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Reconstruction of mainland Portugal fisheries catches 1950-2010

F Leitão, V Baptista, K Erzini, D Iritani and D Zeller

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Email: d.zeller@fisheries.ubc.ca

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Leitão, F[1]., Baptista, V[2]., Erzini, K[1]., Iritani, D.[3] and Zeller, D. [3]

Affiliations:

1 Centro de Ciências do Mar, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal

2 Instituto Ciências Biomédicas Abel Salazar,Universidade do Porto, Rua Jorge Viterbo Ferreira, nº 228, 4050-313 Porto, Portugal

3 *Sea Around Us* project, Fisheries Centre, University of British Columbia, Vancouver, V6T 1Z4, Canada

Email adress:

Francisco Leitão (fleitao@ualg.pt); Vânia Baptista (vania_bap@hotmail.com); Karim Erzini (kerzini@ualg.pt); Davis Iritani davisiritani@gmail.com; Dirk zeller d.zeller@fisheries.ubc.ca

Abstract

Fishing activities in mainland Portugal waters represent an important economic activity that supplies the high fish demand of national consumers, ranked high globally with an average annual per capita consumption of approximately 60kg. The Portuguese domestic mainland fisheries are largely concentrated in near-shore waters, with sardine (*Sardina pilchardus*), horse mackerel (*Trachurus mediterraneus Trachurus trachurus*), chub mackerel (*Scomber japonicus*), hake (*Merluccius merluccius*) and octopus accounting for most of the landings. Although there have been studies on unreported catches, by-catch and discarding in different fisheries, this is the first study to provide an overall estimate of the total quantity of catches, including discards from 1950-2010 based on a fishery-by-fishery approach. Furthermore, to make comparative analyses of the catches and discards among the different fisheries, each fishery was assigned to one of the following sectors: industrial (large-scale commercial), artisanal (small-scale commercial), or subsistence and recreational (both small-scale non-commercial). Overall, reconstructed total catches amounted to just under 21.6 million t for 1950-2010, which is slightly more than 2 times the 10,592,310 t of landings officially reported by Portugal for the same time period. The industrial sector (15.4 million t) accounted for nearly 72% of total catches as estimated here, while the artisanal, recreational and subsistence sectors accounted for 6 million t (28%), 58,000 t (0.3%) and 54,000 t (0.3%) of the total catches, respectively. Discards contributed the most to unreported catches, accounting for 7.6 million t of total catches (i.e., 35%), while unreported landings amounted to around 2.9 million t (13%) over the 1950 to 2010 time period considered here.

Introduction

Fish (or seafood) is an integral part of the Portuguese social and cultural heritage, as one might expect in a country with a great maritime tradition. The Portuguese Exclusive Economic Zone (EEZ) includes the Portugal mainland (322,000 km^2, www.seaaroundus.org, Figure 1), Azores (1.06 million km^2) and Madeira (454,500 km^2), amounting to almost 50% of all European Union (EU) EEZs. However, the Portuguese mainland EEZ is the smallest component of the total Portuguese EEZ.

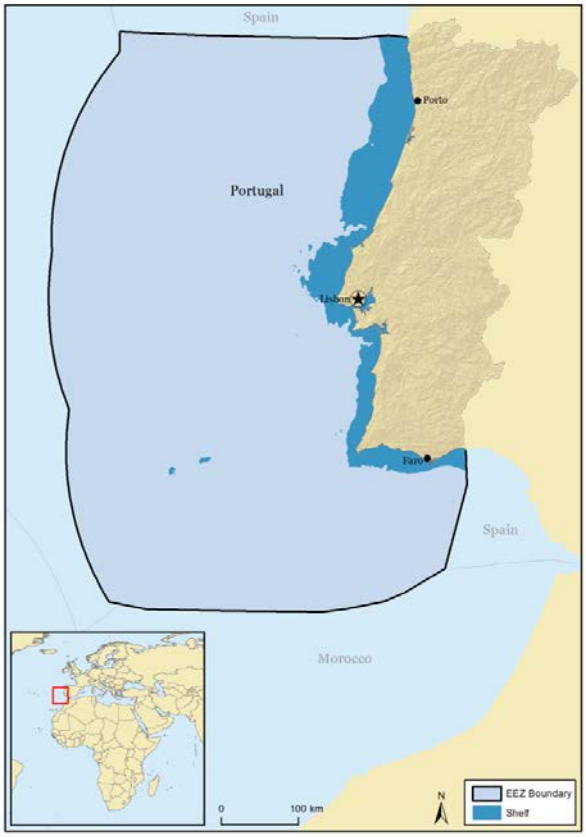


Figure 1. Portugal mainland, showing boundary of Exclusive Economic Zone (EEZ) as well as shelf areas (< 200 m).

The richness of the fish assemblages, with approximately 360 commercial species (according to DGPA- the Portuguese Directorate of Fisheries and Agriculture) is related to the geographic location of the country, with strong North Atlantic and Mediterranean influences. A variety of gears are used in the domestic fisheries, ranging from trawls and purse seines to static gears such as gill nets, longlines, and traps. In fact, Portuguese fisheries are highly diverse in their characteristics and present peculiarities in relation to other areas. In many cases, different types of gear compete for the same scarce resources.

Beyond the 150m isobath, the fish biomass is dominated by blue whiting (*Micromesistius poutassou*), whereas in inshore waters, the variability in assemblage composition is much greater. Species such as sardine (*Sardina pilchardus*), horse mackerel (*Trachurus mediterraneus Trachurus trachurus*), mackerel (*Scomber scombrus*) and sparids comprise significant and highly variable proportions of the population abundance (Gomes *et al.* 2001).

