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AN ESTIMATE OF THE TOTAL CATCH IN THE SPANISH MEDITERRANEAN SEA AND GULF OF CADIZ REGIONS (1950-2010)

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Abstract

The underestimation of fisheries removals is a global issue that spans countries from different continents and different socio-economic situations. Underestimation of catches is especially important in countries where fishing fleets are highly diversified, the enforcement of fishing management is low, data availability is poor, and there is high demand for fish products in local markets. This is the case for Mediterranean countries. Here, we estimated total removals of marine resources by Spain from 1950 to 2010 for the Spanish Mediterranean Sea and Gulf of Cadiz regions following a catch-reconstruction approach. We first collected information from scientific publications, grey literature and secondary sources of information (i.e., personal communications, interviews with managers and fishers) to complement officially reported catch data, which are publicly available from FAO databases and from national and regional statistics. A literature search and fishers interviews provided assessments of missing catch sectors that are time-point estimates. These were used as anchor points of reliable data upon which we then estimated total catch using interpolation to fill in the periods for which quantitative data were missing. Overall, the reconstructed catch was 70% larger than the nationally reported data for the same time period. Results illustrated that unreported removals and discards represent important portions of total removals in the study area. Unreported landings and discards accounted for, on average, 42% of total removals between 1950s and 2010, and were composed of black market sales, subsistence fishing, artisanal fishing, recreational fishing and illegal catch, in addition to discarding. By the late 2000s, recreational fishing was the most important sector for unreported landings (~36%), followed by black market sales (~32%), subsistence fishing (~17%), unreported artisanal fishing (~12%) and illegal catch (~2%). While FAO landings data showed an increase of landings from 1950 to the mid-1960s and a decline from the mid-1970s to 2010, a different trend emerged after accounting for all fisheries removals. Reconstructed total catches revealed an earlier maximum of total removals in the late 1950s, a plateau being reached during the 1960s and 1970s, and a decline from the early 1980s to 2010. Our estimates of total fisheries catches represent an improvement over official catch data, and suggest a different historical trend of marine resource use.

1. Introduction

Fishing is an important human activity shaping marine ecosystems (Pauly *et al.* 2002; Costello *et al.* 2010), and exploited marine resources are in a worrisome state (Christensen *et al.* 2003; Pauly *et al.* 2003; Coll *et al.* 2008a; Froese and Proelß 2010; Kleisner *et al.* 2012). Several national and international initiatives aim to halt degradation trends and ensure the sustainability of fisheries, such as the European Community EC 2371/2002, the new Common Fisheries Policy (CFP) and the Marine Strategy Framework Directive (MSFD), which aims at achieving a Good Environmental Status (GES) in EU marine waters by 2020, at the latest, the Canada's Oceans Act, U.S. Commission on Ocean Policy, and the Code of Conduct for Responsible Fisheries of The Food and Agriculture Organization (FAO) of the United Nations (UN) (FAO 1995; Department of Justice Canada 1996; European Community 2002; US Commission on Ocean Policy 2004; EC 2008).

The world's officially reported catches increased from the 1950s to the early 1990s and fluctuated from then until the present (Pauly *et al.* 2003; FAO 2010). However, it is now well recognized that officially reported catches are frequently underestimated (FAO 2002; Zeller and Pauly 2007) due to Illegal, Unreported and Unregulated (IUU) catches (Bray 2000; Evans 2000; FAO 2002; Pitcher *et al.* 2002; Agnew *et al.* 2009). Moreover, while China over-reports its domestic catches (Watson and Pauly 2001), it also massively under-reports the catches of its distant-water fleets (Pauly *et al.* 2012). Underreporting is caused, among other things, by unaccounted discarding practices (Kelleher 2005), recreational fishing (Coleman *et al.* 2004), illegal catch (e.g., Atlantic bluefin tuna, ATRT 2006), as well as smaller-scale fisheries which may not have a national management mandate, and which frequently are not taken into account in the overall assessment of fisheries removals from marine ecosystems.

IUU catches are caused by a lack of monitoring and enforcement by countries and regional organizations to control fishing activities, due to inappropriate or insufficient legal and disciplinary measures for those not following the rules, and due to lack of political will. IUU practices impair the correct assessment of exploited marine species, and our ability to understand how fishing activities impact commercial and non-commercial species, marine communities and ecosystems, therefore they complicate or even defeat the development of suitable management actions. They also lead to underestimation of the contribution of fisheries to Gross National Product, while having costs associated with control and inspection (FAO 2002; Zeller and Pauly 2007). IUU can also have social impacts due to competition with legal activities, and especially with artisanal fishing. This is a fundamental issue, since management effectiveness of the world's marine fisheries is generally low or very low (Mora *et al.* 2009), the spatial expansion of fisheries and overexploitation of the marine ecosystems is increasing (Coll *et al.* 2008a; Swartz *et al.* 2011), and fisheries are rapidly evolving towards targeting lower trophic-level organisms with potential further impacts on marine ecosystems (Anderson *et al.* 2011).

The underestimation of fisheries removals is a global issue that spans countries from different continents and in different socio-economic situations (e.g. Zeller *et al.* 2007; Zeller and Pauly 2007; Wielgus *et al.* 2010; Zeller *et al.* 2011b). Underestimation of catches is especially important in countries where fishing fleets are highly diversified, the enforcement of fisheries management is low, data availability is poor, and there is high demand for fish products in local markets. This is the case for Mediterranean countries (Coll *et al.* 2006; Tsikliras *et al.* 2007; Le Manach *et al.* 2011).

The Mediterranean Sea, including the Black Sea basin, is the largest (over 3.4 million km^2) and deepest (average 1,460 m, maximum 5,267 m) enclosed sea on Earth (Figure 1). It is located

between Africa, Europe, and Asia, and it is connected through the Strait of Gibraltar to the Atlantic Ocean in the West and through the Suez Canal to the Red Sea and the Indian Ocean in the Southeast. The Mediterranean and Black Seas have, generally, narrow continental shelves and a large area of open sea. They are hotspot of biodiversity and host approximately 7-10% of the world's marine biodiversity with high percentages of endemic species (Bianchi and Morri 2000; Coll *et al.* 2010). Given the generally high human population along its shores, the long history and diversity of human impacts and the enclosed feature of this sea, the Mediterranean has been altered extensively throughout history. At present, fishing impacts, as well as habitat loss and degradation, pollution, eutrophication, and the introduction of alien species are the most important threats to diversity (Coll *et al.* 2010; Costello *et al.* 2010; Coll *et al.* 2012).

Official Mediterranean fisheries landings have steadily increased from the 1950s to the 1980s, decreased in the 1990s and have fluctuated since then (Figure 2a). The most important countries fishing in the Mediterranean Sea are Italy, Spain, Greece, Turkey, Tunisia and Egypt (FAO 2011b; Sea Around Us 2011). Major species in the reported data include European sardine (*Sardina pilchardus*), European anchovy (*Engraulis encrasicolus*), and other small and medium-sized pelagic fish such as round sardinella (*Sardinella aurita*), horse mackerel (*Trachurus* spp.) and mackerel (*Scomber* spp.), and demersal species, such as European hake (*Merluccius merluccius*), red mullets (*Mullus* spp.), anglerfish (*Lophius* spp.) and blue whiting (*Micromesistius poutassou*). Invertebrate catches of the Mediterranean Sea are also economically important such as, for example, that of red shrimp (*Aristeus antennatus*), European spiny lobster (*Palinurus elephas*), rose shrimp (*Parapenaeus longirostris*), Norway lobster (*Nephrops norvegicus*) and cephalopod species (Farrugio *et al.* 1993; Papaconstantinou and Farrugio 2000; Lleonart and Maynou 2003). The Mediterranean Sea also yields important catches of tunas and associated species, especially of Atlantic Bluefin tuna (*Thunnus thynnus*) and swordfish (*Xiphias gladius*).

Scientific and management advice in the Mediterranean Sea is implemented by national and regional entities (or Regional Fisheries Management Organization, RFMO), in addition to several international organisations, such as the General Fisheries Commission for the Mediterranean (GFCM), in cooperation with the Fisheries Department of the United Nations Food and Agriculture Organisation (FAO), and the European Community (EC), the International Commission for the Conservation of Atlantic Tunas (ICCAT) and the United Nations Environmental Program (UNEP). The GFCM is composed of 23 countries in addition to the EU, and its objectives are to promote the development, conservation, and best management of living marine resources in the Mediterranean Sea, as well as the sustainable development of aquaculture. Its recommendations are compulsory and it cooperates with FAO. Moreover, the Scientific, Technical and Economic Committee for Fisheries (STECF) of the EU, and in particular the sub-group for the Mediterranean and Black Sea (SGMED), provides scientific recommendations about fisheries of EU Member States. All the EU Member States have to collect fisheries data following the Data Collection Framework (DCF), with the main objective to provide the basic data needed to evaluate the state of fishery resources and the fisheries sector for scientific advice regarding the Common Fisheries Policy (CFP) of the EU. Each EU Member state should collect primary biological, technical, environmental and socio-economic data.

In addition, ICCAT is a RFMO, i.e., an intergovernmental fishery organization, responsible for the conservation of tunas and related species in the Atlantic Ocean and adjacent seas. Of particular interest is the eastern Atlantic and Mediterranean population of bluefin tuna, albacore (*Thunnus alalunga*), swordfish and Atlantic bonito (*Sarda sarda*). ICCAT develops studies with a principal focus on the effects of fishing on the stocks abundance and compiles data of other fish species that are caught during tuna fishing, such as by-catch of sharks. In the

Mediterranean Sea, FAO also implements regional cooperative projects. UNEP's Regional Activity Centre helps Mediterranean countries to implement the Protocol on Specially Protected Areas and Biological Diversity in the Mediterranean. Moreover, several NGOs are also strongly involved in general fisheries policy, notably *WWF*, *Oceana*, *Ecologistas en Accion* and *Greenpeace* (Romberg and Sardà 2005; MAPA 2007).

Despite many stakeholders being involved in fisheries monitoring and management, considerable evidence of substantial unreported landings and failures of the control system are available for many European and Mediterranean countries (Tinch *et al.* 2008; Mora *et al.* 2009; Le Manach *et al.* 2011; Zeller *et al.* 2011b), including Spain. Unreported landings in Spain, and the ecological and socio-economic problems associated with this, have made it to the public media on several occasions (Annex 1). In 2007, a special report by the European Court of Auditors highlighted many deficiencies and failures of control, inspection and sanction systems of six European countries, including Spain (Court of Auditors 2007). The Court stated that overfishing generated by over-capacity and the considerable weaknesses of the European fisheries control system are threatening European fish stocks. The Court concluded that (i) fishing data collected in Member States of the European Union are unreliable and incomplete, and are inadequate as a basis for setting Total Allowable Catches (TACs) and quotas; (ii) national inspection procedures to detect and prevent infringements are ineffective; and (iii) the penalties imposed by national authorities when infringements are detected are not sufficiently onerous to act as a deterrent. Spain was pointed out on several occasions as a frequent offender due to, for example, extensive underreporting of catch of large pelagic fish.

Although FAO and other organizations recognize the importance of IUU practices (FAO 2002), and European countries have officially committed themselves to estimate and control IUU catches (MAPA 2007), local and regional fisheries experts, government employees, and fishers are aware of the limited nature of official fisheries data and of the large amount of unreported catches. Administrations in charge of collecting the data rarely show the will to quantify these missing catches. Therefore, estimates of IUU in the region are still very scarce, with data only available for Greece (Tsikliras *et al.* 2007), Corsica (Le Manach *et al.* 2011), Turkey (Ulman *et al.* in press) and the Balearic Islands (Carreras *et al.* 2013).

In this study, we contribute to the global effort of estimating the world's total fisheries removals lead by the *Sea Around Us* project (Pauly 2007), which is estimating IUU catches by country globally (Zeller and Pauly 2007). Here, we estimated total removals of marine resources for 1950-2010 by Spain from the Spanish Mediterranean Sea and Gulf of Cadiz regions (Figure 3). Although it is not part of the Mediterranean Sea, we included the Spanish Gulf of Cadiz region in our study because this gulf shares similar ecological and socio-economic traits with the Spanish Mediterranean area.

To estimate total fisheries removals, we followed the catch-reconstruction approach first conceptualized by Pauly (1998), methodologically developed by Zeller *et al.* (2007) and Zeller and Pauly (2007), and previously used in various regions of the world's oceans (e.g. Zeller and Pauly 2007; Wielgus *et al.* 2010; Zeller *et al.* 2011a; Zeller *et al.* 2011b). We collected information from scientific publications, grey literature and secondary sources of information (i.e., personal communications, informal interviews with managers and fishers, newspapers) to complement official catch data, which are publicly available from FAO databases and from national and regional statistics. A literature search and interviews with fishers provided assessments of missing sectors (i.e., discards, recreational fishing, and black market sales) that are time-point estimates and were used as anchor points of reliable data. We then estimated total catch using interpolation between anchor points to fill in the periods for which quantitative data were missing. When data were not available or had limitations, we documented those.

Our approach required occasional inferences and interpolations that are also documented. We justify them, despite data uncertainties, given the less acceptable alternative outcome which is the interpretation of non-reported or missing data as zero catches (Zeller and Pauly 2007). We were motivated by the fact that estimates of total fisheries removals are the most fundamental data to understand and assess the role of fishing on exploited ecosystems. When fishing data are underestimated, the impact of fishing is also underestimated, which may threaten not only exploited resources but also the future economic viability of the fishing industry.

