and at present, this represents the principal elasmobranch product marketed in Portugal. The flesh of these fishes is sold for human consumption either directly (in the case of many species of Rajidae and Squalidae) or indirectly (i.e. processed into other food products) (Nunes et al.[1]).

Portugal's elasmobranch fishery is not regulated, and thus there are no established size or catch quota limits. The "fishery" consists mainly of: 1) targeted deep-sea elasmobranch longlining; 2) targeted pelagic elasmobranch surface longlining; 3) bycatch of deep-sea elasmobranchs from black scabbardfish, *Aphanopus carbo*, longlining; 4) bycatch of pelagic elasmobranchs from teleost gill-netting, purse seining, and bottom trawling; and 5) bycatch of skates and rays from crustacean bottom trawling.

Despite their species' high-risk nature, elasmobranch fisheries have been little studied in this region. In Portugal, what little work has been published consists mainly of internal reports, most of which came from the Portuguese Marine Research Institute (Instituto de Investigação das Pescas e do Mar, IPIMAR)

[1] Nunes, M. L., I. Baptista, R. M. Campos, and A Viegas. 1989. Aproveitamento e valorização de algumas espécies de tubarão. Relat. Téc. Cient. INIP, Lisboa, 7, 38 p.

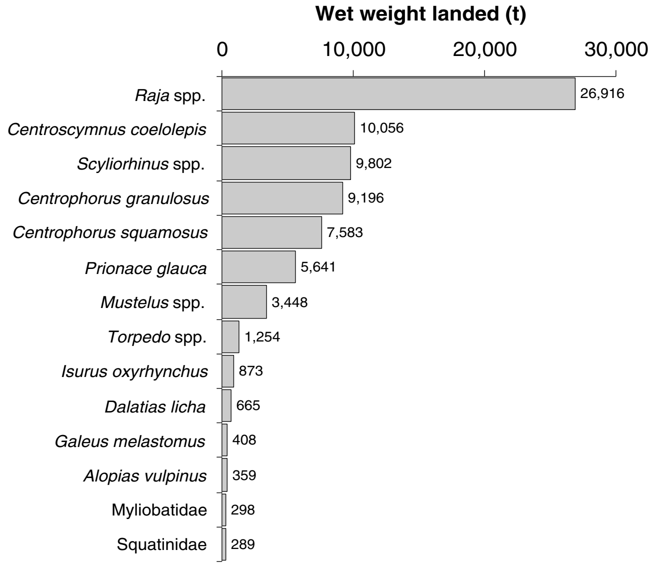

Figure 1.—Distribution of catch (wet weight landed) for each of the 14 most heavily landed elasmobranch species (> 250 t) reported in the Portuguese commercial fishery between 1986 and 2001.

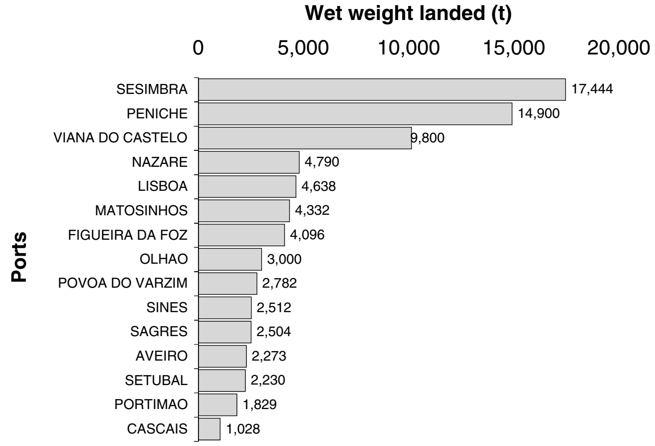

Figure 2.—Distribution of catch (wet weight landed) for each of the 15 ports with the heaviest landings (> 1,000 t) of elasmobranchs reported in the Portuguese commercial fishery between 1986 and 2001.

(Silva[2,3,4], Silva and Pereira[5], and Figueiredo et al.[6]). This paper provides an introductory overview of the commercial Portuguese elasmobranch fishery and its evolution over the period between 1986 and 2001 and suggests possible avenues of future research.

Data Sources

The data for this study were obtained from the central commercial fishery authority for the Portuguese government (Direcção Geral das Pescas). Landed weights were totaled for each species, for all ports, for 1986–2001. Species whose landed weight exceeded 250 t are shown in Figure 1.

Landed weights were compiled by port for all species during the period. Ports with landings of >1,000 t are shown in Figure 2. Ports or regions with landings for a specific species >25% of the total landings of that species for all of Portugal, are shown in Figure 3. Annual species landings trends were further examined using a linear regression analysis (Table 1, Fig. 4–13).

Mean yearly price per kilogram (PPK) was calculated per species to examine changes in "demand" and the results of linear regression analysis are given in Table 2. Mean yearly PPK for all species was also calculated (Fig. 14).[7]

Changes in fishing "effort" during the study period were examined. The number of vessels registered to fish in Portuguese waters was totaled for each year between 1992 and 2000 and trends were examined. (No data were available for 1986–1991.)

Yearly weight landings and mean yearly PPK's were compared to examine the current "status" of the 14 most heavily landed elasmobranch, i.e. the slopes of the regression analyses of yearly landings and mean yearly PPK's, for each species, were reviewed (Table 2), and those species exhibiting significant trends are shown in Figures 4–13.