Coastal and maritime activities have traditionally been important for the national economy and the historical, social, and cultural identity of Portugal. The country has long relied on fishing as a major means of subsistence and many coastal communities depend almost exclusively on fisheries and related activities. The exploitation of fisheries resources in Portuguese waters has traditionally been dominated by small-scale coastal and estuarine fisheries. In fact, local, artisanal fisheries remain socially and economically important for the coastal populations that have increased in recent decades. The historical development of the Portuguese mainland fisheries has been described by several studies. In 1821, the Portuguese fishing fleet had 2,457 boats and 21,159 fishers, while by 1853, the fleet had grown to 3,430 boats and 29,564 fishers (Alves 1991).The commercial fishing industry continued to develop and, by 1886, a total of

6,176 boats and 29,766 fishers were employed in the industry (Baldaque da Silva 1891). When the population of commercial fishers from 1853 to 1911 is compared to the total national workforce, there is a continuous decline in the relative number of commercial fishers. In 1853, fishers accounted for 1.4% of the total working population. However, by 1890, this had declined to 1.0%, and by 1911 to 0.7% (Alves 1991). A slight increase in the number of fishers was observed in 1950, when the percentage of fishers in the total working population was 0.9% (Alves 1991).

In line with the typical modernization of fisheries and contrasting the decline of the number of fishers, the number of fishing boats increased between 1821 and 1950. Furthermore, there were substantial technological improvements and changes in the fisheries during this time. For example, in the mid 1800s, steam-powered vessels were introduced to the fishing fleets, which resulted in a reduction of total fishers. Additionally, fishers began to deploy for the first time an industrial gear, the otter trawl, which immediately created conflicts between the small-scale sector and this newly developing industrial sector. It resulted in artisanal fishers demanding government intervention to stop "… the destruction of artisanal gears, the destruction of fish spawning grounds, due to the speed of the nets and small sizes of meshes used…" (translated from Alves 1991). As a response, the Portuguese government passed a provisional law in 1891 restricting bottom trawl fisheries, which the owners of trawlers immediately contested.

According to Hill and Coelho (2001), there was a decrease in the number of vessels in the Portuguese fishing fleet between 1989 and 1999, but this was compensated by an increase in vessel power. By 1996, 98% of the fishing fleet was motorized - a 2% increase from 1986. According to a 1991 population census, there were 20,114 people employed in Portuguese

fisheries, i.e., less than 1% of the total employable population (Anon. 1998). Of these, 97% were males, often with low levels of education – 9% of the males were illiterate and 68% had no education beyond primary school (Anon. 1998). In general, young fishers had higher levels of education than older fishers.

None of the historical accounts published between 1800 and 1950 on Portuguese fisheries address bycatch or discards. The lack of information on bycatch and discards from this time period might suggest that either most of the nearshore, artisanal catches were consumed or used and not discarded, or that discarding may have been low and utterly ignored. Brandão *et al.* (2000) describes how all fish were processed, salted, and dried by Portuguese women, indicating that fish discards may have been minimal between 1800 and 1950 and that the idea of the fishing industry being mainly a male activity is a misperception (Harper *et al.* 2013).

Early accounts of fisheries history of some of the commercially-important fisheries contributed to the knowledge of specific target fisheries (Brito 1943; Galvão 1953; Brandão *et al.* 2000; Reis *et al.* 2001). These studies, and more recent reports and surveys provide some information on life histories and fisheries of traditional commercial target fisheries. More recently, it is generally recognized that the intense exploitation of many target species (e.g. hake, octopus, and sardine) is a matter of concern and that depleted stocks lead to serious conservational and socio-economic problems.

Membership in the European Union in 1986 brought significant changes to the Portuguese fishing industry. For instance, Portugal lost its autonomy in negotiating fishing access to developing countries for its distant water fleet, which led to the loss of access to some fishing grounds, including areas Portugal had been fishing historically, such as the Moroccan waters.

Cod (*Gadus morhua*), fished by the distant water fleet, was especially important supplying on average 15% (±6.5%) of the total amount of fish consumed in Portugal between 1938 and 1989. The EU Common Fisheries Policy is based on Total Allowable Catches (TACs) and quotas for some species, fishing area, gear restrictions, minimum size requirements of fish, minimum mesh sizes, and maximum percentages for incidental catches. This had repercussions for Portuguese fisheries. Portugal had the highest *per capita* seafood consumption in the EU, but with a deficit in catches, Portugal had to turn to increased seafood imports.

Since the early 1980s, several studies on the selectivity of fishing gear and the bycatch and discards by Portuguese fisheries have been published (Table 1). This includes studies that investigate discarding practices in order to improve the understanding of how much unreported catch remains at sea and to provide data for gear modifications. However, other information, such as discard survivorship rates, is still lacking.

Efforts to conserve the biodiversity of coastal marine ecosystems in Portugal are constrained by political uncertainty and bureaucracy. With a recent increase in public awareness of problems associated with fisheries, the issue of discards has resulted in an ongoing debate over what at-sea practices should be adopted by Portugal within the framework of the new EU Common Fisheries Policy that will lead to a ban of discarding.

Table 1: Discard rates by fisheries gear types and sectors for Portugal's mainland fisheries.