2. The Spanish Mediterranean Sea and Gulf of Cadiz regions

2.1. The study area

Our study area spans the Spanish Mediterranean Sea and the Gulf of Cadiz regions (Figure 3). This region is mainly located in the Balearic FAO area 37.1.1 and the South-East Atlantic area 27.IXa (Figure 1), and includes five Autonomous Regions (AR) with seventeen provinces (PR) and approximately 24 million people (Table 1). This area is bordered by the Gulf of Lions (France) in the north, Moroccan and Algerian waters in the south and the Sardinia FAO area 37.1.3 including the Tyrrhenian Sea and adjacent waters to the east.

The Spanish fleets in the area mainly fish in FAO area 37.1.1, the Balearic region, and in the South-East Atlantic FAO area 27.IXa, in the Spanish Gulf of Cadiz (Figure 3). Data from FAO show that the official Spanish landings from the Mediterranean Sea are mainly originating from the Balearic region, since they are very similar to total Spanish Mediterranean catches in FAO dataset (Figure 2b). The rest of Spanish Mediterranean landings mainly come from the Gulf of Lions and Mediterranean fisheries targeting large pelagic fish. Official Spanish Balearic landings from the FAO database showed an increase from the 1950s to the early 1980s, and a decline thereafter (Figure 2b). However, total official catches coming from the Balearic region have shown a steady increase until the mid-1990s. This increase is mainly due to an expansion of Spanish fishing in Algerian and Morocco national waters (FAO 2011a, 2011b).

The continental shelf in the Spanish Mediterranean and Gulf of Cadiz regions is generally narrow, and the 50 m depth is usually found approximately 3 nm from shore (Figure 3). Fishing activities are mainly coastal or littoral, and last on average 12 hours. The main fishing fleets operating in the area are bottom trawling (~24% of the fleet), purse seine (~9%), bottom and surface long lines (~3%), and a diverse artisanal fleet (~64%) (Table 2). The area contains 95 fishing harbours, >90 first-source fishing markets (or *Lonjas*, where catches that are unloaded in the harbour are commercialized), and several fishers labour organizations or '*Cofradias de pescadores*' (which are unique to Spain and date back to early Medieval times, Álvarez Ereipa 2008) (Table 1). In 2008-2009, the total number of vessels in the study region was 4,140, with total declared power of 453,593 Kw and a mean total length of 12 meters (MARM 2011) (Table 1). In the late 2000s, more than 13,000 people directly worked as fishers in the area (Table 1).

2.2. Legislation, management and control of fishing activities

Several governmental and inter-governmental institutions at different hierarchical levels (European Community, national, regional and local scale) are involved in the legislation, management and/or control of fishing activities in the study area, such as the EC, ICCAT, the Spanish Ministry of Environment, and Rural and Marine Areas or *Ministerio de Medio Ambiente, y Medio Rural y Marino* (MARM), previously known as well as *Ministerio de Agricultura, Pesca y Alimentacion* (MAPA), located in the capital of the country (Madrid), the AR through regional government bodies, the municipalities, and the *Cofradias*.

The legislation regarding the management of marine resources in the Mediterranean Sea is generally guided by the EC Regulation 1626/94, the EC Regulation on the Management of Mediterranean fisheries 1967/2006, and the recent EC Regulation 1343/2011 amending the previous one, through which a system based on the direct control of fishing effort is established. This system is based on general rules, such as the definition of selectivity and other technical measures by fleet, the limitation of number of days per week and hours per day that fishing is allowed and limitation of engine power, the establishment of minimum legal sizes for main commercial species, the prohibition of trawling in coastal areas of either less than 50 meters depth or within 3 nm of the coast, and the prohibition of purse seining in areas shallower than 30 m or closer than 300 m from the coast (Romberg and Sardà 2005; MAPA 2007). Indirect measures to control fishing effort do not exist in the Mediterranean Sea, except for bluefin tuna, which is the only species that is regulated using Total Allowable Catch (TAC). However, some Mediterranean countries have exceptions to EC regulations, and there is a general lack of application and enforcement of the rules (MAPA 2007; Mora *et al.* 2009).

The national legislation applies to the Spanish fleet within the national jurisdiction (12 nm territorial sea), the Exclusive Economic Zone beyond territorial waters (EEZ) and the Zone of protection for the Mediterranean Sea (ZPP), and in theory is more restrictive than the EC regulations. The AR manages fishing activities in the coastal region, in addition to shellfish and aquaculture activities. Moreover, AR governments establish temporal limits to maximum catch of specific species by fleet during certain periods of time to protect the resources. The self-organizing *Cofradías* also play a key role in the management and control of fishing activities in coastal waters since they employ a system of 'Territorial Use Rights in Fisheries' (TURF) (Franquesa 2005). Other measures to limit fishing effort are the establishment of marine protected areas, which are managed by MARM, AR or by both. There are also approximately 100 artificial reefs in the study area where bottom fishing is prohibited (MAPA 2007).

Control of fishing activities in Spain is developed in coordination by MARM and other Ministries such as the Ministry of Defence, AR and by local authorities and *Cofradías* that control local markets and trade. Measures of control include vessel and harbour inspectors and a compulsory satellite vessel monitoring system for vessels larger than 15 meters in length. In addition, AR governments can implement their own vessel monitoring system. However, these measures have been identified as insufficient by the Spanish national and regional governments, and their enforcement is low (MAPA 2007; Mora *et al.* 2009).

The marketing of the catch obtained from the study area involves several actors and institutions (Alegret 2005). Approximately 70% of all fresh catches are directly sold in the *Lonjas* (the first-source fishing markets) to central markets and the exporting industries, while 30% is directly sold from vessels or through other markets authorised by AR, but they have to be registered in *Lonja* statistics (MAPA 2007). *Cofradías* benefit from these markets which promote benefits for fishers and, although it is not compulsory to sell the product in *Lonja*, in many *Cofradías* it is socially reinforced (Franquesa 2005). The central markets distribute fresh products to local markets. In the *Lonjas*, fishers' organizations, cooperatives and associations of ship-owners and traders are the ones organizing the marketing of landings (through auctioning) to central markets and exporters, and they are also in charge of registering total landings. However, despite *Cofradías* and *Lonjas* providing socially-accepted regulations to limit the overexploitation of the resources (Franquesa 2005; Álvarez Ereipa 2008), there is a generally low satisfaction by fishers towards fishing regulations, and there are many fishers, many potential landing places and large facilities to directly sell catches illegally, for example to restaurants, shops, and tourists (Romberg and Sardà 2005).

3. Material and methods

3.1. Catch-reconstruction approach

To estimate total fisheries removals from our study area, we followed the catch-reconstruction approach documented in several previous studies (Zeller *et al.* 2007; Zeller and Pauly 2007; Zeller *et al.* 2011b) that consists of six general steps:

(i) Collection of time series of available reported landings from regional (i.e., Autonomous Regions [AR], *Cofradías*), national (MARM and other government bodies) and international (i.e., FAO and ICCAT) agencies;

(ii) Identification of those fisheries sectors and components that currently produced or could have produced unreported catches using literature searches and secondary data sources (i.e., interviews with fishers and fisheries experts, newspapers, and personal observations during visits to harbours, *Cofradias* and *Lonjas*);

(iii) Searches for available alternative information regarding those sectors and components that produced unreported removals;

(iv) Collection of alternative estimates and development of anchor points in time for missing data;

(v) Interpolation between anchor points for time periods to estimate the different components of unreported removals;

(vi) Estimation of total fisheries removal time series as the sum of total reported landings and unreported removals.

For each year, we defined total fisheries removals (*TR*) as the sum of total fisheries landings (*TL*) and total discards (*TD*) for *S* caught species and *F* number of fishing fleets as following:

$$TR = \sum_{s=1,\, f=1}^{S,N} (TL + TD) \qquad \text{Eq. 1}$$

TL for *S* caught species and *F* number of fishing fleets was composed by the following elements:

$$TL = \sum_{s=1,\, f=1}^{S,N} (OL + UL) = \sum_{s=1,\, f=1}^{S,N} (OL + BM + IC + AC + RC + SF) \qquad \text{Eq. 2}$$

Where *OL* is official landings and *UL* is unreported landings. *UL* is composed of unreported legal catches that go to the black market sales (*BM*), or the proportion of the total catch that, although legally captured, goes into the black market, and illegally caught species (*IC*), which is the proportion of the non-reported catch that is illegal due to including protected species, capturing illegal sizes or using illegal fishing gear. It also includes artisanal catch (*AC*) and recreational catch (*RC*) not reported in official landings, and subsistence fishing (*SF*), or the personal consumption of fishing products by fishers and their families.

TD for *S* caught species and *F* number of fishing fleets is composed of the following elements:

$$TD = \sum_{s=1,\, f=1}^{S,N} (D + PM + GF) \qquad \text{Eq. 3}$$

Where *D* is direct boat-based discards from fishing activities (Kelleher 2005), *PM* is post-escapement mortality, or underwater discards, of those specimens that die after escaping from fishing nets due to physical damages (Suuronen 2005), and *GF* is ghost fishing mortality of

those specimens that die due to lost or abandoned gear or the loss of fishing gear at sea (Brown *et al.* 2005a; Macfadyen *et al.* 2009a). We considered as unreported removals, or IUU catch, all the elements of *TR* that are not included in *OL* and discards.

To calculate *TR*, we collected and compiled all material available, from primary literature and official sites, final projects report, grey literature, statistics from regional institutions, estimates from experts, observations in harbour areas and markets, and opinions of local fishers and fisheries experts collected through interviews. We collected the data in terms of total fisheries removals by fleet and by single species, directing especial effort towards those species that are known to contribute the most to the catch: small pelagic fish, mainly European sardine, European anchovy and other small and medium-sized pelagic fish such as horse mackerel, mackerel and round sardinella, commercial demersal fish, such as European hake and blue whiting, and tuna-like species. Special attention was also paid to highly commercial invertebrate species such as red shrimp and cephalopods (e.g. cuttlefish and octopus). In addition, we used historical clues to understand if underreporting may have happened in the past, and if it may have been larger or lower than in the present.

This study did not include IUU practices related to aquaculture activities, and the by-catch of vertebrate species such as marine mammals, seabirds, and marine turtles (Silvani *et al.* 1999; Tudela 2004), the collection of algae, and the exploitation of highly valuable corals such as the red coral *Corallium rubrum* (Tsounis *et al.* 2007).

3.2. Data sources

We identified the main components of the unreported removals to be: (i) unreported legal landings or those landings that are sold in the black market, (ii) unreported artisanal and recreational removals, (iii) unreported subsistence fishing, (iv) unreported discards, and (iv) illegal catches by Spanish fishing fleets, mainly from driftnets during the 1990s. Data available to the study were sometimes available by ocean (Atlantic Ocean and Mediterranean Sea) or by Autonomous Region (AR). In the latter case, we distinguish the Andalusia Mediterranean region and the Andalusia Gulf of Cadiz region, in the South Atlantic, since the Andalusia Autonomous region has coastlines both along the Atlantic Ocean and the Mediterranean Sea (Figure 3).

3.2.1. Official landings

a) FAO Capture Production data

We used the capture production data available from the Spanish Mediterranean Sea and Gulf of Cadiz areas in the online FAO FishStat capture production database to obtain baseline officially reported catches (Table 3). These datasets are provided to FAO by the national reporting offices and, wherever possible, verified through other sources. Additional estimates are produced by FAO when data are lacking or are considered unreliable (Garibaldi 2012). In our reconstruction, two databases were used: 1) Global dataset of capture production 1950-2009 (extracted February 2011), and 2) Regional dataset of GFCM (Mediterranean and Black Sea) capture production 1970-2008 (extracted December 2010) (FAO 2011a, 2011b).

b) ICCAT

We included information from ICCAT regarding official data reported by Spain from the Mediterranean Sea for bluefin tuna landings and related species such as albacore tuna, bonito, bullet tuna *Auxis rochei*, frigate tuna *A. thazard*, little tunny *Euthynnus alletteratus*, and skipjack tuna *Katsuwonus pelamis* (http://www.iccat.int/en/t1.asp, Task I) (Table 3). Since

data available from ICATT for Spain cover the entire Mediterranean region (thus could be captured anywhere in the Mediterranean Sea outside our study area, Figure 3), we corrected available catches assuming that 100% of the bluefin and bullet tuna catch originated from the study area (i.e., Mediterranean Spanish waters) during 1950-1968, 90% from 1969-1979, 80% from 1980-1989, 70% from 1990-1999 and 60% from 2000-2010. We also corrected available catches from little tunny assuming that 80% originated in the study area from 1969 to 2010.

Swordfish catches were also available from ICCAT database from 1950 to 2010, and were corrected to assume that 80% of the amount was coming from the study area from 1969 onwards. Time series of official landings of pelagic sharks from Spanish waters were also obtained from ICCAT dataset of Task I.

c) National statistics

Different datasets were consulted to reconstruct official landings data from National Statistics and were compared with FAO datasets (Table 3). From an old archive we recovered time series of historic official landings data from 1950 to 1986 (MAPA 1940-1972 1973-1986). From this archive, we retrieved data for main catch groups (fish, crustaceans and molluscs) and 5 regions: (i) Spanish South Atlantic (the Gulf of Cadiz), and (ii) Spanish South Mediterranean (including Ceuta and Melilla territories), (iii) Levante region, (iv) Tramontana Region, and (v) the Balearic area. This dataset also included tuna species data from the *Almadrabas*, or fixed tuna traps, which are an old fishing technique of setting nets in a maze that leads to a central pool that is used to capture large pelagic fish and that existed since Roman times in the Mediterranean Sea. A recent dataset was available from 1996 to 2008 by FAO areas 37 and 27 directly from the website of MARM (http://www.marm.es/es/estadistica/temas/estadisticas-pesqueras/pesca-maritima/capturas/default.aspx) (MARM 2011) and the National Spanish Statistics Institute (http://www.ine.es/serv/ estadist.htm#0001).