Catch and Effort History

During the 16-year study period, the total landed weight of elasmobranchs was 82,704 t, averaging 5,169 t (± 795 t) per year. These landings represented 18 families, 29 genera, and 34 species of shark and ray (Table 1). The ten groups most often landed were *Raja* spp., *Centroscymnus coelolepis*, *Scyliorhinus* spp., *Centrophorus granulosus*, *Centrophorus squamosus*, *Prionace glauca*, *Mustelus* spp., *Torpedo* spp., *Isurus oxyrinchus*, and *Dalatias licha* (Fig. 1), and they accounted for 91.2% of the total weight landed (75,433 t).

Care should be taken when examining these results, as the fishermen often identified elasmobranchs by their common

[2] Silva, H. M. 1983. Preliminary studies of the exploited stock of kitefin shark *Scymnorhinus licha* (Bonnaterre, 1788) in the Azores. ICES/CM 1983/G:18, 13 p.

[3] Silva, H. M. 1987. An assessment of the Azorean stock of kitefin shark *Dalatias licha* (Bonnaterre, 1788). ICES/CM 1987/G:66, 10 p.

[4] Silva, H. M. 1988. Growth and reproduction of kitefin shark *Dalatias licha* (Bonnaterre, 1788) in Azorean waters. ICES/CM 1988/G:21, 15 p.

[5] Silva, A. A., and J. J. Pereira. 1999. Catch rates for pelagic sharks taken by the Portuguese swordfish fishery in the waters around the Azores, 1993–1997. ICCAT SCRS/98, 12 p.

[6] Figueiredo, I., M. J. Figueiredo, and O. Moura. 1995. Distribution, abundance and size composition of blackmouth catshark (*Galeus melastomus*) and small-spotted dogfish (*Scyliorhinus canicula*) on the slope of the Portuguese South and Southern West coasts. ICES/CM 1995/G:9, 38 p.

[7] PPK was converted from PTE (Portuguese Escudos) to US$ (United States dollars) using the mean conversion rate for 1999 of 195 to 1.

name. Experience has demonstrated that the fishermen and fishery officials were accurate at identifying individual elasmobranch species. However, two taxa were notable for the way in which they were inappropriately recorded. First, 1.9% (or 1,564 t) of the total landings were attributed to the group "pleurotremata," a taxonomic term adopted for those shark species that fishermen could not identify accurately. Hence, the group "pleurotremata" was excluded from Figure 1. Second, 1.3% (or 1,036 t) of the total landings were attributed to *Oxynotus centrina*. The Portuguese common name for this species, "peixe porco," is also the common name for a local teleost, *Balistes carolinensis*. Hence, the data for *Oxynotus centrina* was considered unreliable and was also excluded from Figure 1. Finally, 290 t of elasmobranch liver and 2,101 t of elasmobranch oil were also landed during the period between 1986 and 2001. These totals are still included in the grand total of 82,704 t.

The ten ports with the highest landings were Sesimbra, Peniche, Viana do Castelo, Nazaré, Lisboa, Matosinhos, Figueira da Foz, Olhão, Póvoa do Varzim, and Sines (Fig. 2). These ports accounted for 82.6% of the landings, or 68,295 t. The remaining 17.4% of the total weight landed was drawn from an additional 59 ports scattered throughout continental Portugal.

Some elasmobranch species were landed along much of the coast of Portugal. These included *Raja* spp., *Scyliorhinus* spp., *Torpedo* spp., *Isurus oxyrinchus*, *Galeus melastomus*, *Dasyatidae*, *Hexanchus griseus*, *Lamna nasus*, *Cetorhinus maximus*, *Echinorhinus brucus*, and *Etmopterus* spp. (Fig. 3). Other elasmobranch species were often caught in specific regions. Total annual landings have been decreasing since 1990 and remained below 5,000 t after 1993 (Fig. 14).

Yearly landings for *Centroscymnus coelolepis* demonstrated a significant increase over the test period (Fig. 5, Table 2). Significant increases in yearly landings were also observed for *Scyliorhinus* spp., and *Galeus melastomus* (Fig. 6, 12, and Table 2). Significant