Fishing sector/ gear type	Study area	Discards (%±SD)	Period	Source
Industrial				
Trawl (crustaceans)	Mainland	55	2009	Pérez et al. (2011)
	South coast	70	1997	Borges et al. (2001)
	South caost	62	1999-2001	Costa et al. (2008)
	Average	**62.0 (7.5)**		
Trawl (fish)	Mainland	34	2009	Pérez et al. (2011)
	South coast	62	1997	Borges et al. (2001)
	Southcoast	72.5	1999-2001	Costa et al. (2008)
	Average	**56.0 (20.0)**		
	Trawl average	**59.0 (13.9)**	1997-2009	
Purse seine (pelagic)	Algarve	27	1997	Borges et al. (2001)
	Central/north coast	8.5	2003	Weise et al., 2005
	Average	**17.7 (13.1)**		
Scabbardfish	Silver scabbardfish	2	2000-2004	Machado and Figueiredo (2009)
	Black scabbardfish	2	2000-2004	Machado and Figueiredo (2009)
	Average	**2.0 (0.0)**		
Artisanal				
Purse seine (demersal)	Algarve	20	1997	Borges et al. (2001)
	Central coast	96.6	2003	Weise et al., 2005
	Average	**58.3 (54.2)**		
Dredges	Multispecies bivalves	16.7	2006	Leitão and Gaspar (2007)
	Multispecies octopus	7	2001	Saldanha (2001)
Hake	South coast (hook)	27.8	1997-1998	Erzini et al. (2001)
	South coast (hook)	0.1	1998	Santos et al. (2002b)
	South coast (gill net)	0.4	1998	Santos et al. (2002b)
	Average	**9.4 (15.9)**		
Trammel net	Central coast	21.9	2004-2005	Batista et al. (2009)
	South coast	13	1997	Borges et al. (2001)
	South coast	49.4	1999-2000	Gonçalves et al. (2007)
	Average	**28.1 (19.0)**	1997-2005	
Recreational/subsistence	Shore angling*	0.8*	2006-2007	Veiga et al. (2010)

* Percentage contribution for total yearly landing. Not estimated here.

The objective of the present study is to reconstruct the total fisheries catches for the Portuguese mainland EEZ from 1950-2010, by fishing sectors plus discards. As official data were occasionally insufficient in taxonomic or quantitative detail, an assumption-based approach

had to be substituted, following the catch reconstruction principles as outlined in Zeller *et al.* (2007).

Methods

The Portuguese continental shelf waters are included in ICES region IXa and the EEZ waters include IXb2 in the Northeastern Atlantic. The Portuguese coast extends from the mouth of the Minho river southwards to Cape São Vicente (Cape St. Vincent), then eastwards to the Spanish border at the Guadiana river (Figure 1). The continental shelf is relatively narrow and its most conspicuous irregularity is the Nazaré Canyon. Situated on the west coast, at about 39º 30' N, and reaching depths of around 5000 m, this canyon divides the west coast shelf into a northern, flatter section up to 70 km wide, and a southern, steeper section up to 20 km wide to the Cape São Vicente, before widening to around 30 km along the south coast (Gomes *et al.* 2001).

Data sources

The data used in the catch reconstructions were obtained from the Portuguese National Statistical Office (INE, Instituto Nacional de Estatistica). Data for national landings were obtained by: 1) manually transcribing individual records from the INE digital library[1] for years from 1950 to 1999; and 2) extracting data for 2000 onwards from the recently digitized INE time series[2].

[1] http://winlib3.ine.pt/winlib/winlib.aspx [Accessed April 2012]
[2] http://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes [Accesses April 2012]

Data were also acquired from the Food and Agriculture Organization of the United Nations for 1950 to 2010, to enable comparison of the globally reported catches and national sources.

Categorization of landed taxa

Data differed in taxonomic resolution over the years that were of interest for this study (1950 to 2010). Thus, it was necessary to create generalized taxonomic categories to allow comparability between years. The categorization of taxa into commercial categories was based on FAO standard classifications and nomenclature.

Gear types/fishing sectors

All fisheries and their corresponding gear types as derived from national data and information were assigned to globally generalized sectors to allow comparisons among countries around the world, as conducted by the *Sea Around Us* project (Pauly 2007). The industrial sector encompasses all large-scale commercial fisheries including the Portuguese trawl and pelagic purse seine fisheries. The artisanal sector consists of small-scale commercial fisheries including those that use demersal purse seines, trammels, hooks and gillnets to target hake, and dredges for mollusks. Scabbardfish (*Lepidopus caudatus*) catches, despite the involvement of artisanal methods and small boats, were included in the industrial sector for the purposes of this study. The re-labeling of scabbardfish catches to the industrial sector was based on the depth (~800 m) at which these fish are caught. As the *Sea Around Us* project allocates catches

to space by sector, and artisanal catches are defined as occurring in shallow, coastal waters, an assignment of 'industrial' was necessary for Scabbardfish.

A preliminary examination of the data assembled by the senior author, summed and grouped all reported landings, landings rejected at auction, and unreported landings by gear type. Subsequently, these data were disaggregated and assigned to the above, standardized sectors. The proportions of landings for each gear type (i.e., trawl, seine, multispecies) were calculated from the total landings and used to separate total landings into landings per taxon per sector. Discards and unreported catches were assumed to be proportional to the sector composition of total reported landings.

Catch Reconstructions

Purse Seine Fisheries

Purse seine landings between 1973 and 1986 were estimated by subtracting artisanal and trawl (both fish and crustacean) landings from total landings. In Portugal, most sardines are caught by coastal purse seine boats that use pelagic purse seines; a small proportion of sardine catches are by small-scale artisanal boats using demersal purse seines that target demersal schooling species.

An average percent contribution of each fishery/gear type to total catches was determined using data from 1969 to 2009 because statistical information was available for all fisheries/gear types for this time period only. The average percentage contributions were used to assign landings for years lacking gear-specific data (Figure 1). No information was available on how

the relative contributions of the different gear types may have changed between 1950 and 1968, therefore, we assumed a fixed contribution by each gear type during these years. From 1969 to 2009, the national data presents relative contributions by gear type (Baeta *et al.* 2009).