From these datasets, we chose the years 1950, 1960, 1970, 1980, 1990, 2000 and 2008 as anchor points and data by detailed species and region was recovered. Data gaps were identified from 1987 to 1995, since official data from the Central Government was not available. Thus, to complement the time series, we used a linear extrapolation using 1986 and 1996 as anchor points.

In addition, the dataset covering 1996 to 2008 included the data from the Gulf of Cadiz in the total estimates for FAO area 27 and could not be separated from the Spanish Northern coastal areas. Contacts to enquire about additional data available from MARM were unsuccessful. Therefore, to separate catch data from the Gulf of Cadiz from FAO area 27 during 1996 to 2008, we first calculated the ratio of catches from the Gulf of Cadiz in relation to catches from the Spanish Mediterranean Sea from the time series of historic official landings (1950-1986) and time series of the Andalusia region (see regional statistics section). Then, we fitted the data to two exponential functions (with $R^2 = 0.75$ and $R^2 = 0.81$, respectively) that were used to predict the ratio from 1996 to 2008.

d) Regional statistics

Official available data from the Autonomous governments of Catalonia, Valencia Region, Murcia Region, Andalusia, and Balearic Islands were obtained from regional administrations (Table 3):

- Catalonia: we used a historic time series of data from 1950 to 1971 (Garrido and Alegret 2006), the available data bases from the Institute of Marine Science (CSIC) from 1970 to 1999,

and the online DAAR (Fisheries Department of the Catalonia Government) dataset from 2000 to 2010 (DAAR 1986-2010).

- Valencia Region: data were available from the Valencia government from 1982 to 2010 (CAPA 2011; PEGV 2011).

- **Balearic Islands**: official landings data were obtained from the Balearic Islands government from 1950 to 1987 and 1998 to 2009 (VVAA 1989; IBESTAT 2011) and from 1990 to 1994 (Massutí 1994). A detailed description of official sources of information can be found in Carreras *et al.* (2013).

- **Murcia Region**: data were obtained from the regional government from 1994 to 2009 (RM 2011) and from 1961 to 2000 from Esteve Selma *et al.* (2003).

- **Andalusia Region:** data were obtained from the regional government from 1987 to 2010 (IDAPES 2011; JA 2011), both for the South Atlantic region (i.e. Gulf of Cadiz) and the Mediterranean region. Historical data from Andalusia were used from 1950 to 2000 (IECA 2011).

It is important to note that some catches landed and reported in Gulf of Cadiz ports have been historically taken outside the Spanish EEZ, in African waters of Morocco and Mauritania (Sobrino *et al.* 1994; Guénette *et al.* 2001; Gascuel *et al.* 2007). Fishing activities in Morocco, with catches landed in the Spanish Gulf of Cadiz, started at the end of the 19th century and ended in 1996, with a clear decline of catches from the late 1980s (Sobrino *et al.* 1994). Fishing activity from Cadiz harbour in Mauritania started during the 1960s and continues today in low quantities (I. Sobrino, personal observation). Since no official record was found on the percentage of the catch landed in Spanish harbours coming from Western Africa waters, and taking into account the historical information available (Sobrino *et al.* 1994; Guénette *et al.* 2001; Gascuel *et al.* 2007), we hypothesised that landings from Morocco were 20% of landed catches in the Spanish Gulf of Cadiz from 1950-1959, 30% from 1960-1969, 40% during 1970-1989, and 30% from 1990-1996, and that landings from Mauritania were 20% during 1960-1980 and 10% from 1981 onwards.

In addition, Spanish fishing vessels from la Bahia de Algeciras, mainly from La Línea de la Concepción and Algeciras, have been fishing in waters surrounding the Rock of Gibraltar (approximately 60 km^2) since early times. The vessels that are used are small, between 10 to 16 m long, with 1 to 3 fishers on board, and mainly fishing with gillnets, small purse seiners and long liners. In 1999, after a conflict between Spain and Gibraltar, fishers' organizations and the Gibraltar government signed an agreement: four Spanish vessels could fish at any one time in the area, operating at a minimum distance of 250 meters from the coast (Annex 1). These vessels principally target horse mackerel (*Trachurus trachurus*), bullet tuna (*Auxis rochei*), and benthic invertebrates (mainly Moroccan cockles, *Acanthocardia tuberculata*) and the activity can be classified as artisanal and subsistence fishing. However, information on how many Spanish vessels have historically been fishing in waters surrounding the Rock of Gibraltar and the level of catches taken is largely absent. However, catches may be small since the area is only a small portion of the fishing grounds in the area (I. Sobrino, personal observation). If we assume that four vessels fish every day in the area, are able to fish 200 days per year, and capture 50 kg·day^{-1}·boat^{-1} on average, we can estimate that Spanish vessels in the waters surrounding the Rock of Gibraltar capture approximately 40-50 tonnes per year.

The separated and available datasets, combined with national statistics covered practically the entire studied period from 1950 to the late 2000s (Table 3).

3.3.2. Unreported landings

As an attempt to provide a first quantification, we carried out a literature research and a series of interviews to fishers and government employees during 2009-2011. This information provided anchor points from where we estimated unreported catches (Table 4). When historical information was available we took that into account, otherwise we extrapolated from intermediate periods of time with available data.

The literature revision was used to identify hot topics where unreported landings occur, such as (i) illegal catch (e.g., bluefin tuna overfishing, Raymarkers and Lynham 1999; ATRT 2006), (ii) illegal fishing techniques (e.g., the Spanish driftnet fishery after the 1992 ban, Silvani *et al.* 1999; Tudela *et al.* 2005), and (iii) portions of misreported legal catch (e.g., sharks catch, OCEANA 2007b; OCEANA 2008) or (iv) catch not reported in the official statistics, as it is mainly the case of recreational fishing (e.g., Gordoa 2003; Coll *et al.* 2004; Morales-Nin *et al.* 2005; TRAGSATEC 2005; Franquesa 2006; Lloret *et al.* 2008a; Gordoa 2009) (Table 5). This information was used to estimate unreported catches by region and main species for time periods available. Time series of official landings of pelagic sharks from Spanish waters that were obtained from ICCAT dataset of Task I were complemented with incidental catch reported for sharks (Megalofonou *et al.* 2005).

A series of interviews with fishers was carried out in different regions of the study area, both in the Spanish Mediterranean and Gulf of Cadiz regions, and had three main objectives: (i) verify the existence of unreported catches and identify principal sources of non-reporting, (ii) quantify, by fishing fleet and target species, the unreported catch, and how this unreported catch may have changed over time, and (iii) collect additional information on discarding. Therefore, we used the information retrieved from fishers' interviews to estimate unreported catches from the professional sector by region and main species. The interviews were carried out during 2009-2011 in ports of all the study area as part of a larger study to collect information on historical and current knowledge of Mediterranean ecosystems and fishing activities from fishers' perceptions (Coll *et al.* submitted). Surveys included questions about historical abundances of organisms, invasion of species, discarding and non-reporting activities. Fishers that were interviewed were chosen due to them being previously known to the interviewers and there was confidence in the objectivity of their responses. A total of 64 fishers were interviewed from twenty-seven harbours distributed in in the four different regions. Most of interviewed fishers had been involved in different fishing segments during their lives and most of them were fishing in the trawling fleet, but had also participated in other fishing activities including purse seiners, long liners, gillnetters and other artisanal gear (Coll *et al.* submitted).

A large proportion of fishing activity can be classified as artisanal fishing in the Mediterranean Sea, targeting a large number of fish and invertebrate species (Alarcón Urbistondo 2002; Coppola 2006; Stergiou *et al.* 2006). In our study area, the catch by the artisanal fishery was mainly registered in the *Lonjas***,** although artisanal fishers can use other marketing mechanisms (Alarcón Urbistondo 2002). Using the fishers' interviews, we also quantified the amount of artisanal catch that is not officially reported.

In addition, within the umbrella of the Data Collection Framework (EC Regulation 199/2008), concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy, carried out by the *Instituto Español de Oceanografía* (IEO), available data were used from the Spanish National Data Collection Program to compare landing declarations and sales notes (I.Sobrino & M. Torres, unpublished data, and Carreras *et al.* 2013). The objective of this exercise was to cross-check this information and quantify the proportion of

landed catch from trawling that was not declared in the sales notes during 2008 and 2009; thus, it was not included in the official landing statistics. This provided us with additional information of unreported catch in these two regions, which was compared with data from fishers' interviews to validate or exclude results from the interviews.

3.3.3 Species breakdown of the recreational, artisanal, and subsistence fisheries in the Spanish Mediterranean Sea and the Gulf of Cadiz

a) Taxonomic composition of the Spanish Mediterranean Sea and Gulf of Cadiz recreational fisheries

The taxonomic breakdown of the Spanish Mediterranean Sea recreational catch was derived from Gordoa *et al.* (2004) who presented data on the species composition (by percent of presence and weight) of recreational catches according to fishing modality. For each species, the percentage by weight for all fishing modalities was summed and then re-scaled to 100%. The final percentage contribution of each species was then applied to the total Spanish recreational catch from 1950 to 2010.

Despite recreational fishing being a popular activity in the Gulf of Cadiz, there is little information regarding the catch composition of recreational fisheries. Thus, we used the Spanish Mediterranean Sea recreational catch composition to disaggregate the total catch from recreational fisheries in the Gulf of Cadiz from 1950 to 2010.

b) Taxonomic composition of the Spanish artisanal and subsistence fisheries

A significant portion of the Spanish artisanal and subsistence catch was reported as 'Marine fishes nei' and 'Marine invertebrates nei'. We used the species composition provided by Fernandez (2009) to reassign these categories to higher resolution taxonomic categories (family level or lower). Annual landings were provided from 1992 to 2006 for artisanal fisheries in the coastal town of Santa Pola (southeast Spain). Landings were reported for 19 species of marine vertebrates, and two species of marine invertebrates. We assumed the two invertebrates, *Octopus vulgaris* and *Sepia officinalis*, made up 90% of the landings originally reported as 'Marine invertebrates nei'. The percent contribution by weight of all species was then calculated separately for marine vertebrates and invertebrates, for the period of 1992 to 2006. The percentage composition for 1992 was carried back, fixed, for the period 1950-1991; similarly, percentages in 2006 were carried forward, fixed, for the period 2007-2010. Species proportions were then applied to the total artisanal catches for 'Marine fishes nei' and 'Marine invertebrates nei' from 1950 to 2010. Because there was a lack of information available regarding the catch composition of subsistence fisheries, we used the artisanal species proportions to determine the species composition of the subsistence catch from 1950 to 2010.

Note we excluded data reported under three general categories, "Morralla", "Revuelto", and "Sopa". From 1992 to 1994, landings of *Mullus surmuletus* and *M. barbatus barbatus* were reported as a combined weight by Fernandez (2009). For these years we assumed that the percentage contribution of each Mullus species was the average percentage contribution of each species from 1995-2006.The category "Other pleuronectiformes" was taken to be "miscellaneous marine fishes" and was set to 10% of the catch. The proportions of the remaining categories were normalized to constitute 90% of the catch.

c) Taxonomic composition of the Gulf of Cadiz artisanal and subsistence fisheries

Species composition of artisanal fisheries landings for the Gulf of Cadiz are available for the years 1996 and 1997 (Silva *et al.* 2002). We separated the landings into invertebrates and vertebrates, then applied the average percentage contribution of each species from 1996-97 to the total catches for 'Marine invertebrates nei' and 'Marine fishes nei' from 1950 to 2010. We used the same species proportions to determine the species composition of the subsistence catch from 1950 to 2010.

3.3.4. Discards

a) Direct boat-based discards

Data regarding discards in the study area were collected from available literature and from interviews with fishers (Table 6). This information provided anchor points used to estimate the rest of catches (Table 4). When historical information was available, we took that into account; otherwise we extrapolated from intermediate periods of time with available data.

Most of the studies and projects that have investigated the existence of discarding in the study area are about discards of bottom trawling activities (e.g., Oliver 2001; Tudela 2004; Bahamon *et al.* 2006; Guijarro and Massutı 2006; Sardà *et al.* 2006). Data regarding discards from purse seine and long line is less common (Table 6). In the case of purse seine, some information existed from the Catalan and Gulf of Cadiz region, including data obtained from fishers' interviews in the Gulf of Cadiz and various areas of the Spanish Mediterranean coast, which documents discarding for trawling, long line, purse seine, gillnets and other artisanal fishing. Combining available information from the literature by region (first by area and then by year) and results from the fishers' interviews (by region in late 2000s), we estimated a possible percentage of discarded catch of the major caught species and fishing fleet by region of the study area.

b) Underwater discarding and ghost fishing

Another source of discarding occurs underwater, after organisms escape from fishing gear but die of injuries or stress after few hours or days (Suuronen 2005). However, mesh-size of Spanish Mediterranean bottom trawling gear was very small until 2010 (bottom trawls used a 40mm diamond mesh codend made of 5mm diameter netting) and the selectivity of the gear was null since the mesh was practically blind (e.g., Bahamon *et al.* 2006; Guijarro and Massutı 2006; Sardà *et al.* 2006; Bahamon *et al.* 2007). Therefore, we assumed that trawling did not produce substantial underwater discarding in the study area from 1950 to 2008.

Additionally, the massive use of artisanal gears such as traps and fixed nets in many artisanal and small-scale Mediterranean fisheries makes ghost fishing a potentially important problem in Mediterranean waters (Brown *et al.* 2005b; Macfadyen *et al.* 2009b). However, there is little data available (Tudela 2004; Brown *et al.* 2005b; Macfadyen *et al.* 2009b). Taking into account that estimated ghost caches in European waters are generally believed to be less than 1% (Brown *et al.* 2005b), we hypothesised that an additional 1% of the official catch of coastal-distributed demersal fish and invertebrates were discarded due to ghost fishing from 1950 to 2010.