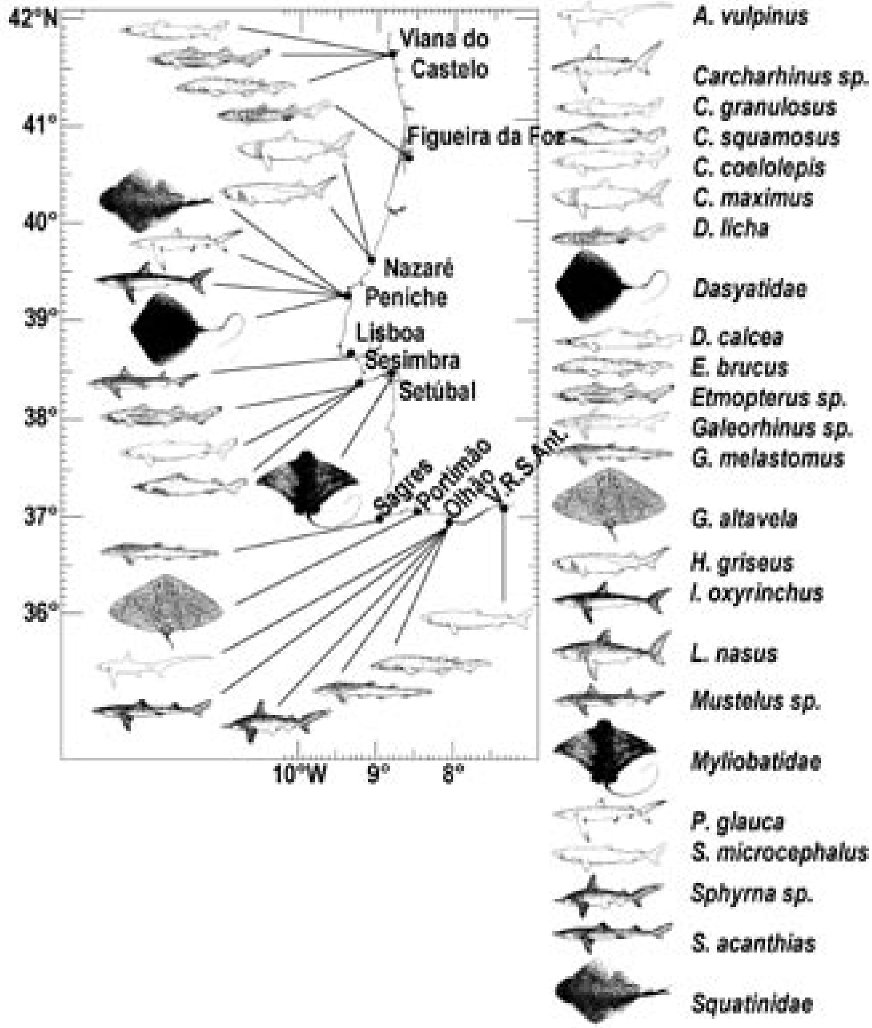

Figure 3.—Distribution of heavy elasmobranch landings by port (where species weight landed is >25% of the total species weight landed for all of continental Portugal), for the Portuguese commercial fishery, between 1986 and 2001.

decreases in yearly landings were observed for *Raja* spp., *Centrophorus granulosus*, *Mustelus* spp., *Torpedo* spp., and Squatinidae (Fig. 4, 7, 10, 11, 13, and Table 2).

As would be expected, mean yearly PPK values increased over the test period for all species, reflecting a price increase associated with inflation (Table 2). However, some species demonstrated marked average annual increases of over 10% per annum. Annual average PPK increases were 10% for *Raja* spp., 8% for *Centroscymnus coelolepis*, 8% for *Scyliorhinus* spp., 12% for *Centrophorus granulosus*, 9% for *Centrophorus squamosus*, 17% for *Prionace glauca*, 10% for *Mustelus* spp., 12% for *Torpedo* spp., 9% for *Isurus oxyrinchus*, 22% for *Dalatias licha*, 16% for *Galeus melastomus*, 14% for *Alopias vulpinus*, 8% for *Myliobatidae*, and 20% for Squatinidae. These PPK increases exceeded the official annual average inflation rate in Portugal during the same period of 4.64% ± 0.92% (Pereira[8]).

[8] Pereira, A. E. 2000. A inflação e o índice de preços no consumidor. Dossiers didácticos. Instituto Nacional de Estatística, Lisboa, 21 p.

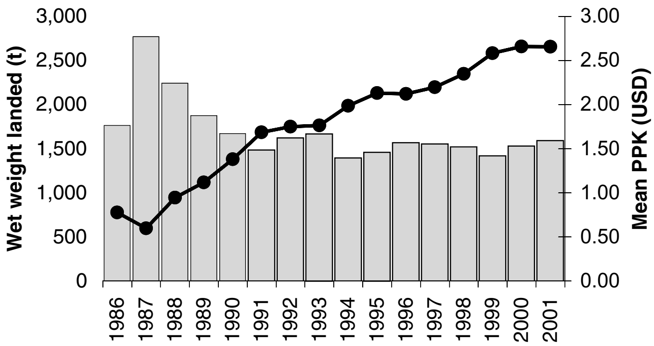

Figure 4.—Annual wet weight landings for *Raja* spp. Mean annual PPK (price per kilogram in US$) is represented by solid line.

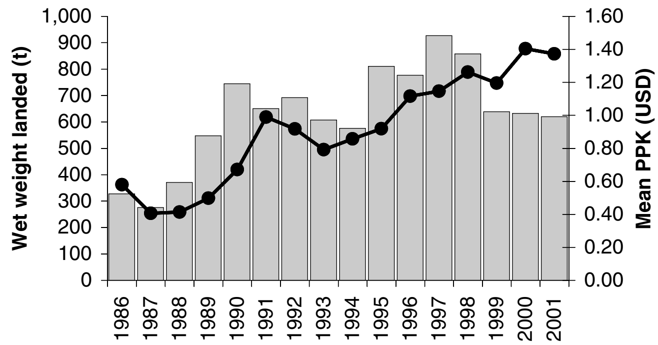

Figure 5.—Annual wet weight landings for *Centroscymnus coelolepis*. Mean annual PPK (price per kilogram in US$) is represented by solid line.

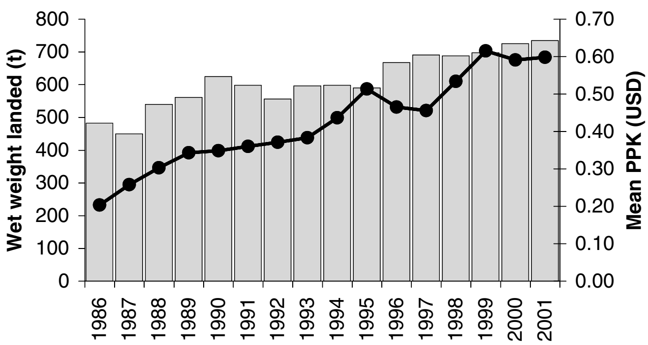

Figure 6.—Annual wet weight landings for *Scyliorhinus* spp. Mean annual PPK (price per kilogram in US$) is represented by solid line.