Artisanal fisheries between 1979 and 1982

Since total trawl and purse seine landings data were available for 1979 to 1982, artisanal landings for this period were estimated by subtracting trawl and purse seine landings from total landings.

Trawl (crustacean and fish) and artisanal landings between 1950 and 1968

The INE statistics are not divided between crustacean and fish trawls for the whole study period. Therefore, it was difficult to determine what proportion of landed fish is from crustacean trawls as by-catch or fish trawls as target catch. However, given the similar discard rates for crustacean and fish trawls (Table 1), this was not considered to be a major confounding effect. The percent contribution of each gear type to total landings was estimated for years when data were available (Table 2). These average percent (±SD) contributions were used to estimate landings for years when gear-specific data were missing.

Increasing the taxonomic resolution

Sardine (demersal purse seine) - artisanal

Besides being caught by industrial pelagic purse seines, sardines (*Sardina pilchardus*) are also caught by artisanal demersal purse seines locally called 'rapa'. Landings statistics for sardines caught by demersal purse seine were available since 1973. For the years when data were unavailable, the percent composition of demersal purse seine sardine in total artisanal landings was estimated using data from 1973 to 2009.

Cephalopods – artisanal

Using data from the DGPA database for years between 1989 and 2009, we were able to estimate the average amounts of cuttlefish caught by nets (78.4±9.5%) and jigs/traps (21.6 ± 9.5%). We used this information to reconstruct the cuttlefish series. Cuttlefish caught with nets were added to overall artisanal catches since the species is usually caught when the artisanal fleet targets fish with nets. The squid and short fin squid were considered to be caught by jigging. Therefore, they were treated as a specific part of the artisanal fishery.

Bivalves (oyster, blue mussel, clams and cockles) - artisanal

It is difficult to extrapolate historical landings data without any knowledge of landings or the number of fishers/collectors involved in this activity. Moreover, we believed that unreported landings due to recreationally collecting shell fish are insignificant. Therefore, for years without data we did not estimate the annual catch. In addition to blue mussel, oysters, and cockles, a group labeled 'other bivalves' was reported in the INE database. These bivalves are caught in coastal subtidal areas with artisanal dredges. The exploitation of bivalves in

Portuguese subtidal areas was started by the Spanish fleet in southern Portugal (between the Guadiana river and Torre de Aires) in 1969, extending thereafter to the northwestern coast (Sobral *et al.* 1989). 'Other bivalves' appear in INE data after 1973. However, we did not extrapolate landings for this grouping back to 1969.

Crustaceans (lobster) - artisanal

Lobster and similar crustacean taxa are caught using crustacean traps. Lobsters are also caught incidentally by trammel nets targeting fish.

Other fishes (scabbardfish, large pelagic) - industrial

The scabbardfish (silver and black) fisheries are relatively recent developments, with significant landings only since the early 1970s. Mainland black scabbardfish landings data are only available since 1991. This fishery has been particularly important on Madeira Island, from where the specific longline technology was imported to the mainland. Considering that this fishery has been introduced relatively recently, only years with available landings data were used for the separation of this target fishery from the overall artisanal fisheries. Scabbardfish are also caught with trawls, but these catches are included in the reconstruction of fish trawl fisheries.

Information on commercial tuna catches is available since at least 1950. INE tuna landings statistics were considered to be associated with artisanal fisheries. In the past, tuna were mainly caught in tuna traps while migrating into and out of the Mediterranean (Dias and Barraca 1971;

Santos 1989). More recently, tuna have been caught mainly as by-catch in shark or swordfish longline fisheries (Santos *et al.* 2002a) or in the last tuna trap operating in Portuguese waters after 1995 (Santos *et al.* 2002b).

The Portuguese swordfish (*Xiphias gladius*) long-line fishery developed after 1986. Nowadays, it plays an important role in Portuguese fisheries due to the amount of people involved and the high market value of this species (Santos *et al.* 2002a). The swordfish is mainly caught by surface long-line. Although the fishing effort primarily targets swordfish, this is a multi-species fishery, where some species of pelagic sharks may be targeted during some seasons or areas, especially when swordfish is less abundant. Several other species, such as billfishes, coastal and pelagic sharks and tunas are caught as by-catch. Tuna, swordfish and sharks fished by longline boats may also be reported to INE as 'marine fish nei' when frozen at sea. Moreover, we assumed that recreational fishing did not account for a significant part of unreported catches because of the catch and release practices implemented in big-game fisheries since 2000.

Recreational and subsistence catches

Until recently, little attention has been paid by fisheries scientists and managers to the economic importance and potential impacts of saltwater recreational fisheries in European Community waters and in Portugal (Veiga *et al.* 2010). Subsistence fishing has always taken place throughout Portugal, for daily livelihood (food provision) or as a source of additional, casual income. Prior to 2006, no recreational angling license was required. According to official statistics, a total of 201,522 saltwater fishing licenses were issued in 2007, with

141,046 (70%) for shore angling. However, many people with recreational licenses (legal anglers) use recreational fishing as an additional source of subsistence despite daily recreational bag limits. This implies that in Portugal subsistence fishing is confounded with recreational angling. Recreational/subsistence fisheries are legal, as long as the daily bag limit of 10 kg per angler is respected. However, recreational/subsistence catches are entirely unreported. For our purposes, we are not concerned with legality or adherence to bag limits, we are only concerned with estimating the potential total catches being taken (Veiga *et al.* 2010).

Pelagic sport fishery: The Portuguese Federation for Boat Sport Fisheries was created in October 1980. On the Portuguese mainland, sport fishing has become more popular over the last 15 years and includes big game sport fishing, targeting large pelagics and sharks, as well as bottom fishing for demersal fish in coastal waters. Although there is no data collection system, big game fishing is regulated by the International Game Fishing Association (IGFA), with catch and release being common practice, and only suspected record-breaking fish being retained and landed. Thus, retained catches were deemed negligible.