Although underwater discarding and ghost fishing is estimated here, these data are not included in the reconstructed catch data being used by the global *Sea Around Us* project, as it is currently not feasible to reliably estimate these components for all countries and fishing gears in the world.

4. Results

4.1. Different components of total fisheries removals

4.1.1. Official landings: FAO databases and national and regional statistics

The two FAO datasets (the global dataset from 1950-2009 and GFCM dataset from 1970-2008) showed similar official landings of Spain from the Mediterranean area 37 (Figure 4a). Spanish official landings from the Mediterranean FAO area 37 ranged from 92,000 to 183,000 tonnes. However, this was substantially lower than the official national dataset, especially from 1961 to 1985 (Figure 4a). Official landings available from the Spanish Gulf of Cadiz area of the South Atlantic FAO area 27 from FAO global dataset from 1950-2009 were also lower than national data available, especially during 1965 to 1978 (Figure 4b).

The combination of data from both Spanish areas (Mediterranean and South Atlantic) using different sources also documented data discrepancies (Figure 4c). Overall, we observed a general increase of official landings in the Spanish Mediterranean and Gulf of Cadiz regions from 1950 (approximately 200,000 t·year^{-1}) to the late 1960s (with a maximum of 374,162 t·year^{-1}) and a decline from the 1970s to 2008 (to 130,000 t·year^{-1}). When comparing data from national statistics and Autonomous Region statistics (Figure 4d), we also found differences in terms of official landings reported from the study area (Figure 4c). The catches by region were slightly lower than in national statistics during the 1960s and 1970s, but were higher from the 1990s onwards. This may suggest changes in the mechanisms of reporting landings from regional to national administrations.

Andalusia was the region that officially registered most landings, even after official data had been corrected to take into account landings that were caught outside Spanish waters, in Morocco and Mauritania (Figure 4d). The Catalan and Valencia regions followed with similar amounts (historic data for the Valencia region from 1950 to early 1980 were not available: we assumed constant catch through this period). The Balearic Islands and Murcia region had similar official landings: minimum values recorded for the Balearic Islands were 3,000 t·year^{-1} and maximum values were 5,800 t·year^{-1}, while catches, in Murcia, fluctuated between a minimum of 3,000 t·year^{-1} and maximum of 7,700 t·year^{-1} (Figure 4d).

Combining data from the *Almadrabas* or fixed tuna traps (from historic official landings data from 1950 to 1986) with data from ICCAT including declared Spanish catches of tuna-like species and swordfish, we reconstructed the minimum official landings of these large pelagic fish from the study area (Figure 5a). In 1943, *Almadrabas* generated a total of 13,000 t·year^{-1}, but this amount declined to 1,400 t·year^{-1} by 2000. ICCAT data started in 1950 with a reported 1,850 t·year^{-1}, which increased to 3,700 t·year^{-1} in 2009. ICCAT data on by-catch species of sharks were non-existent for most of the time period analysed (Figure 5b). Species listed in these statistics were blue shark (*Prionace glauca*), thresher sharks (*Alopias vulpinus* and *A. superciliosus*), shortfin mako (*Isurus oxyrinchus*), cooper shark (*Carcharhinus brachyurus*), tope shark (*Galeorhinus galeus*), hammerhead sharks (*Sphyrna* spp.) and a category of "Other squaliformes". Jointly, i.e., combining the *Almadrabas* and information from ICCAT for tuna-like species, swordfish and pelagic sharks show a global decline of catches from 1950 to the 1960s, with current catches fluctuating around 4,000 t·year^{-1} (Figure 5a).

Comparing the original national or regional data with corrected data to take into account catches from foreign waters by the Andalusia region and catches of large pelagic fish, we found that the overall trend of official landings changed (Figure 6a). A decreasing trend of official landings from 1960 to 2008 emerged, while the duration of the increase was reduced to the

1960s, since it was mainly due to catches originating from African fishing grounds and landed in Andalusia.

Official landings of main species caught in different years suggested some changes in species composition over time (Figure 7). Sardine, hake and anchovy were the main species caught during the study period, but their catch declined over time, especially that of hake and anchovy. Horse mackerel fluctuated, and mackerel showed an increase. Additionally, official landings of elasmobranchs clearly declined from the 1950s to the 1970s, while round sardinella, octopuses, and blue whiting increased substantially. The striped venus clam (*Chamelea gallina*) was very important in the 1950s and 1970s (especially in the Gulf of Cadiz region), and red shrimp landings (mainly from the Mediterranean Sea) were especially important in the 1950s and 1980s, showing clear fluctuations. The rest of the fish and invertebrate species that contributed to less than 1% of the catch increased with time, from 20% in the 1950s to >30% in late 2000s (Figure 7).

4.1.2. Unreported fisheries removals

From the literature, we identified the key components of unreported catches, such as (i) illegal catch, (ii) illegal fishing techniques, (iii) misreported legal catch, and (iv) catch not reported in the official statistics, such as recreational fishing. All the available information was used to estimate unreported catches by region and main species for time periods available (see sections below).

Interviews with fishers in different regions of the study area enabled us to verify the existence of unreported catches, to identify principal sources of non-reporting and provide a first quantification.

a) The 'black market' and subsistence fishing

Seventy-seven per cent of interviewed fishers confirmed the existence of unreported catches, while 19% denied their existence and 4% did not answer. Principal sources of non-reporting were fish that was consumed by fishers' family and relatives (54%) (so-called 'take-home catch', treated here as a part of subsistence fishing), followed by fish that directly went to family businesses (e.g., fish shops or restaurants, 33%) and fish that was directly sold to traders (30%). Important amounts of catches were also directly sold to individuals in the harbour area (18%), while other sources of non-reporting identified were less important: such as direct sales to other local industries (7%), direct sales through the Internet (7%) and sales to central markets (4%).

According to fishers, these unreported catches added, on average, 20% of additional catch to the officially reported landings in the region, while responses from the Gulf of Cadiz recognised larger values closer to 50% (although less data were available from this region than for the Mediterranean area). Available data obtained from the Spanish National Data Collection Program, which is being carried out by the *Instituto Español de Oceanografia* (IEO) for the Gulf of Cadiz regarding landing declarations and sale notes quantified a mean of 23.5% of catches that were caught by trawlers but that where not declared in the *Lonjas* during 2008-2009. Results of a similar study carried out by the IEO in the Balearic Islands with observers on board trawlers during 2001-2010 highlighted that, on average, 11% of all catches are not officially recorded (Carreras *et al.* 2013). These independent estimates are in agreement with our estimates from trawlers (Figure 8a). Therefore, we used this mean as representative of the area, both in the Mediterranean and the Gulf of Cadiz, although these estimates may be rather conservative. More than 40% of fishers stated that unreported catches were associated with trawling, purse seining, long lining, gillnets and artisanal fisheries (Figure 8a). Mean values of

non-reporting were highest for long lining (19% ± 4%), gillnets (18% ± 3%), trawling (17% ± 2%), and purse seine (15% ± 3%) (Figure 8a).

Data from fishers' interviews indicated that considerable amounts of fish were used for self-consumption by the fishers and their families (treated here as subsistence fishing) or for family businesses (i.e., commercial ventures). According to fishers, this was a common practice in the whole area. Personal observations by the authors at fishing harbours enabled us to estimate that, on average, each fisher takes home between 1-3 kg of fish per day. Therefore, we estimated total unreported catch due to take-home subsistence fishing could be between 3,000 to 8,000 t^{-1}·$year^{-1}$. This represents 2-6% of total estimated catches.

Fishers also indicated that this non-reporting was especially important during some periods of the year (20% of fishers that were interviewed indicated seasonality), especially during Christmas holidays, summer holidays and Easter holidays, while 18% did not think that non-reporting was related to any particular season, and 60% did not reply. Fishers mentioned a total of 27 species of fish and invertebrates that were unreported in different regions, including those species with important catches (Figure 8b).

Fishers provided enough data to investigate whether non-reporting had increased or decreased over time. Of the fishers interviewed, 41% declared that non-reporting had decreased over time since they started fishing, while 12% thought that it had increased, and 47% did not answer or did say they did not know. The mean decline in unreported catches was -26% in the Mediterranean, fishers indicated a mean decline of -27%, in line with historical anchor points (Table 4). However, in the Gulf of Cadiz, fishers argued that non-reporting had increased by +2%. To account for this information in our estimate of total catch, we compared data with the assumption that non-reporting had been similar during all-time series investigated and the assumption that had declined from 1950 to 2010 by 26% (Figure 6b).

When accounting for the non-reporting in total landings of the region (Figure 6b), we observed that trends in total catches showed the highest value in 1958 with approximately 400,000 $t·year^{-1}$ of catches to a minimum value in the late 2000s of 163,000 $t·year^{-1}$, and a declining trend since the 1960s.

b) Unreported artisanal and recreational fishing

Data from fishers interviews was also used to estimate the total amount of artisanal catches (i.e., small-scale commercial) that are unreported (Figure 8a). In principle, artisanal fisheries should get registered in official statistics as other fisheries, but this is not always the case. Of all fishers interviewed, 44% identified artisanal fisheries as important in terms of unreported catches. Fishers indicated that, on average, non-reporting of artisanal fisheries may represent an additional 20±3% in addition to official landings.

Another important source of unreported catches is the catch from recreational fishing (Table 5). This catch can represent an important amount and it is not captured in official statistics. In Spain, recreational fishing needs to be associated with a recreational fishing licence. It is a well-established economic activity in the study area. It represents a highly diversified activity (Franquesa *et al.* 2004; Gordoa *et al.* 2004; Gaudin and de Young 2007), comprising both shore-based fishing (e.g., pole and line, or diving) and boat-based fishing (including diving). Different types of recreational fisheries exist: (i) shore fishing with pole and line, (ii) fishing when diving, both from coast or from a vessel, (iii) diving competitions, (iv) charter activities that include fishing as a tourist attraction, and (v) fishing from rented vessels (Franquesa *et al.* 2004).

Boat-based species caught during competitions are mainly bluefin tuna, little tunny, bonito, skipjack tuna and albacore tuna. Main species for shore-based fishing are more diverse and include table fish such as the gilthead seabream (*Sparus aurata*), white seabream (*Diplodus sargus*), European seabass (*Dicentrarchus labrax*), sand steenbras (*Lithognathus mormyrus*), conger eel (*Conger conger*), octopuses (mainly the common octopus *Octopus vulgaris*), and salema (*Sarpa salpa*) (Franquesa *et al.* 2004; Gordoa *et al.* 2004).

Despite the importance of recreational fisheries in the Mediterranean Sea (Gaudin and de Young 2007), little information on total removals from these activities exists to date (Franquesa *et al.* 2004) (Table 5), although preliminary studies from the mid-2000s for our study area (including Spanish Mediterranean and Andalusia region) estimated a total annual fish harvest of 19,740 t (Gordoa *et al.* 2004; Franquesa 2006; Gaudin and de Young 2007). By region, Andalusia and Catalonia are the regions with largest absolute values of recreational removals, followed by the Balearic Islands, Valencia and Murcia (Figure 9a). If recreational removals are compared to commercial catches, the Balearic Islands are the region with the largest recreational catches relative to commercial fisheries, followed by Catalonia and Murcia (Figure 9b). Overall, recreational catch represented 13.2% of that from commercial fisheries in the mid-2000s. Since historical data on the importance of recreational fisheries were not available, we assumed that its importance was similar back to the 1980s, but was lower from the 1950s to the 1970s (accounting for half of the amount in terms of landings, thus 6.6%).

When we included recreational catches in total catches of the region, we observed that the overall trends of total catches peaked in 1958 with approximately 413,000 $t \cdot year^{-1}$, then fluctuated to 1982 and declined to a minimum value of 180,000 $t \cdot year^{-1}$ in the late 2000s (Figure 6c).

c) Illegal catches and non-reported catches of vulnerable species

Finally, unreported catches are also due to (i) illegal catch of commercial species (undersized or species that have quotas such as bluefin tuna), (ii) illegal fishing techniques (such as the Spanish driftnet fishery after the 1992 ban), and (iii) portions of misreported catch of protected species or species at risk (such as pelagic sharks).

Illegal catch in the study area is mainly directed toward juvenile commercial species (such as juveniles of demersal species as European hake or small pelagic fish like sardines or anchovies). This unreported catch can be substantial and we tried to quantify it while analysing non-reporting going to the black market (see section on black market sales) (Figure 8a, juvenile hake, anchovy and sardine). It was also included in discarding quantifications

However, there is an important component of illegal catch which is directed at commercial large pelagic species, mainly bluefin tuna (Raymarkers and Lynham 1999; ATRT 2006), and pelagic by-catch species which are frequently vulnerable and data deficient. The Mediterranean bluefin tuna fishery has been considered to be mismanaged for many years (ATRT 2006; MacKenzie *et al.* 2009). For more than a decade, the eastern Atlantic and Mediterranean bluefin tuna has been heavily fished by oversized industrial purse-seine fleets that flout ICCAT's catch limits and compromise sustainability of the fishery. Studies that analysed the international trade in bluefin tuna from 1998 to 2010 found significant gaps between the catch limits set by ICCAT and the reported amount of bluefin tuna traded on global markets each year (ATRT 2006, 2010; Mielgo Bregazzi 2011) (Table 4). The percentage of over-quota for bluefin tuna ranged from 5-10% in 1999-2004 to a maximum of 140% in 2010. Using these data, we calculated the percentage of over-quota from 1998 to 2010 and applied it to available bluefin tuna data from ICCAT for our study area (Figure 10).