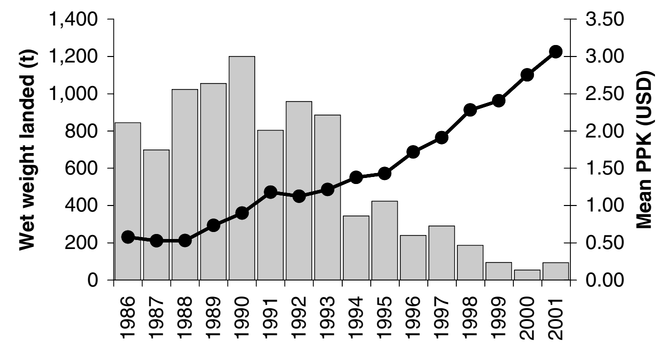

Figure 7.—Annual wet weight landings for *Centrophorus granulosus*. Mean annual PPK (price per kilogram in US$) is represented by solid line.

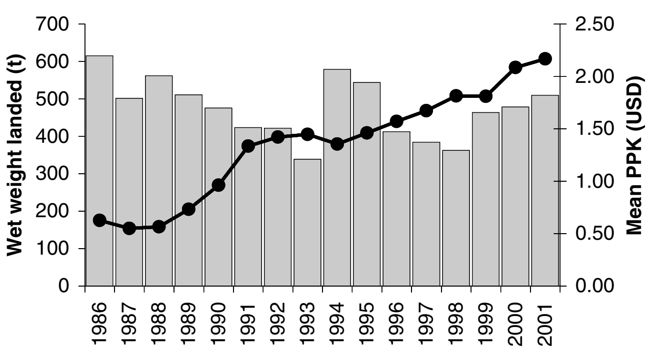

Figure 8.—Annual wet weight landings for *Centrophorus squamosus*. Mean annual PPK (price per kilogram in US$) is represented by solid line.

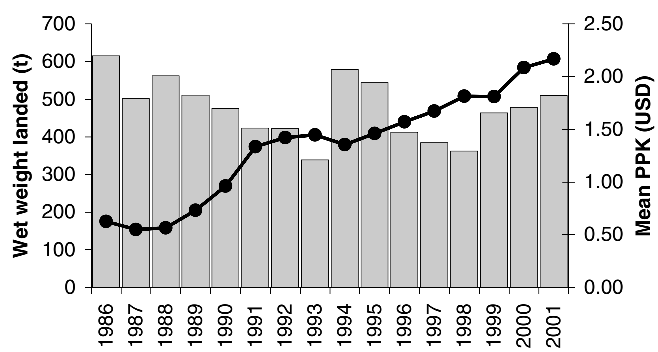

Figure 9.—Annual wet weight landings for *Prionace glauca*. Mean annual PPK (price per kilogram in US$) is represented by solid line.

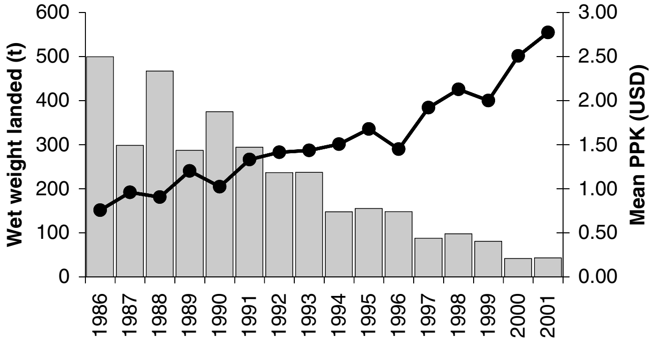

Figure 10.—Annual wet weight landings for *Mustelus* spp. Mean annual PPK (price per kilogram in US$) is represented by solid line.

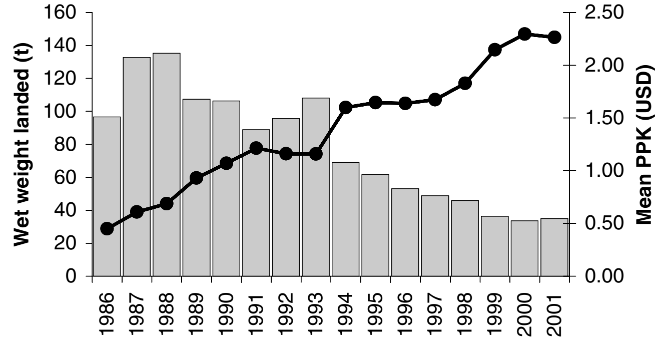

Figure 11.—Annual wet weight landings for *Torpedo* spp. Mean annual PPK (price per kilogram in US$) is represented by solid line.

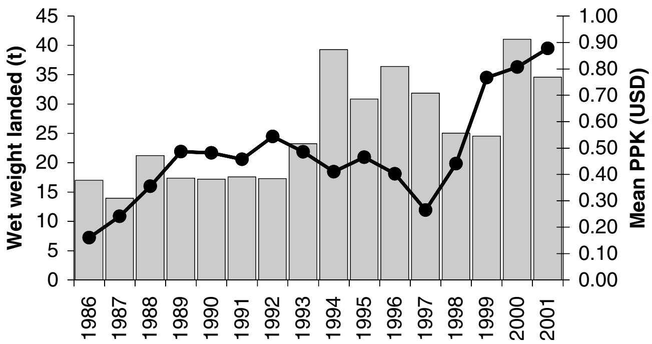

Figure 12.—Annual wet weight landings for *Galeus melastomus*. Mean annual PPK (price per kilogram in US$) is represented by solid line.