For bottom sport fishing, the main targets are sea breams (Sparidae) as well as cephalopods (squid, cuttlefish). Given the lack of catch data and the fact that quantities caught probably reflect trends in tourism, it was not possible to rebuild sport fishing catches.

For the subsistence/recreational catches, we used the estimates of Veiga *et al.* (2010) for the percentage contribution of recreational/subsistence catches in relation to total annual national reported landings as a proxy of these unreported catches. This study covered the Algarve and a significant proportion of the southwest coast, or approximately 1/3 of the Portuguese coast. In the absence of more reliable information for the remaining southwestern and northwester

coasts, we assumed that the proportions of subsistence/recreational catches in relation to total landings is equal to those determined by Veiga *et al.* (2010).

In order to separate, at least approximately, subsistence (i.e., the main driver is self- or family-consumption as a cost-effective protein alternative) from recreational (i.e., main driver is pleasure) we applied the following generalized assumptions to the estimated combined catch time series. For 1950, we assumed 80% was subsistence and 20% was recreational, while for 2010 we assumed 90% recreational and 10% subsistence. Percentages were interpolated for intervening years. Both subsistence and recreational sectors were assumed to catch identical taxa.

Estimation of discards

The discards percentages applied to rebuild catches by gear type or fishery are presented in Table (1). The reconstructions of discarded catches were made based on both at-sea discarding due to legal (quota limits) or economic reasons (e.g., high grading) and landings that remained unreported due to being rejected at auction (for economic or sanitary reasons).

Fisheries that target cephalopods using pots (e.g., octopus) or traps (e.g., octopus and cuttlefish) have low discard rates compared to fisheries that deploy nets. Cuttlefish landings from jigs and traps were considered to have an insignificant discard rate. Octopus landings were separated from the overall artisanal fisheries landings, since this is a specific pot and trap fishery with very low discard rates (Table 1). The squid and short fin squid were considered to

be caught by jigging. Therefore, they were also treated as a specific artisanal fishery with a negligible discard rate.

The most commonly collected bivalves were oysters (*Ostrea edulis*) and mussels (*Mytilus* spp.) mainly in estuaries, coastal lagoons, and coastal salt marshes of southern Portugal, where they were collected by hand during low tide until the first decade of the 20th century (Ruano 1997). In the last two decades, oysters have also been produced in both bottom cultures (in lagoons) and in offshore cultures. No discarding is expected for this group (Leitão and Gaspar 2007).

Lobster and similar crustaceans are caught with crustacean traps and despite the absence of scientific studies the discard rate is expected to be low. Thus, no discards rate was applied to rebuild this particular fishery.

Given the lack of specific studies for the white scabbardfish, and based on the authors' personal knowledge of the longline fishery, the discard rate for benthopelagic scabbardfish species was considered to be similar (Table 1).

The observed discard rate for the Portuguese tuna trap was less than 1%, with all individuals caught above the minimum landing size commercialized. Therefore, no discard rate was applied for the tuna reconstruction. Tuna, swordfish (*Xiphias gladius* and similar species) and sharks fished by longline boats may also be reported to INE as "marine fish nei" when frozen at sea. Given the commercial value of the species, and the absence of detailed landings information, discards were considered insignificant. Moreover, we assumed that recreational fishing did not account for a significant part of unreported catches because of the catch and release practices implemented in big-game fisheries since 2000.

Reconstruction of total catches

Total reconstructed catches were derived as follows:

Total catch = Reported landings + reported auction rejects + unreported at-sea discards + unreported industrial catches + unreported artisanal catches + unreported recreational catches + unreported subsistence catches

In the absence of accurate gear/fishery specific data on rejections at auction, the total quantities of fish rejected were redistributed to gear type/fishery in proportion to their reported landings (i.e., we assumed simple proportionality).

The amount of reported fish rejected at auction became available after 1995 after Portugal entered the EU. For the post-1995 period, the average percentage of landings rejected at auction was 4.21 ± SD 1.44% of the landed catches. To the authors' best knowledge, most of the fish rejected at auction are purse seine caught sardine and other small pelagics. However, due to the lack of species-specific data, the percentages of unreported fish due to rejection at auction were only used to estimate total landed catches, rather than being assigned to specific gear types. Prior to 1994, poorer onboard processing and storage conditions could have resulted in higher rates of potential rejections at auction. Nevertheless, we believe that historically, poorer quality landings were still auctioned. Therefore, the average auction rejection percentage of 4.21% for the period with data (1995 and 2009) was used for estimating auction rejections for all years.

Results and discussion

Fisheries statistics supplied by countries to the Food and Agriculture Organization (FAO) of the United Nations have been shown to under-report fisheries catches in almost all countries (e.g., Zeller *et al.* 2007; Wielgus *et al.* 2010; Harper and Zeller 2011; Zeller *et al.* 2011a; Zeller *et al.* 2011b; Harper *et al.* 2012; Le Manach *et al.* 2012). This is largely due to national reporting systems failing to account for, or at least periodically estimate and interpolate (see Zeller *et al.* 2007 for a suggested estimation approach), Illegal, Unreported, and Unregulated (IUU) catches including the generally unreported non-commercial components of small-scale fisheries which are often substantial in developing countries.

A comparison between the national INE data and the FAO data, after excluding the catches of non-domestic species as best as possible, suggested reasonable overall matches between the two datasets (Figure 3). A detailed, realistic comparison could not be accomplished, as some groups/taxa are possibly fished in both EEZ waters as well as more distant waters (within the same FAO area). Furthermore, FAO data do not present catches by gear types or sectors. Thus, for the present exercise of reconstructing total catches for the mainland EEZ, the more detailed INE mainland data was accepted as a reported baseline. These data, being partially available by gear type or fishery, allow more readily the application of gear- or fishery-specific discard rates.