Illegal fishing techniques are also used in the study area. The most problematic was the Spanish driftnet fishery (Silvani *et al.* 1999; Tudela *et al.* 2005) (Table 4). Driftnet fisheries are especially problematic due to the large amounts of by-catch they produce. This gear type poses serious threats for the conservation of large pelagic fish and elasmobranchs, and other organisms such as cetaceans, marine turtles and seabirds (Tudela 2004). Resolutions adopted in 1989 and 1991 by the General Assembly of the United Nations recommended a moratorium on all large-scale pelagic driftnet fishing by 1992. In 1992 the European Community and Spain prohibited driftnet fishing in the Mediterranean with nets more than 2.5 km in length, as did the GFCM in 1997 under a binding Resolution. A total ban on driftnet fishing on large pelagic species by the EU fleet in the Mediterranean entered into force from 2002 (GFCM 1997b; EC 1998). Despite these prohibitions, several claims of fraud have been reported after the ban and the activity continues in Mediterranean European and non-European waters (OCEANA 2005; Tudela *et al.* 2005; OCEANA 2006b, 2007a). In the Southern Spanish Mediterranean area, important amounts of by-catch of mainly sunfish (*Mola mola*) and other pelagic fish (such as shortfin mako, blue shark, smooth hammerhead *Shyrna zygaena*, eagle ray *Myliobatis* sp. and marbled electric ray *Torpedo marmorata*) were documented by Silvani et al. (1999) during 1992-1994 while driftnets were targeting swordfish (Silvani *et al.* 1999). Of total catch, sunfish represented 71% of the catch in 1992, 93% in 1993 and 90% in 1994. This fleet operated on both sides of the Strait of Gibraltar, as it was following the seasonal migration of swordfish.

To take into account these illegal and non-reported catches until 1994, we quantified the amount of driftnet by-catch of sunfish and other species in the area, and converted total number of individuals by species to weight (using FishBase, Froese and Pauly 2013) and scaling total catches to 100% of operations in the area (percentage of followed operations were 1.4%, 3% and 10.2% annually during three years in Silvani *et al.* 1999). Total swordfish catch accounted for 980 $t \cdot year^{-1}$, 900 $t \cdot year^{-1}$ and 580 $t \cdot year^{-1}$ in 1992, 1993 and 1994, respectively, and other commercial fish species were 478 $t \cdot year^{-1}$, 20 $t \cdot year^{-1}$ and 5 $t \cdot year^{-1}$ in 1992, 1993 and 1994, respectively. Total amounts of by-catch of sunfish were quantified to be of approximately 6,000 $t \cdot year^{-1}$, 12,000 $t \cdot year^{-1}$, and 17,000 $t \cdot year^{-1}$ in 1992, 1993 and 1994, respectively (we used a mean body weight of sunfish of 200 kg). Other species were estimated to be 69 $t \cdot year^{-1}$, 21 $t \cdot year^{-1}$ and 50 $t \cdot year^{-1}$. Since the use of driftnets in the Alboran Sea started in the 1980s and lasted until 1994 (Silvani *et al.* 1999; Tudela *et al.* 2005), we assumed that historical by-catch had existed since 1975 until the activity of this fleet stopped in 1994 (Figure 10).

Portions of misreported catch of protected species or species at risk also occur, both for demersal and pelagic species in other fisheries. For demersal species (such as small and medium-size sharks and rays), we tried to capture this catch while quantifying non-reporting going to the black market (see section on black market sales), and this was also included in the estimation of discards, as it seems that most of Mediterranean demersal sharks and rays caught are either discarded or landed as whole carcasses (Hareide *et al.* 2007). Some of these species are kitefin shark (*Dalatias licha*), velvet belly (*Etmopterus spinax*), blackmouth catshark (*Galeus melastomus*), small-spotted catshark (*Scyliorhinus canicula*), and longnose Spurdog (*Squalus blainville*). Artisanal fisheries also capture some small sharks and rays, although not in large volumes (Hareide *et al.* 2007). The main species are small-spotted catshark and skates (*Raja* spp.). They may be landed or discarded, depending on the size and price.

In case of large pelagic sharks, official data from ICCAT is very poor (Figure 5b), and most likely substantial underestimates. Spain is the second largest exporter of shark fins to the Hong Kong market after China (Hareide *et al.* 2007; OCEANA 2008; Lack and Sant 2011) and fin sale is a profitable activity for Spanish fisheries (OCEANA 2007b, 2008). Currently, 42% of shark species in the Mediterranean have been assessed as threatened and 29% are endangered or critically endangered according to IUCN criteria (Cavanagh and Gibson 2007; Abdul Malak *et al.* 2011), with fisheries being the major threat to their conservation. Unfortunately, it is unclear what proportion of Spanish pelagic shark catches come from the Mediterranean Sea (Hareide *et*

al. 2007; OCEANA 2008). There are no specific Mediterranean pelagic fisheries targeting migratory oceanic sharks, but these species constitute a large component of by-catch in tuna and swordfish fisheries operating in coastal and offshore waters using long lines, driftnets, purse seines and *Almadrabas* (or fixed tuna traps) (Silvani *et al.* 1999; Macías *et al.* 2004; Megalofonou *et al.* 2005; Hareide *et al.* 2007).

Some shark data from illegal driftnets in Spanish waters were already available from Silvani and co-authors (Silvani *et al.* 1999) to complement ICCAT official data from the 1980s to 1994 as explained above. Data from ICCAT (http://www.iccat.int, Task I) came mainly from surface long-line that target tuna and swordfish in the Spanish Mediterranean Sea. Long-lining emerged at the beginning of the 20th century in this area, with a clear expansion in the 1960s to 1980s (Rey *et al.* 1988; Macías *et al.* 2004). Although data are not abundant about this fishery, a study in 2001-2002 in the Western Mediterranean (including Balearic Islands, Catalonia and Andalusia) documented important amounts of elasmobranchs and other non-commercial species in the catch (Macías *et al.* 2004). The study described that in 2001 and 2002, elasmobranchs were 0.5-1% of swordfish catches (mainly including thresher sharks, blue shark and shortfin mako) and other species represented 2-4% of swordfish catches (including sunfish, sting rays *Dasyatis* spp., and other non-commercial fish) (Macías *et al.* 2004; OCEANA 2006a).

Another study carried out by observers at landing sites and on-board fishing vessels was used to complement the information about total catch of sharks (Megalofonou *et al.* 2005). The authors documented incidental catches and discards of sharks from long-lines and driftnets and provided information on species composition, distribution, and abundance. In this study, five fishing gears were examined during 1998-1999: swordfish long-line, “American type” swordfish long-line, albacore long-line, bluefin tuna long-line, and driftnet. As a whole, sharks represented 13.5% in biomass of the catch sampled, and the main species were blue shark, shortfin mako, common thresher shark, and tope shark. In our study areas, sharks represented 34.3%, 1.7% and 1.4% of total biomass caught in the Alboran Sea, Balearic Islands and Catalan Sea, respectively. Other species represented 1.1%, 4.4% and 0.2%, respectively (Megalofonou *et al.* 2005).

Comparing this information about by-catch of large pelagic sharks and official data from ICCAT, it was clear that the latter seemed to be incomplete (Figure 5b). Therefore, we complemented the official dataset using the official swordfish catch to calculate by-catch of sharks and other non-commercial species (assuming 10% for sharks and 3% of other species) (Figure 10). Additionally, in fixed tuna traps, the main species of elasmobranchs traditionally caught as by-catch were large individuals of common thresher, basking shark (*Cetorhinus maximus*), blue shark, devil ray (*Mobula mobular*) and sometimes great white shark (*Carcharodon carcharias*), but only data from Italy exists (Hareide *et al.* 2007). Therefore, we assumed a 5% by-catch of large pelagic sharks in Spanish *Almadrabas* from 1950 to 2000 (Figure 10).

After accounting for different sources of illegal catch or by-catch of pelagic species, we observed that catches were higher for driftnets, followed by the over-quota of bluefin tuna (Figure 10). However, when accounting for these illegal catches in total catches from the study area (Figure 6c), illegal catches made a low contribution to total removals: the highest value was still observed in 1958 with approximately 414,000 t·year^{-1}, fluctuated to 1982 and declined to a minimum of 182,000 t·year^{-1} in 2008-2010.

4.1.3. Discards

Scattered quantitative data existed about boat-based discards of bottom trawling activities in the study region, which is mainly linked to demersal species but can also discard small and medium-sized pelagic fish (e.g. Oliver 2001; Tudela 2004; Bahamon *et al.* 2006; Guijarro and

Massutı 2006; Sardà *et al.* 2006) (Table 6). Available data regarding discards from purse seine and long-line were less abundant (Table 6). In the case of purse seine, only some information existed from the Catalan and Gulf of Cadiz region, partly from the fishers' interviews in the Gulf of Cadiz and various areas of the Spanish Mediterranean coast, which documented discarding for trawling, long-line, purse seine, gillnets and other artisanal gears (Figure 11).

Data on discards from trawling was available intermittently for the mid-1990s and 2000s from some regions, with the exception of Murcia (Figure 11a). Discarding by trawls ranged from 14-57% of official landings, depending on regions and time period. In 2009-2011, we could retrieve information by region and fishing fleet (Figure 11b). Valencia region was the area that showed the highest discards from trawling and purse seine, followed by the Gulf of Cadiz with highest discards from artisanal gears, and the Balearic Islands with highest discards from gillnets. Discards from trawling, purse seine and gillnets were overall high in Catalonia, Valencia and Southern Mediterranean area (Figure 11b). These results are presented as the percentage of discards with respect to total landings. In the case of percentage of discards by fleet (Figure 11b) it has to be noted that gillnets and artisanal gears show important percentages of discards in the Balearic Islands and Andalusia, but since they are expressed as a fraction of official landings by fleet, the absolute amount of discards by these fleets is lower than the ones generated by trawling.

Historical data available from other fleets showed that in Catalonia, discards from purse seine may have slightly increased from the 1990s to 2010, while long-line discards could have slightly decreased (Figure 11c). According to our interviews with fishers, and data from the literature, discards from the artisanal fishery in the Gulf of Cadiz may have experienced an increase from the 1990s to 2010 (Figure 11c). Data on discards by main species in the catch (Figure 7) illustrated that several species, including commercial species, are subjected to discarding (Figure 11d). This discarding is highly variable and medium-to-high for the principal species, both pelagic and demersal. Although available data from trawling showed an increase of discards from the 1990s to 2010 (Figure 11a), most interviewed fishers stated that, overall, non-targeted catch had declined with time (47%), with a mean decline of -7%. On the other hand, some fishers suggested that it had increased over time (17%), and a quarter considered that discarding remained unchanged (26%). The rest stated they did not know or did not answer.

Using the data available from boat-based discards in the study area (Figure 11), we estimated total boat-based discards. Since it was not obvious that discarding changed with time, we used data from the 1990s to 2010 as representative of the entire time period from 1950 to 2010. This decision may be underestimating discards in the past if discarding has truly decreased with time as several fishers stated. Additionally, taking into account that estimated ghost caches in European waters are generally believed to be approximately 1% of official catch (Brown *et al.* 2005b), we added an additional 1% of coastal-distributed demersal fish and invertebrates that were discarded due to ghost fishing. These ghost-discards are presented here but not included in the reconstructed data incorporated in the global database of the *Sea Around Us* Project.

When accounting for these boat-based discards and ghost catches in the total catch estimates (Figure 6c), we observed that discards made an important contribution to total catches: the highest value was observed in 1958 with approximately 515,000 $t \cdot year^{-1}$, fluctuated to 1982 and declined to a minimum of 229,000 $t \cdot year^{-1}$ in 2008-2010.

4.2. Total fisheries catches compared to official landings

Total reconstructed fisheries removals in the Spanish Mediterranean and Gulf of Cadiz were estimated by summing all catch components investigated here: official reported landings, discards and unreported catches. Overall, the total reconstructed catch is 1.7 times that of the available reported catch for the same time period. Reported landings represented 58.5% of the total reconstructed catch, followed by IUU landings (22%) and discards (19.5%) Unreported landings were investigated in terms of black market and subsistence fishing, artisanal fishing and recreational fishing. They also included a small portion of illegal catch. Of these elements of unreported catch, in 2008 recreational fisheries were the most important (~36%), followed by black market (~32%), subsistence fishing (~17%), artisanal (~12%) and illegal catch (~2%).

The total reconstructed catch grew quickly through the early part of the time period from 315,000 t in 1950, to 513,000 t in 1958. After this point, however, there was an overall gradual decline of total catch, with substantial fluctuations including peaks in the late 1970s, 1982, and 1994. The rate of decline increased from the mid-1990s, when it declined to an average of 227,000 $t \cdot year^{-1}$ for 2008-2010. When compared to official estimates of landings from FAO (Figures 6a and 12) a slightly different trend emerged: while the FAO data showed an increase of landings from 1950 to the mid-1960s and a clear decline from early 1980s to date, reconstructed total catches showed an earlier peak of total removals in the late 1950s, and a decline from the mid-1970s to the present.

Total removals in the study area were mainly assigned to the industrial sector (Figure 13a), with landings contributing 69%, while discards followed, with 20% of total removals. Recreational, artisanal and subsistence fishing removed smaller amounts of catch from the ecosystems, making up 6%, 3% and 2% respectively. (Figure 12a). The catch was dominated by miscellaneous invertebrates and sardines, comprising 24% and 20% respectively. Hake (10%) and anchovy were the next most prominent species. Beyond these taxa, the catches are very diverse. (Figure 12b). Clear declines with time are observed for important commercial species such as hake, anchovy, and sardine, while other species increased in the catch in recent years, such as round sardinella, other pelagic fish such as mackerel and blue whiting, and octopuses and other invertebrates.