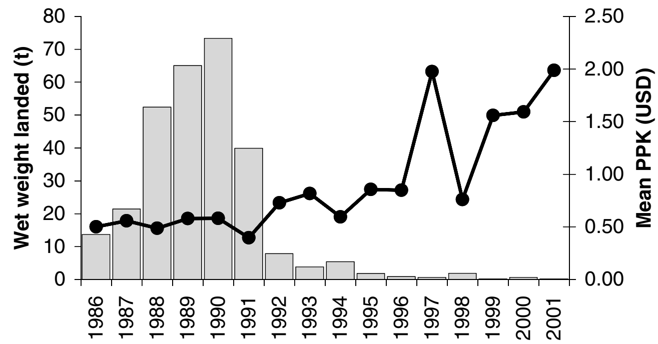

Figure 13.—Annual wet weight landings for Squatinidae. Mean annual PPK (price per kilogram in US$) is represented by solid line.

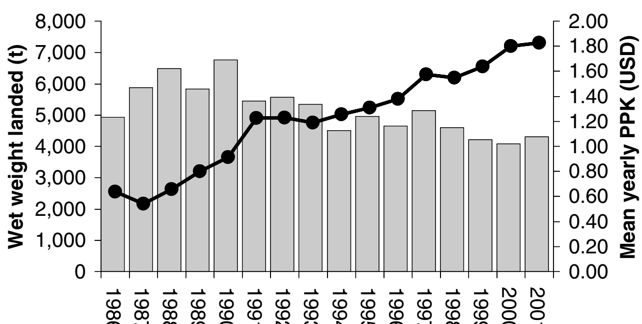

Figure 14.—Annual elasmobranch landings reported in the Portuguese commercial fishery between 1986 and 2001. Mean annual PPK (price per kilogram in US$) is represented by the solid line.

Mean yearly PPK for all elasmobranch landings increased from 0.64 in 1986 to 1.83 in 2001; a mean yearly increase of 7.88% ± 12% (Fig. 14). Interestingly, mean yearly PPK briefly peaked in 1991. During the previous year, total landings reached a maximum peak at 6,768 t and then dropped by 19.5% to 5,451 t (Fig. 14). The increased mean yearly PPK in 1991 could therefore possibly reflect an increased demand for elasmobranch fishes during that year (Fig.14) which was not echoed by sufficient landings.

The total number of registered fishing vessels decreased from 6,864 in 1992 to 5,013 in 2000, a decrease of 27% or a mean yearly decrease of 3.84% ± 1.85%. During the same period, landings of *Scyliorhinus* spp. increased (from 556 to 725 t, an increase of 30%) (Fig. 6). This was repeated for *Centrophorus squamosus* (from 422 to 478 t, an increase of 13%) (Fig. 8), *Galeus melastomus* (from 17 to 41 t, an increase of 137%) (Fig. 12), and *Alopias vulpinus* (from 13 to 15 t, an increase of 12%).

During the same period (i.e. 1992–2000), landings of *Centrophorus granulosus* decreased at a much greater rate than the total vessels registered (from 958 to 54 t, a decrease of 94%) (Fig. 7). Similar observations were made for *Prionace glauca* (from 374 to 316 t, a decrease of 16%) (Fig. 9), *Mustelus* spp. (237 to 41 t, a decrease of 83%) (Fig. 10), *Torpedo* spp. (from 96 t to 34 t, a decrease of 65%) (Fig. 11), *Dalatias licha* (from 25 t to 5 t, a decrease of 80%), *Myliobatidae* (from 15 t to 9 t, a decrease of 43%), and Squatinidae (from 8 t to 1 t, a decrease of 92%) (Fig. 13).

Table 1.—Species of elasmobranchs recorded in Portuguese waters, indicating: species with confirmed landings (•) and unconfirmed landings (?) by the commercial fishery (after Sanches, 1986).

Order	Species	Order	Species
Lamniformes	? *Alopias superciliosus*	Squaliformes (cont.)	• *Somniosus microcephalus*
	• *Alopias vulpinus*		*Somniosus rostratus*
	Carcharodon carcharias		*Squaliolus laticaudus*
	• *Cetorhinus maximus*		• *Squalus acanthias*
	• *Isurus oxyrinchus*		? *Squalus blainvillei*
	• *Lamna nasus*	Hexanchiformes	*Chalmydoselachus anguineus*
	? *Mitsukurina owstoni*		*Heptranchias perlo*
	Odontaspis ferox		• *Hexanchus griseus*
	Odontaspis noronhai	Pristiformes	*Pristis pristis*
Carchariniformes	*Apristurus laurussonii*	Squatiniformes	• *Squatina squatina*
	? *Carcharhinus falciformis*	Torpediniformes	? *Torpedo marmorata*
	? *Carcharhinus limbatus*		? *Torpedo nobiliana*
	? *Carcharhinus longimanus*		? *Torpedo torpedo*
	? *Carcharhinus obscurus*	Rajiformes	*Amblyraja radiata*
	? *Carcharhinus plumbeus*		? *Dasyatis centroura*
	• *Galeorhinus galeus*		? *Dasyatis pastinaca*
	• *Galeus melastomus*		*Dipturus batis*
	• *Mustelus asterias*		*Dipturus linteus*
	• *Mustelus mustelus*		*Dipturus oxyrinchus*
	• *Prionace glauca*		• *Gymnura altavela*
	Pseudotriakis microdon		• *Leucoraja circularis*
	Rhizoprionodon acutus		*Leucoraja fullonica*
	• *Scyliorhinus canicula*		*Leucoraja naevus*
	? *Scyliorhinus stellaris*		*Manta birostris*
	• *Sphyrna zygaena*		*Mobula mobular*
Squaliformes	• *Centrophorus granulosus*		• *Myliobatis aquila*
	• *Centrophorus squamosus*		*Pteromylaeus bovinus*
	• *Centroscymnus coelolepis*		? *Raja asterias*
	Centroscymnus crepidater		? *Raja brachyura*
	Centroscymnus cryptacanthus		• *Raja clavata*
	• *Dalatias licha*		? *Raja maderensis*
	• *Deania calcea*		? *Raja microocellata*
	• *Echinorhinus brucus*		? *Raja miraletus*
	• *Etmopterus pusillus*		? *Raja montagui*
	• *Etmopterus spinax*		• *Raja undulata*
	• *Oxynotus centrina*		*Rhinobatos rhinobatos*
	Scymnodon obscurus		*Rostroraja alba*
	Scymnodon ringens		