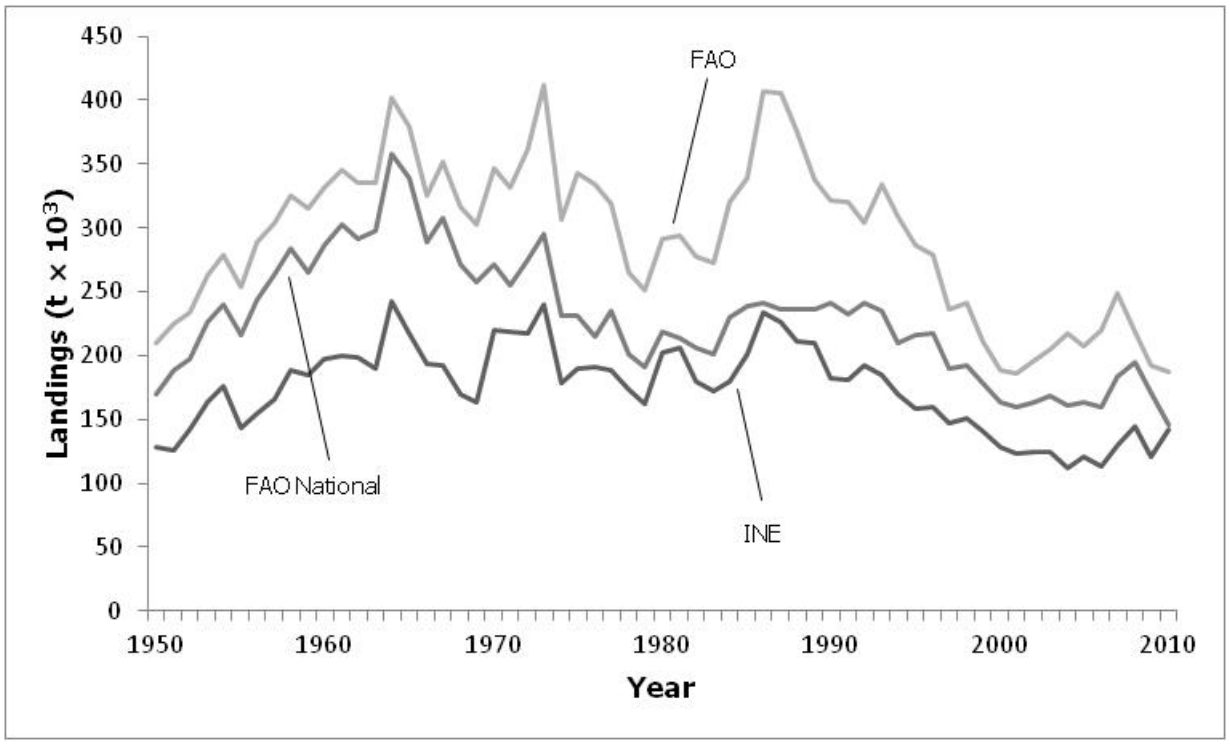


Figure 2: Comparison between national (INE) data for domestic Portuguese mainland catches and FAO data adjusted by exclusion of clearly non-domestic taxa, 1950-2010.

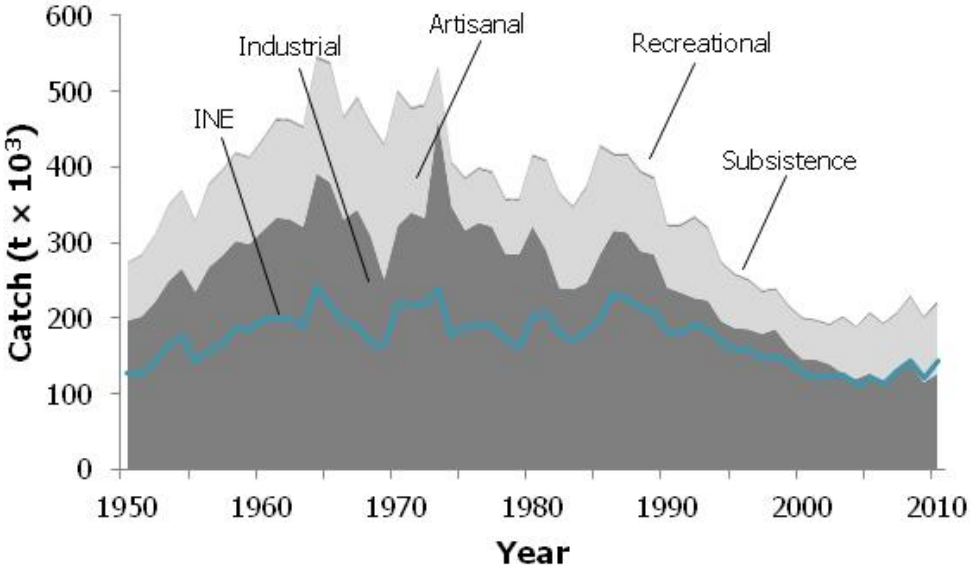
Overall, the total reconstructed catches by Portugal in their EEZ waters between 1950-2010 amounted to just under 21.6 million t, which is 2 times higher than the 10.6 million t reported by INE to FAO as official catches (Figure 4a). This difference was mainly due to estimated discards of 7.6 million t).

The industrial sector made up the largest portion of total Portuguese catches, with over 15.4 million t. Catches by the artisanal sector were second highest and summed to over 6 million t. Recreational and subsistence catches accounted for 58,000 t and 54,000 t between 1950 and 2010, respectively (Figure 4a).