5. Discussion

This study provides a first estimate of total fisheries removals by Spain from the Spanish Mediterranean Sea and Gulf of Cadiz regions (1950-2010). Despite several limitations highlighted below, this study shows that IUU catches may be large, making up an average of 43% of total fisheries removals, including discards. This percentage of IUU catches increased with time from 1950 to 2010 and was always more than 38% of the total catch, demonstrating the importance of IUU catches in Spanish fisheries. These overall IUU estimates are, in fact, in line with the estimates of the European Court of Auditors (Court of Auditors 2007), where it was pointed out that Spain may be non-reporting 40% of total catches.

Other estimates of IUU in Mediterranean ecosystems have highlighted similarly high IUU proportions of the catch, e.g., in Corsica(with 5 times more catch than officially reported, Le Manach *et al.* 2011), in the Balearic Islands with 3 times more catch (Carreras *et al.* 2013), or the 35% IUU in Greek waters (Tsikliras *et al.* 2007). Our estimates are higher than the one from Greek waters but smaller than the ones from Mediterranean Islands. This is logical, since the two Mediterranean Islands studied are highly dependent on tourism and infrastructure to record and monitor catches is lacking. Moreover, even recent research have reported significant IUU catches from North European ecosystems, such as the Baltic Sea with an average of 30%

unreported catches (Zeller *et al.* 2011b). On average, our estimate is higher than the preliminary global average of 18% calculated for 2000-2003 (Agnew *et al.* 2009).

Unreported catches, including discards, represent a significant handicap to the work of regional and international organizations, and assessments by fisheries scientists. They bias data availability and therefore our ability to understand how fishing activities impacts species, marine communities and ecosystems (Zeller and Pauly 2007). When fishing data are underestimated, the impact of fishing is also underestimated, which may threaten not only exploited resources but also the future economic viability of the fishing industry. Therefore, the estimates of total fisheries removals we present in this study represent an improvement over official data, and should be taken into account when progressing towards ecosystem-based fisheries management, since fishing mortality for many species may be higher than previously estimated. This study shows that relying solely on officially reported data may imply the underestimation of fishing mortality.

It has to be noted, however, that these first estimates of IUU catches by Spanish fisheries could still be underestimated, because important information gaps still exist, especially in historical time series. Significant technological changes have occurred over the last 60 years and incentives for fishing development and fishing laws have changed and evolved over time (Bas *et al.* 1985; Bas *et al.* 2003, Table 4; Bas 2009). A similar reconstruction approach should be applied to reconstructing fishing effort development over time. This could help scientists and policy makers to understand what the real impact of fishing on marine resources of the Spanish Mediterranean and Gulf of Cadiz regions is.

This study excluded by-catch of marine mammals, seabirds, and marine turtles, and the illegal catch of precious species such as red coral. However, by-catch of marine mammals, seabirds, and marine turtles can be large (Camiñas and De la Serna 1995; Silvani *et al.* 1999; Camiñas 2004; Biton Porsmoguer 2009). Moreover, data reconstructed for commercial fish and invertebrates is approximate due to uncertainties associated with the estimates (Table 4) and misidentification of landed species (e.g., Oltra *et al.* 2008). Future efforts to improved data on species identification are fundamental.

The fishers interviewed for this study confirmed the existence of a black market, which was further corroborated by personal observations in various ports (E. Morote and M. Coll, pers. obs.). Although the true amount of catches that go into the black market is very difficult to estimate, fishers provided a first order estimate of the magnitude of this black market. This is in line with the fact that despite *Cofradías* and *Lonjas* providing socially-accepted regulations to limit the overexploitation of the resources, there is a generally low satisfaction and hence low compliance by fishers with fishing regulations, as there are many potential landing places and large facilities to directly sell catches illegally (Romberg and Sardà 2005). Thus, due to the irregular nature of the black market, our estimates of black market catches may be very conservative. Furthermore, in 2007, the EU Court of Auditors stated that in Spain the sale notes for frozen produce were not recorded, even though the quantities they represented were very substantial. In addition, in Spain none of the catches by vessels under 10 metres in length were taken into account for quota monitoring, even though such vessels account for a substantial proportion of the national fleet. Vessels less than 10 metres account for 67% of the fleet in terms of the number of ships and 11% and 3% in terms of capacity in kW and GT, respectively (Court of Auditors 2007). Representatives of the Spanish and Regional Governments have stated in the past that unregulated catches are an important problem (MAPA 2007), but no clear measures have been adopted to estimate these catches and incorporate these in the official statistics. This study strongly highlights the necessity to do that.

It is important to note that some species may be more vulnerable to being unreported or under-reported. For example, it is clear that juveniles of European hake are substantially unreported, as they represent a substantial part of illegal catch. Trawling for hake, which has been the most

important demersal species in the Mediterranean in the past, has resulted in catches that consist almost entirely of immature fish (Oliver 2001). Other examples are European sardine and anchovy, as they are subjected to substantial market price fluctuations and have been heavily discarded through all the time period analysed (Table 4). We should note that total removals of this species have declined over time, likely suggesting overfishing in line with previous assessments (Palomera *et al.* 2007; Abdul Malak *et al.* 2011). Additionally, the growing demand of feed for cage-tuna may pose some pressure on unreported catch of small pelagic fish (I. Palomera, Institute of Marine Science of Barcelona, pers. comm.). Therefore, specific studies about unreported and discarded events of these highly caught species could improve our estimate of total catch removal of fisheries from the Spanish Mediterranean Sea and Gulf of Cadiz regions.

Other components of total fisheries removals may still be underestimated. For example, recreational fisheries also produce discards, which we did not take into account (Franquesa *et al.* 2004; Gordoa *et al.* 2004; Gaudin and de Young 2007). Catches by recreational fisheries are an important part of total fisheries removals and its importance has grown over time, since game fishing is a growing leisure activity in many Mediterranean areas. Although data are still scarce, they probably have a significant impact on some species, such as bluefin tuna and swordfish, whose low age classes suffer particularly. The impact of this activity on marine populations and ecosystems in the Mediterranean still requires to be adequately addressed. In addition, the use of aquatic resources as bait in recreational fisheries is an issue to be investigated. Although trolling in recreational fisheries usually employed artificial baits and lures, the use of baitfish and live bait is common in anchored boat and shore-based recreational fisheries. For example, sardines are used to fish bluefin tuna and swordfish from anchored boats. For salema, seaweeds/alga are used and for other species sardines, anchovy, shrimps, hermit crabs, mussels and squids are the common baits employed. No quantitative data are available to estimate the scale of artificial and natural baits in Mediterranean recreational fisheries. The use of fish and other aquatic resources as bait needs to be monitored throughout the Mediterranean, especially for those species at risk of overexploitation as well as those which are targeted species in other fishing sub-sectors (Franquesa *et al.* 2004; Gordoa *et al.* 2004).

In this study, we assessed the contribution of illegal catch to total removals, especially of illegal catches from driftnets during the 1980s and 1990s. However, other sources of illegal catch also exist. For example, fishing likely occurs in protected or restricted areas (Lloret *et al.* 2008a; Lloret *et al.* 2008b), or with other illegal gear with small mesh size. Information regarding these activities is not available, and would require an in-depth investigation of fishing activities. Additionally, a variety of medium-scale and industrial pelagic long-line fleets targeting large pelagic fish operate in Mediterranean waters, ranging from local coastal state fleets to large industrial foreign fleets, including Japanese, Flag of Convenience (FoC), and even non-flagged 'pirate' fleets. The present reconstruction included only data from the Spanish domestic fleet reported to ICCAT. We also included unreported unofficial data from independent assessments. However, FoC and pirate fleets are estimated at about 100 vessels (GFCM 1997a), and there is no data on catches (Tudela 2004). Additionally, although there is little data on by-catch from purse seiners in the Mediterranean Sea, purse seiners targeting bluefin tuna in French waters were observed to incidentally catch stingray (35 individuals during 190 fishing days) and sunfish (34 individuals) in 2003, in addition to cetaceans and marine turtles (Fromentin and Farrugio 2005). Occasionally some basking sharks and devil rays are also captured by artisanal fisheries, but quantitative data are not available (Bartolí 2009).

Our study highlights the importance of artisanal fisheries in the area. In fact, the diversity and economic importance of artisanal gears in small-scale fisheries are essential features of

Mediterranean fishing (Tudela 2004). Static nets are usually more selective, catching larger fish, although fishers indicated that gillnets can produce substantial discards. Different types of nets can, in turn, also vary in intra- and inter-specific selectivity. Beach seines, deployed in very shallow grounds to catch small fish, are common in some Mediterranean waters and are relatively unselective. A different kind of beach seine ('*sonsera*') is used to catch Mediterranean sand eel (*Gymnammodytes cicerellus*) in a limited area off the coast of northern Catalonia. Our study suggests that the artisanal sector is also involved in producing substantial amounts of discards and unreported catches. Moreover, small-scale fisheries are also involved in the by-catch of populations of endangered species (Tudela 2004).

Artisanal fisheries are also responsible for high rates of abandoned gear that can be potentially important for ghost fishing. The massive use of fixed nets (and other artisanal gears such as traps) in many small-scale Mediterranean fisheries, makes ghost fishing by abandoned or discarded gears a problem in Mediterranean waters but has attracted scant attention (Tudela 2004). The results of a study carried out with gillnet and trammel net ghost fishing in shallow (15–18 m) rocky bottoms in the Atlantic waters off the coast of the Algarve in southern Portugal indicated that abandoned gillnets produce important catches (Erzini *et al.* 1997). Osteichthyes were the most numerous group among the 39 species recorded, accounting for 89% of the total number of specimens. The other groups included gastropods, other molluscs and crustaceans. Sparidae, however, made up about 33% of total catches in numbers. There is evidence suggesting that nets lost in deeper waters may have an even longer effective fishing life span, running to years (Tudela 2004). This is a matter of concern since some deep gillnet fisheries operate in Mediterranean waters. The results of Erzini *et al.* (1997) also implicated ghost fishing in disturbing demersal food-webs in a similar way to that reported for trawl discards (Erzini *et al.* 1997).

Our study also illustrated that discards were another important source of unreported catches. On average, they represent 20% of total removals and for some species it can be higher than 50%. Discards are produced due to several reasons in the area, for example, due to (i) discards of caught juveniles with length size smaller than the legal landings size, (ii) discards of species of legal size, but with low or no market value, (iii) discards due to willing to better use the capacity of the boast to keep other species with higher commercial value (the so called 'upgrading'), and (iv) discard of illegal species. Information on discards in our study area also confirmed the magnitude of the problem in terms of total mortality, especially produced by trawling, though they vary considerably in amount and composition depending on region, boat size, season, bottom type and depth of the exploited ground (Table 6 and Figure 11). The first regional study addressing the magnitude of discards in the western Mediterranean involved the monitoring of fishing fleets in seven ports (six Spanish and one Italian). Combined data gave discard estimations ranging from 23–67% of total catch while fishing in less than 150 m deep, 13–62% for depths of 150 to 350 m and 14–43% for slope waters deeper than 350 m (Carbonell 1997; Carbonell *et al.* 1998). Data from a single locality, the Catalan port of *Vilanova i la Geltru* (north-western Mediterranean), illustrated high variability. Monitoring of the fleet there revealed that the annual average of discards ranged between 13% and 39% of the total catch for small boats (< 150 hp) and between 17% and 48% for larger boats (> 150 hp), depending on the depths exploited. The amount discarded, however, peaked at 75% and 67%, respectively, in the case of larger boats operating in spring and smaller ones operating in the summer on shelf bottoms (< 150-m depth) (Tudela 2004).

High discard levels are also common for Mediterranean deep sea trawl fisheries. Discards by the trawling fleet operating on the upper slope (230–611 m) off Alicante (South-East Spain) have been estimated at 35% of the total catch (Soriano and Sánchez-Lizaso 2000). The low selectivity

of trawling is highlighted by data from this fishery showing that up to 95 species are taken; only 12 of these species account for nearly 89% of the total, and 89 species are discarded. The analysis of discards in the Norway lobster and red shrimp fisheries at 280–720 m in the Balearic Islands (western Mediterranean), estimated average discards of 42% of the total catch, and led the authors to conclude that "an important fraction of the catch of the two deep-sea decapod crustacean fisheries of the Western Mediterranean is discarded" (Moranta *et al.* 2000). Longer tows, to compensate for the lower density of target species, result in higher discard rates. Discarding can also involve small size classes of important commercial species. The bulk of discards (66%) in the Balearic deep sea crustacean fisheries correspond to undersized marketable species. Although a fraction of discards from trawl fisheries may survive, little data on which to base quantitative estimates exist. Observations derived from aquarium experiments carried out on board point to relatively low mortality of crustaceans caught as a by-catch in Catalan trawl fisheries, whereas survival rates of fish are highly heterogeneous and vary strongly according to the species (i.e., most of small pelagic and medium-sized pelagic fish die, while many demersal sharks survive) (Sánchez 2000).

Additionally, the Spanish long-line fleet operating from the Strait of Gibraltar (5°W) to 7°E near Sardinia, and from 42°N to the Algerian coast produces important amounts of by-catch (Camiñas and De la Serna 1995). In the early 1990s, a Spanish fleet of 30 long-liners operated throughout the year in the south-western Mediterranean. By-catch, excluding turtles, accounted for 10% of total landings in weight (Camiñas and De la Serna 1995). In our study, we were only able to take part of these discards into account and thus our results are underestimates.

Overall, our results illustrate that discarding is a problem for most of the species caught in our study area, and that the general estimate of discards for the Mediterranean and Black Sea of 4.9% from Kelleher (Kelleher 2005) was unrealistically low. Our findings are also in line with the Spanish Ministry which calculated that total discards from bottom trawling in the Mediterranean Sea are at least 20% of the total caught biomass annually (MAPA 2007). From fixed nets, there is approximately 8% discards annually. Since a debate is now occurring about what to do with discarding practices at the European level, results such as ours are essential for clarifying this debate. Discarding is an important issue, as it is a major source of fishing mortality and wastes a large amount of biomass at sea every year.