Table 2.—Slopes of species landings and price per kilogram (PPK) as estimated using a linear regression analysis for each of the 16 most heavily landed elasmobranchs reported in the Portuguese commercial fishery between 1986 and 1999. Species with significance of F value < 0.05 (marked with *) displayed a significant change over time for the parameter analyzed. This change was an increase if the corresponding slope was positive and a decrease if the corresponding slope was negative.

	Landings (kg/year)				PPK (US$/year)					
Species	Slope	r^2	Sig. F	Rem.	Slope	r^2	Sig. F	Rem.	n	Category[1]
Raja spp.	–47.413	0,41	0,01	*	0,13	0,960	0,00	*	16	III
Centroscymnus coelolepis	24.983	0,42	0,01	*	0,06	0,893	0,00	*	16	II
Scyliorhinus spp.	16.400	0,87	0,00	*	0,02	0,944	0,00	*	16	II
Centrophorus granulosus	–72.067	0,75	0,00	*	0,16	0,946	0,00	*	16	III
Centrophorus squamosus	–6.461	0,15	0,14		0,10	0,941	0,00	*	16	I
Prionace glauca	10.733	0,23	0,06		0,05	0,744	0,00	*	16	I
Mustelus spp.	–28.265	0,88	0,00	*	0,11	0,909	0,00	*	16	III
Torpedo spp.	–6.731	0,85	0,00	*	0,12	0,970	0,00	*	16	III
Isurus oxyrinchus	–238	0,00	0,80		0,12	0,635	0,00	*	16	I
Dalatias licha	–9.716	0,44	0,00	*	0,06	0,701	0,00	*	16	III
Galeus melastomus	1.434	0,58	0,00	*	0,03	0,508	0,00	*	16	II
Alopias vulpinus	–755	0,02	0,57		0,07	0,816	0,00	*	16	I
Myliobatidae	–164	0,02	0,64		0,05	0,830	0,00	*	16	I
Squatinidae	–3.434	0,42	0,01	*	0,09	0,643	0,00	*	16,00	III

[1] Category I: significant changes were not discernible for landings and / or price and therefore the status of the species was undetermined; Category II: significantly increasing landings and significantly increasing price were interpreted as a species subjected to possible commercial exploitation; Category III: significantly decreasing landings and significantly increasing price were interpreted as a species subjected to possible risk of over-fishing.

Landings and mean yearly PPK for *Centroscymnus coelolepis* both increased significantly over the period of study (Fig. 5 and Table 2). This observation was repeated for *Scyliorhinus* spp., and *Galeus melastomus* (Fig. 6, 12, and Table 2).

Landings for *Raja* spp. decreased significantly, while mean yearly PPK increased significantly over the period of study (Fig. 4 and Table 2). This observation was repeated for *Centrophrous granulosus*, *Mustelus* spp., *Torpedo* spp., and Squatinidae (Fig. 7, 10, 11, and 13 and Table 2).

Discussion

Between 1986 and 1996, the Portuguese commercial fishing fleet landed 2,437,700 t of fishes and invertebrates, a mean of 221,609 ± 4,827 t per annum (DGPA, 1998). During the same period, 62,333 t of elasmobranchs were landed, constituting 2.56% of the total catch. During the period of this study (1986–2001), mean annual elasmobranch landings were 5,169 ± 795 t. By comparison, Indonesia recorded mean annual landings of 70,000 t between 1987 and 1991. Mexico, the United States, and the Philippines reported mean annual landings of 34,000, 25,000, and 18,000 t, respectively (Bonfil, 1994). By comparison, other European nations such as Spain, Italy, and Norway reported mean annual landings of 18,000, 10,000, and 8,000 t between 1987 and 1991, respectively (Bonfil, 1994).

Information about the distribution of elasmobranch species throughout Portuguese waters has not been previously available except for limited data provided by IPIMAR research surveys (Figueiredo[9,10]). Figure 3 indicates that some elasmobranch species were landed relatively heavily at specific ports, suggesting some relationship between species distribution and geographic location. This possibility is supported by the fact that fishing vessels rarely strayed far from their home port during normal operation (i.e. <20 km except in exceptional circumstances). In addition, modern fishing ports in Portugal have grown up around traditional fishing villages, and there is little evidence to suggest that local demand or infrastructure resulted in heavier landings of specific elasmobranch species in a given region.

One possible reason for the regional difference in elasmobranch landings is an interplay between the distribution of these species throughout Portuguese waters as dictated by their ecology, local bathymetry, and the specificity of different fishing techniques.