Total reconstructed catches increased from around 275,000 $t \cdot year^{-1}$ in 1950 to a peak of just under 550,000 $t \cdot year^{-1}$ in 1964, before beginning a gradual but continuous decline to around

200,000 t·year^{-1} by the mid 2000s (Figure 4a). Since then, total catches appear to have stabilized at this substantially reduced level of catch.

a)



b)

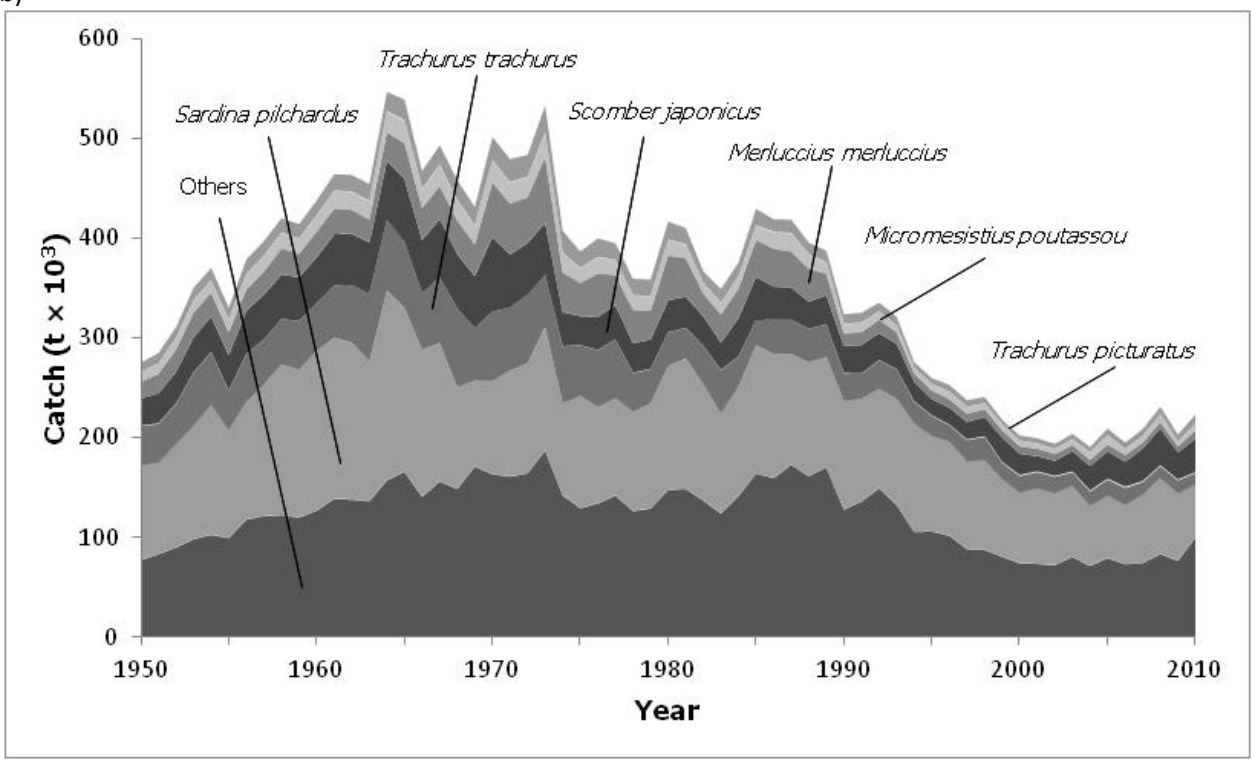


Figure 3: Total reconstructed catches for mainland Portugal for 1950-2010, a) by fisheries sectors plus discards. Note that recreational and subsistence catches are too small to show effectively. Also note that the officially reported data (source: INE landings) are overlaid as line graph; and b) by major taxa, with 'others' representing 234 additional taxa with lesser contributions and 'marine fishes nei'.

All three sectors show a similar trend in total catch increasing from 1950 to the 1970s and then declining overall to 2010. The industrial sector shows an increase in total catch from around 197,000 t·year^{-1} in 1950 to its peak in 1973 (465,000 t·year^{-1}) and declines to 126,000 t·year^{-1} by 2010 (Figure 4a). In comparison, the artisanal sector increases in total catch from around 76,000 t·year^{-1} in 1950 to a peak of 177,000 t·year^{-1} in 1970 before gradually declining to around 94,000 t·year^{-1} in 2010.

In 1957 and 1960, net haulers and the power-block were introduced in sardine purse seiners (Reis *et al.* 2001), representing significant advances in technology. The introduction of radar and sonar (1975), mesh and net size regulations (1987), minimum catch size (1989), and effort reduction (1997) did not change the declining trend observed in the industrial and artisanal sectors after their peaks in the early 1970s.

The fishing effort (number of boats) shows an increasing trend until the mid 1960s (Figure 5), matching the general increase in total catches over the first decades (Figure 4a).