Our estimates of total fisheries removals from the Spanish Mediterranean Sea and Gulf of Cadiz regions (1950-2010) enabled us to observe that overall catch declined since the mid-1960s, although fishing effort and fishing capacity had increased substantially from 1960s to date (Table 4) (Coll *et al.* 2008b). This suggests a declining catch per unit of effort, a clear indicator of overfishing. This overall trend differs somewhat from the official trend and highlights that degradation of marine resources in the region started earlier than we previously though. Overall, results illustrate that the Spanish Mediterranean and Gulf of Cadiz regions were already being depleted in the 1950s and 1960s, in line with the general perception of the long history of exploitation of the Mediterranean Sea (Pauly *et al.* 1998; Lotze *et al.* 2006; Coll *et al.* 2010; Fortibuoni *et al.* 2010; Lotze *et al.* 2011). Additionally, species that were less important in the catch have been increasing with time, with a diversification of species that are now for sale in fish markets. These species may be useful indicators of ecosystem change.

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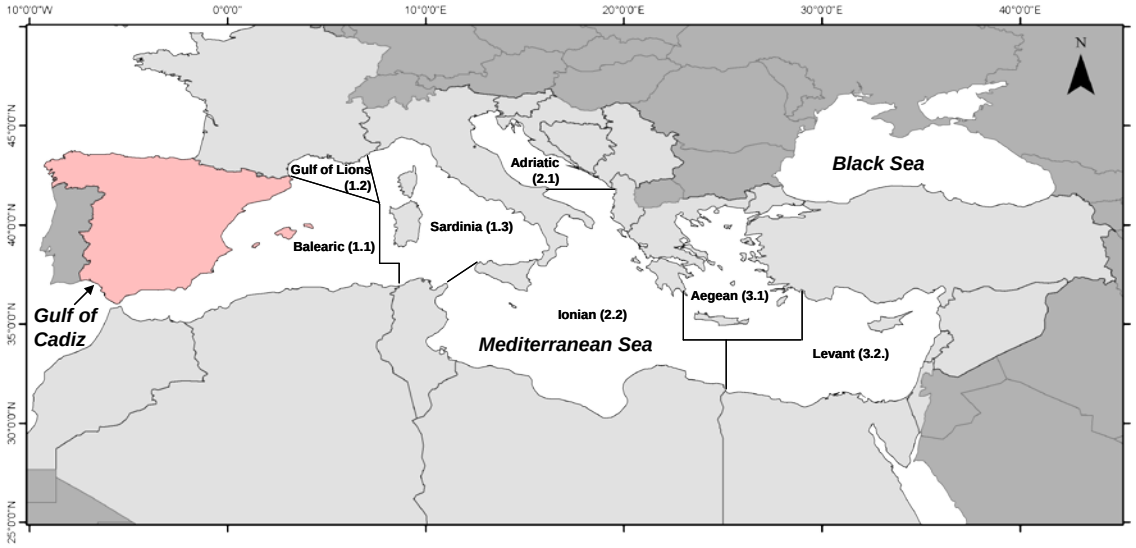
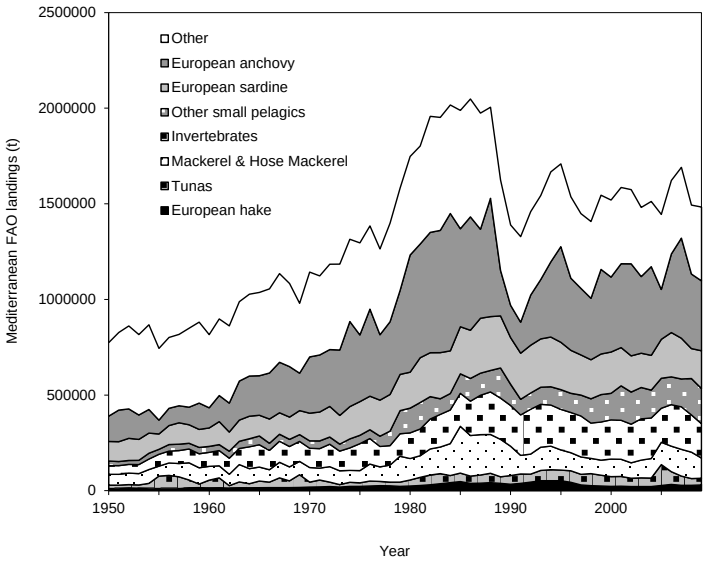


Figure 1. The Mediterranean Sea, the Gulf of Cadiz, and FAO fishing areas.

a)



b)

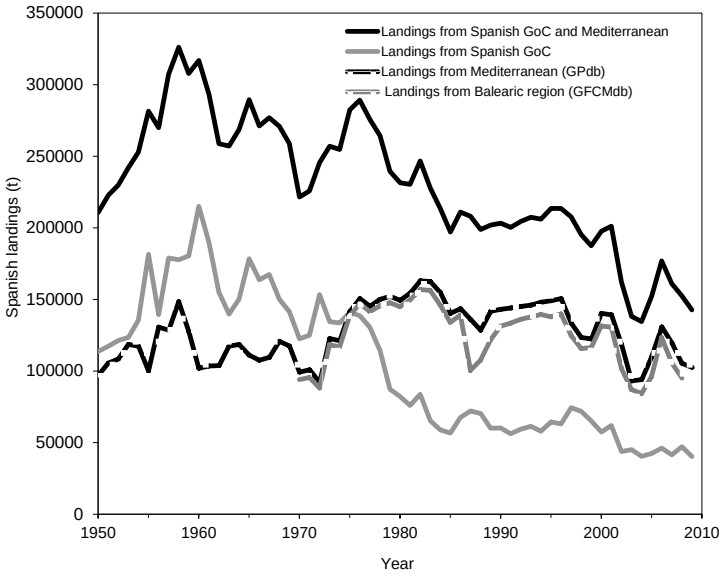


Figure 2. a) Official landings (t) from the Mediterranean Sea for 1950s to the 2010, and b) Spanish official landings (t) from the Mediterranean (FAO area 37.1.1) and Spanish Gulf of Cadiz (FAO area 27.IXa) (FAO 2011b).

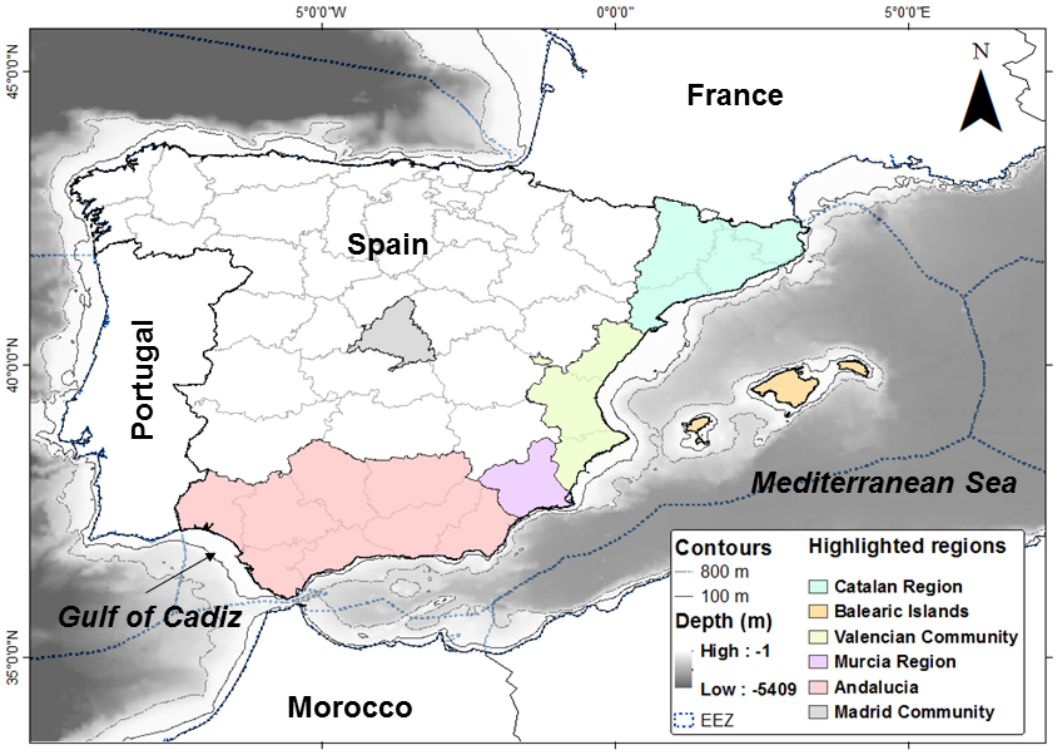


Figure 3. The Spanish Mediterranean Sea and Gulf of Cadiz regions. Waters under each country jurisdiction are highlighted.

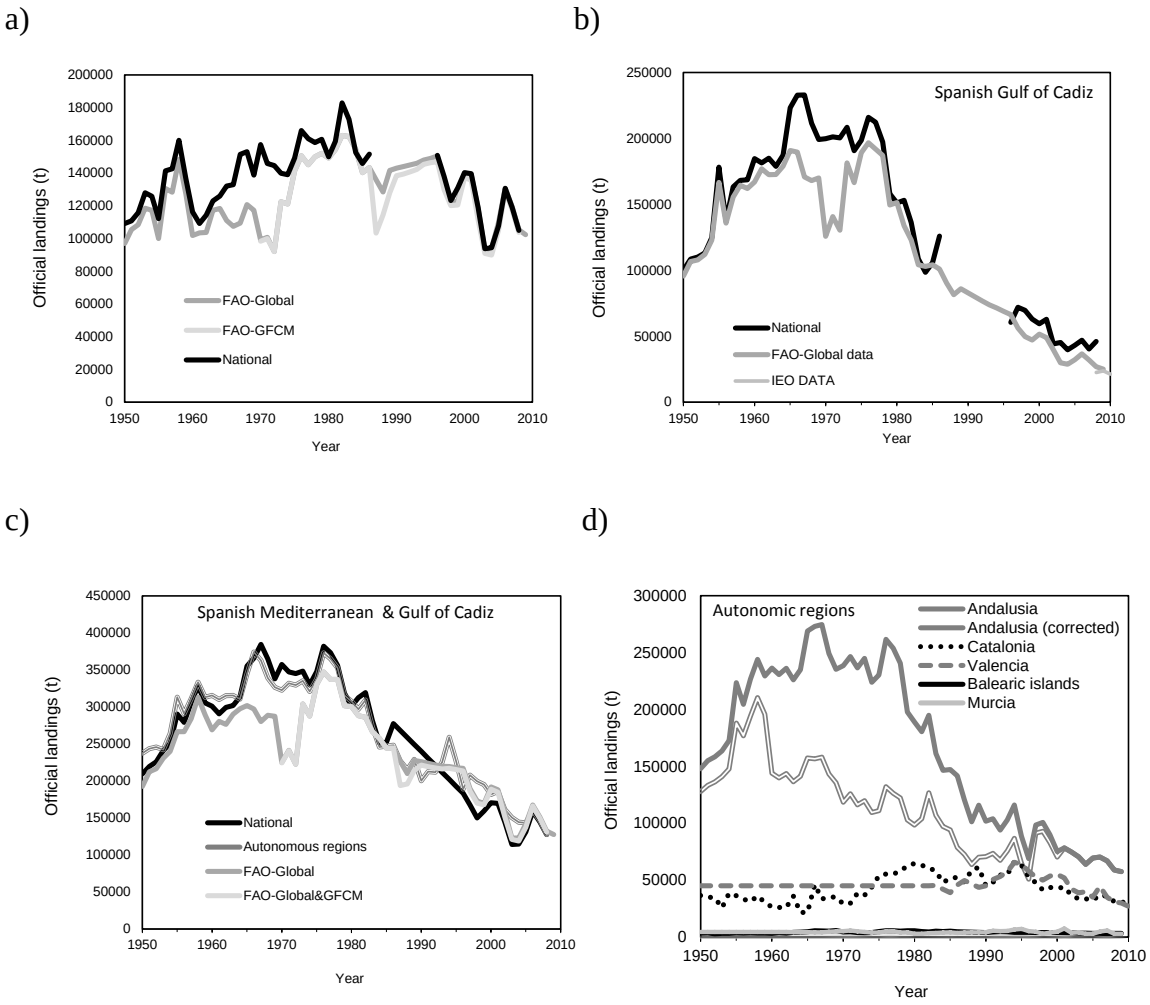
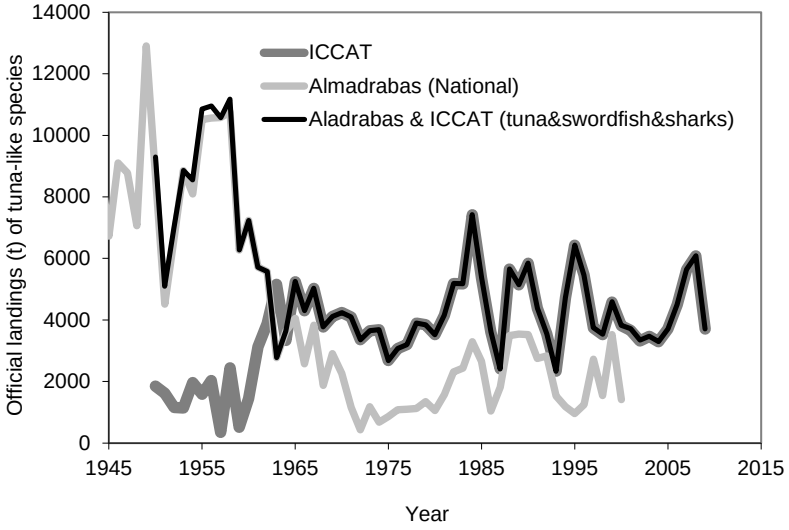