The possible effect of bathymetry and fishing techniques on the capture of specific species may be evidenced by the higher landings of *Raja* spp. and *Gymnura altavela* from the port of Olhão. In this region of Portugal, the 1,000 m isobath is approximately 58.8 km from the coastline (Viriato et al., 1996). The shallower conditions in this area favor crustacean bottom trawlers, one of the principal sources of these benthic elasmobranch species.

Similarly, the largest bottom longline fleet in Portugal operates from the port of Sesimbra, located very close to the edge of the continental shelf. Here, the 1,000 m isobath is only 13.7 km from the coastline (Viriato et al., 1996). Vessels from Sesimbra are large and able to operate down to 3,000 m, while vessels from other ports are generally smaller and are seldom able to operate below 1,000 m. During a survey of deep-sea fishes by the Portuguese Marine Research Institute (IPIMAR), one of the authors (Correia[11]) observed that *Centroscymnus coelolepis* was very rarely caught at depths shallower than 800 m. Depth of fishing operation could therefore account for the heavier landings of the deep-sea sharks *Centroscymnus coelolepis* and *Centrophorus squamosus* in this region. Finally, the port of Peniche operated a large surface long line fleet, possibly accounting for the relatively higher landings of *Prionace glauca* and *Isurus oxyrinchus*, and the lower landings of deep-sea sharks.

These examples appear to support the conjecture that the use of specific fishing techniques and operation depths could have been species selective and account for the composition of landings at specific geographic locations. Unfortunately, there is insufficient information available to draw solid conclusions about habitat preferences (Capapé, 1985). In addition, there is a relative lack of literature on the topography of Portuguese waters below 400 m (Viriato et al., 1996). In an effort to better understand the Portuguese EEZ and improve the management of marine resources, the IPIMAR is currently conducting topography surveys along the Portuguese coastline, with the ultimate objective of mapping the sea floor down to a depth of 1,000 m.

The increase in landings demonstrated between 1992 and 1995 (Fig. 14) could be the result of increasing demand. One possible scenario is that an interest in marketing elasmobranchs was rekindled when deep-sea sharks were caught in large numbers as bycatch of the "booming" *Aphanopus carbo* fishery. When the value of the flesh was recognized and demand grew, elasmobranchs may have then been increasingly targeted during the late 1980's and early 1990's.

There have been no CPUE (catch per unit effort) studies for the Portuguese commercial elasmobranch fishery. In the absence of CPUE data, another approach was used to try and get some indication of fishery trends. Changes in the annual landings of each species were compared with changes in a "demand" indicator—mean annual price per kilogram. This allowed some cautious inferences about the "status" of each elasmobranch species. Every species was ranked according to three distinct categories: category I, where significant changes were not discernible for landings and/or price and therefore the status of the species was undetermined; category II, where significantly increasing landings

[9] Figueiredo, I., M. J. Figueiredo, and O. Moura. 1995. Distribution, abundance and size composition of blackmouth catshark (*Galeus melastomus*) and small spotted dogfish (*Scyliorhinus canicula*) on the slope of the Portuguese south and southern west coasts. Int. Council Explor. Sea, Demersal Fish Committee, CM 1995 (G:9), 38 p.

[10] Figueiredo, M. J., I. Figueiredo, and J. Correia. 1996. Caracterização geral dos recursos de profundidade em estudo no IPIMAR. Relat. Cient. Téc. Inst. Port. Invest. Marít. 21, 50 p.

[11] Correia, J. 2003. Oceanário de Lisboa, Doca dos Olivais 1990–005 Lisboa, Portugal.

and significantly increasing price were interpreted as a species subjected to possible commercial exploitation; and category III, where significantly decreasing landings and significantly increasing price were interpreted as a species subjected to possible risk of over-fishing (Table 2). This theoretical approach was supported by the observation that mean yearly price per kilogram briefly peaked in 1991 while landings slumped, potentially reflecting an increased demand by the consumers of elasmobranch fishes during that year.

In general, annual elasmobranch landings decreased over the period between 1986 and 2001. During the same period of time, teleost and invertebrate landings also decreased suggesting that there had not been an obvious shift in target taxa (DGPA, 1998). One reason for this decline was probably as a response to a directive from the European Union to reduce the size of fishing fleets throughout Europe (DGPA, 1998). Between 1992 and 1999 the fishing fleet decreased by 23.1%. This was paralleled by a 23.5% decline in total landings for all species of fishes and invertebrates. However, during the same period elasmobranch landings decreased by 32.7% suggesting that a reduction in the size of the fishing fleet alone did not account for the decline in elasmobranch landings.

Mean price per kilogram increased over the period of study for all of the 14 species examined. This result probably reflects, in part, a natural price increase due to inflation. However, all displayed rates increased well in excess of the official rate of inflation. This suggests that an increased consumer demand was driving the price of elasmobranch meat and by-products higher.

Centroscymnus coelolepis and *Scyliorhinus* spp. demonstrated significantly increased landings and a significantly increased price over the period of study (category II, Table 2). As these species may be subjected to commercial exploitation, their stocks should be monitored closely, allowing the formulation of adequate management strategies.

The rate at which the fishing fleet decreased in size was greatly exceeded by the rate at which landings decreased for all category III species (i.e. *Raja* spp., *Centrophorus granulosus*, *Mustelus* spp., *Torpedo* spp., and Squatinidae). As such, it is possible to suggest that decreasing "effort" alone, did not account for the decreased landings observed. This conjecture is supported by the fact that some species demonstrated increased landings over the same period of study (e.g. *Centroscymnus coelolepis*, *Scyliorhinus* spp., *Prionace glauca*, and *Galeus melastomus*). One could therefore very cautiously suggest that the category III species are at risk of being over-exploited and are in need of immediate management.