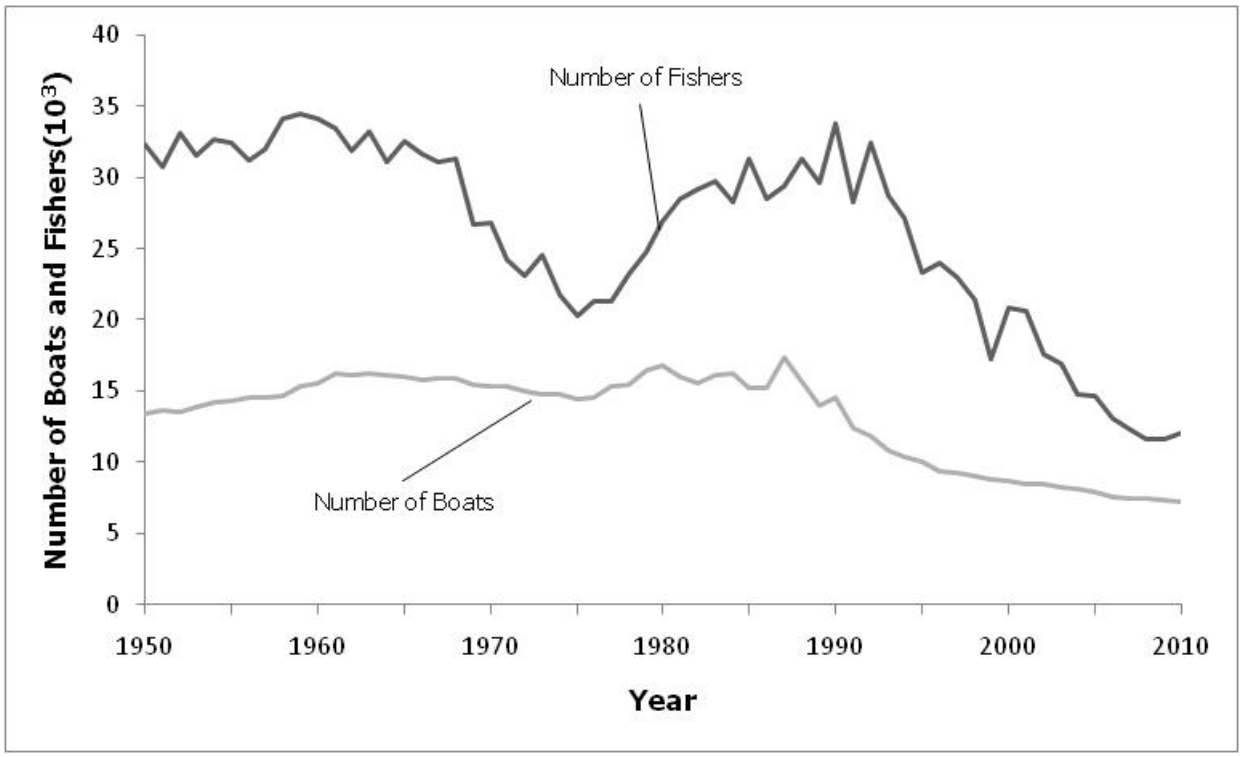


Figure 4: Total number of boats and fishers involved in Portuguese fishing activities from 1950 to 2010.

The number of active fishing boats, as well as the number of fishers decreased substantially after the mid 1980s, when Portugal joined the European Union (Figure 5). This corresponds to the time when fisheries showed a marked decline in catches (Figure 4a). Starting in the 1990s, the number of boats and number of fishers reached the lowest level ever recorded. Therefore, the decline in fishing capacity in the Portuguese mainland fisheries appears to mirror the decline in landings since the mid 1980s. The decline in the number of fishers may be related to the precariousness of employment and the low financial rewards in this sector (Brandão *et al.* 2000), which may also be a reflection of overall reduced resource availability along the coast, and also due to policy directions of the EU Common Fisheries Policy. Furthermore, the

population of fishers, mainly composed of people with low education levels (but with high practical knowledge, transmitted over generations), has been ageing (Brandão *et al.* 2000).

Over the last two decades, Portugal experienced a considerable reduction in catches, while sea food imports have increased. This can in part be explained by the decline in the activities of the Portuguese distant water fleet, which has operated in foreign waters for decades, and in some cases centuries. Successive restrictions on access to fishing grounds historically used by the distant water fleet, mainly in the North and South Atlantic, together with conservation measures through the Common Fisheries Policy, have had an impact on the sector (Reis *et al.* 2001). According to a report by OCEAN2012 (2013), Portugal is one of the countries in the European Union (EU) that is most dependent on fish imports from outside the EU to meet its consumption needs.

Many, but not all, discarded species cannot be used for direct human consumption. However, fish or sharks and even many invertebrates not used for human consumption can be used for fish meal. Therefore, under the no discards policy to be implemented by the revised EU Common Fisheries Policy, there may be new economic opportunities based on the large quantities of discards estimated here. In fact, many societies adhere to the principle that human beings have a moral obligation to make best use of natural resources and minimize wastage (Kelleher 2005). The opportunity exists now for Portuguese fishers to utilize the developing discard ban by doing what fishers have done well for centuries, namely innovate and adapt to changing conditions and circumstances. Avoidance, minimization and utilization of former

discards is only one more step in this process, and should be embraced not opposed by the fishing community as an urgently needed step in the right direction for sustainable fisheries.

The findings of this study raise some concerns regarding the future of the domestic Portuguese fisheries sector. A marked under-reporting of total catches has been observed, suggesting inadequate monitoring and data recording mechanisms in the country. However, unreported catches are dominated by discards, a wasteful practise that will hopefully be addressed through the revised CFP. This requires improved and comprehensive data collection and monitoring, as well as changed approaches to fishing and fish retention and utilization. Therefore, it may be useful to evaluate the potential of currently discarded catches. For example, Costa and Borges (1998) illustrated that shark discards constituted 15.5% of the total catch by weight of all species caught in trawls off the southern coast of Portugal. The most frequently discarded species was *Scyliorhinus canicula* (Scyliorhinidae) (5.1% of the total catch by weight), which is occasionally sold, as a limited market exists for it (Costa and Borges 1998). All other shark species caught are always discarded due to their low commercial value. In this case, as deep water shark discards represent a considerable proportion of the total catch, they are potentially valuable commercial species and could be important as a by-catch if a market were developed for them.

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