Interestingly, the five category III species diverge somewhat phylogenetically. It could be expected that species showing signs of over-exploitation would share common life-history traits, such as low fecundity and long gestation periods (Natanson and Cailliet, 1986). However, *Mustelus* spp. is often associated with higher rates of reproduction (Yudin and Cailliet, 1990). The fact that this species was associated with other category III animals is a motive for concern. It either casts doubt on the interpretation of landings and price trends, or alternatively, it could indicate very strong fishing pressures, or even the removal of the sexually mature size class, as the cause of decline in this species.

In conclusion, it appears as if *Centroscymnus coelolepis*, *Scyliorhinus* spp., *Prionace glauca*, and *Galeus melastomus* are currently being heavily targeted, while *Raja* spp., *Centrophorus granulosus*, *Mustelus* spp., *Torpedo* spp., and Squatinidae may be at risk of over-fishing, either within localized fishing grounds, or throughout the EEZ. These species certainly merit the focus of future research.

The limitations of price per kilogram and registered fishing vessels as indicators of "demand" and "effort" should be carefully considered when examining the conclusions of this article. Clearly, CPUE studies are required for the development of robust management plans. However, in the absence of CPUE data, perhaps the relationship between PPK and landings in historical data sets can be used as a useful early warning indicator of species at possible risk of over-exploitation.

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Literature Cited

Berkeley, S. A., and W. L. Campos. 1988. Relative abundance and fishery potential of pelagic sharks along Florida's east coast. Mar. Fish. Rev. 50(1):9–16.

Bonfil, R. 1994. Overview of world elasmobranch fisheries. FAO Fish. Tech. Pap. 341, 119 p.

Cailliet, G. M., and D. W. Bedford. 1983. The biology of three pelagic sharks from California waters and their emerging fisheries: a review. CalCOFI Rep. 24:57–69.

Capapé, C. 1985. Nouvelle description de *Centrophorus granulosus* (Schneider, 1801) (Pisces, Squalidae). Données sur la biologie de la reproduction et le régime alimentaire des spécimens des côtes tunisiennes. Bull. Inst. Natl. Sci. Tech. Océanogr. Pêche Salambô. 12:97–141.

DGPA. 1998. Pescas em Portugal 1986–1996. Inst. Nac. Estatística, Direcção-Geral Pescas Aquicult. (DGPA), Lisboa, 279 p.

Gruber, S. H. 1982. Role of the lemon shark, *Negaprion brevirostris* (Poey) as a predator in the tropical marine environment: a multidisciplinary study. Fla. Sci. 45:46–75.

Holden, M. J. 1973. Are long-term sustainable fisheries for elasmobranchs possible? Rapp. P.-V. Reun. Cons. Int. Explor. Mer. 164:360–367.

________. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. *In* F. R. Jones (Editor), Sea fisheries research, p. 117–137. J. Wiley & Sons, N.Y.

________. 1977. Elasmobranchs. *In* J. A. Gulland (Editor), Fish population dynamics, p. 187–215. J. Wiley & Sons, N.Y.

Holts, D. B. 1988. Review of U.S. west coast commercial shark fisheries. Mar. Fish. Rev. 50(1):1–8.

Last, P. R., and J. D. Stevens. 1994. Sharks and rays of Australia. CSIRO, Sydney, 513 p.

Musick, J. A., S. Branstetter, and J. A. Colvocoresses. 1993. Trends in shark abundance from 1974 to 1991 for the Chesapeake bight region of the U.S. mid Atlantic coast. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 115:1–18.

Natanson, L. J., and G. M. Cailliet. 1986. Reproduction and development of the Pacific angel shark, *Squatina californica*, off Santa Barbara, California. Copeia 1986(4):987–994.

Pratt, H. L. Jr., and J. G. Casey. 1990. Shark reproductive strategies as a limiting factor in directed fisheries, with a view of Holden's method of estimating growth parameters. U.S. Dep. Commer., NOAA Tech. Rep. NMFS. 90:97–109.

Pepperell, J. G. 1992. Trends in the distribution, species composition and size of sharks caught by gamefish anglers off south-eastern Austra-

lia, 1961–90. Aust. J. Mar. Freshwater Res. 43:213–225.
Sanches, J. G. 1986. Nomenclatura e diagnose dos principais peixes marinhos de Portugal (ciclóstomos, seláceos e holocéfalos). Lisboa, INIP (Pub. Avulsas. 9), 184 p.
Sminkey, T. R., and J. A. Musick. 1995. Age and growth of the sandbar shark, *Carcharhinus plumbeus*, before and after population depletion. Copeia 1995 (4):871–883.
Stevens, J. D. 1992. Blue and mako shark by-catch in the Japanese long-line fishery off south-eastern Australia. Aust. J. Mar. Freshwater Res. 43:227–236.
Viriato, A., M. J. Figueiredo, I. Figueiredo, and J. CorreiaJ. 1996. Atlas de apoio à pesca de arrasto na vertente continental portuguesa. Inst. Invest. Pescas Mar. IPIMAR, Lisboa, 51 p.
Yudin, K. G., and G. M. Cailliet. 1990. Age and growth of the gray smoothhound, *Mustelus californicus*, and the brown smoothhound, *M. henlei*, sharks from central California. Copeia 1990(1):191–204.