Figure 4. Official landings (t) from a) Spanish Mediterranean area FAO 37, b) Spanish Gulf of Cadiz area (South Atlantic FAO area 27), c) both Spanish Mediterranean and Gulf of Cadiz regions (FAO areas 37 and partial 27), and d) official landings by Autonomous regions (Source: FAO, Spanish National Statistics and Autonomous governments, Table 3).

a)



b)

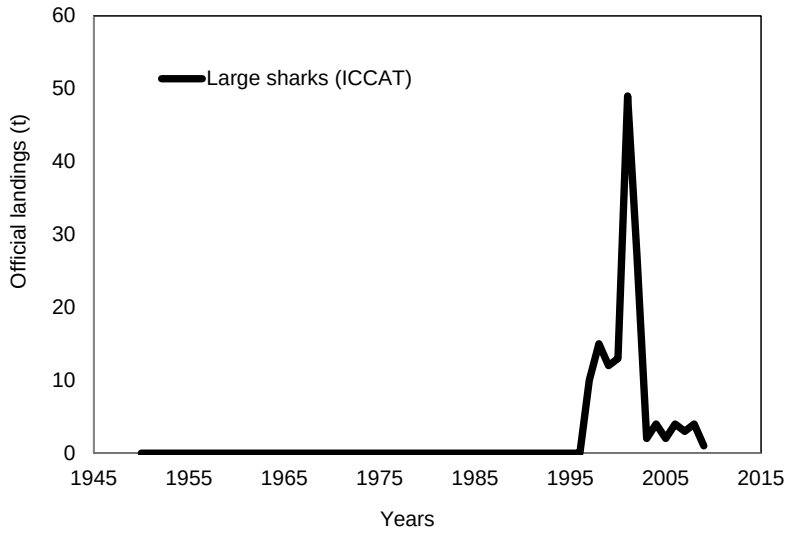
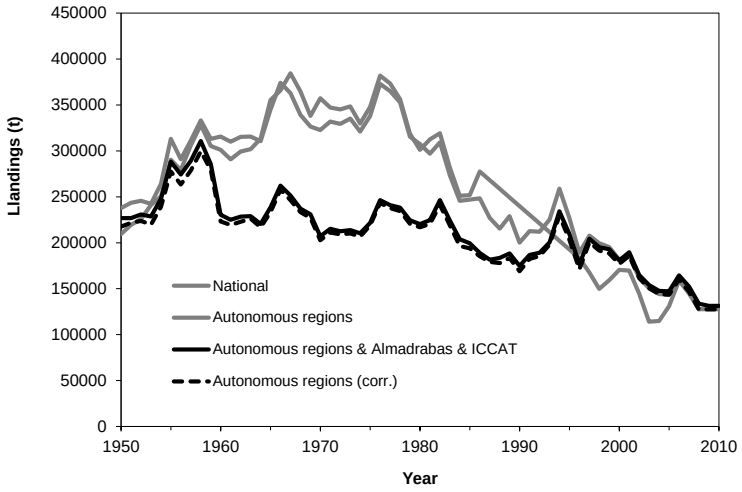


Figure 5. Official landings (t) of a) tuna-like species and b) large pelagic sharks (Source: ICCAT (Table 3)).

a)



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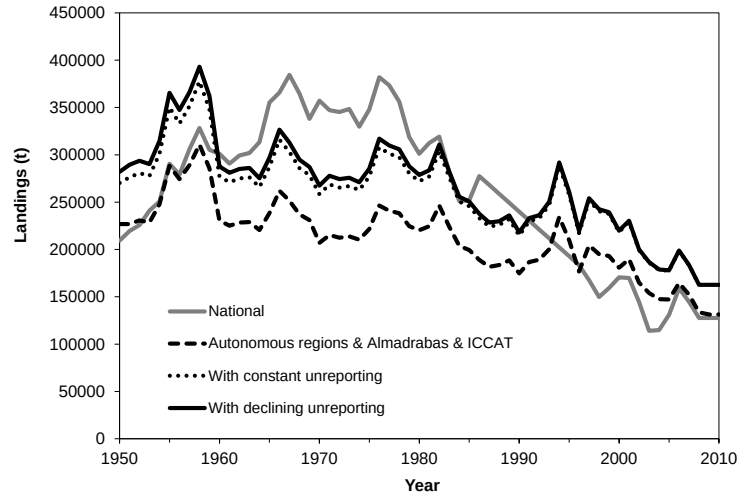

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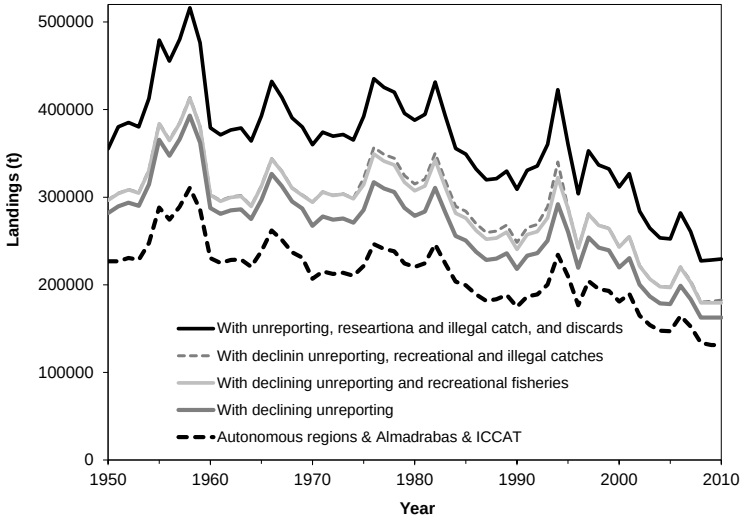


Figure 6. Comparison of different components of total removals (t): a) official landings, b) official and non-reporting, c) official, non-reporting, recreational, illegal and discards (Sources: Table 3, 4 and 5).

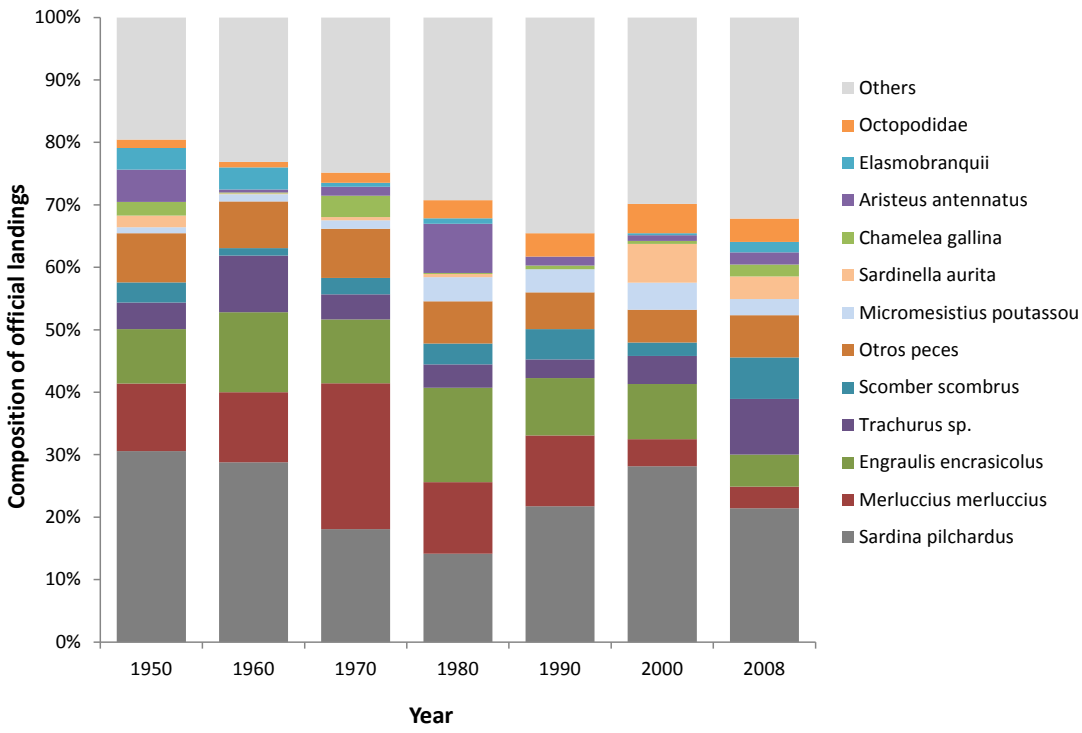


Figure 7. Composition of official landings by main caught species in 1950, 1960, 1970, 1990, 2000 and 2008 (Source: Spanish National Statistics and Autonomous governments, Table 3).

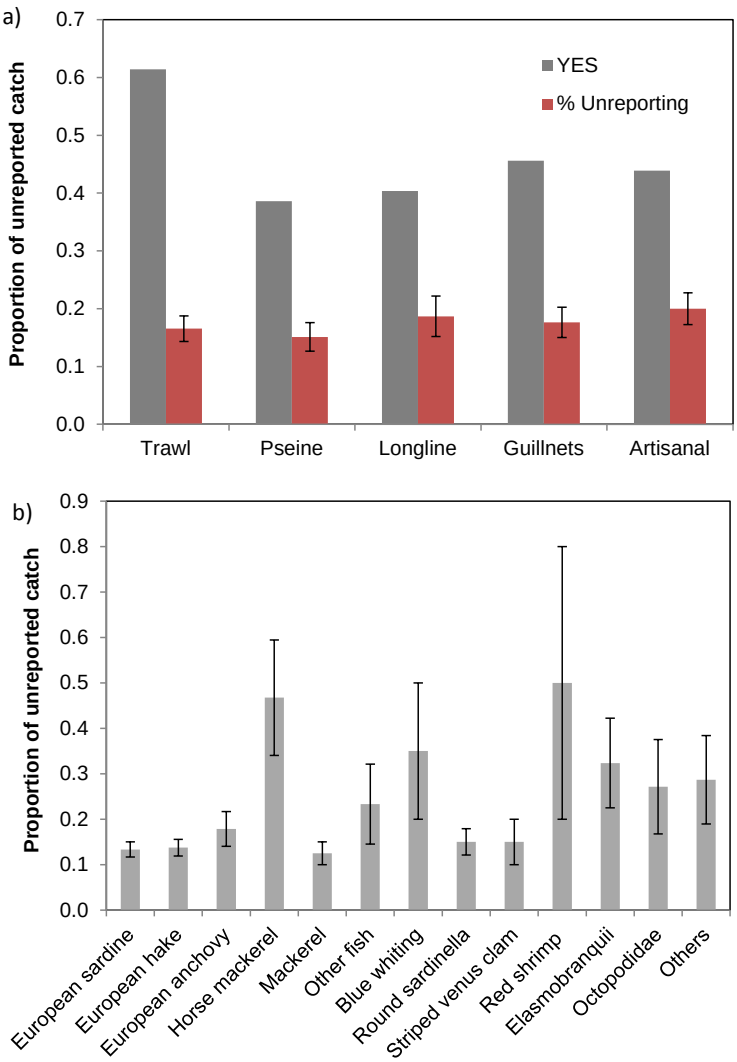
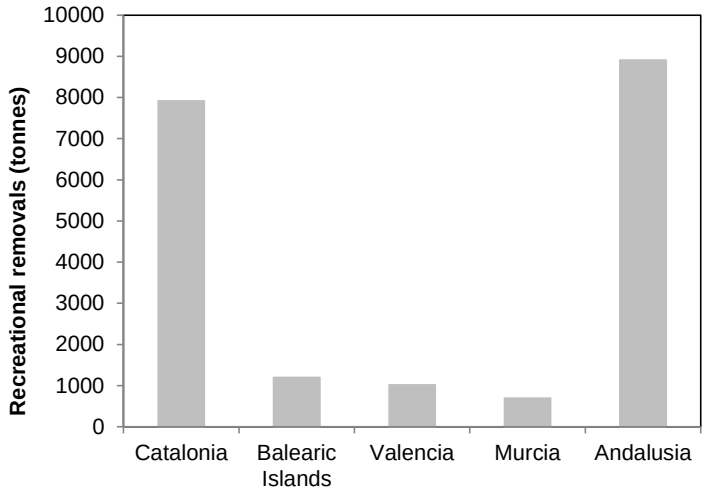


Figure 8. Proportion of unreported catches a) by main caught species, and b) by fleet and percentage of fishers affirming that non-reporting exists by fleet.

a)



b)

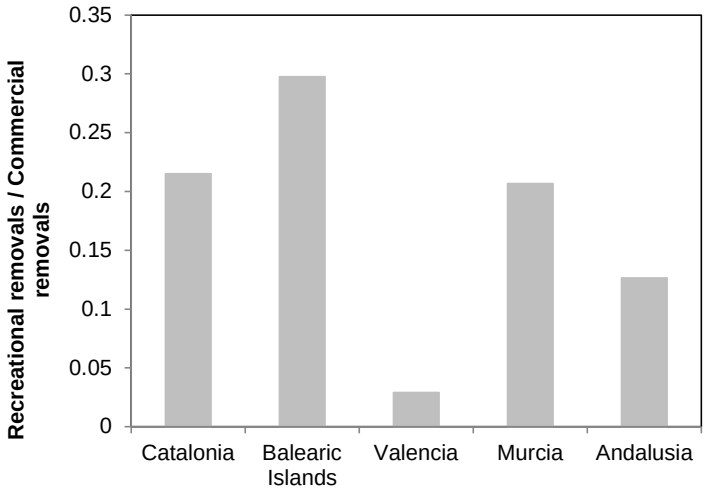


Figure 9. Recreational removals (t) by a) region and b) in comparison with commercial official landings (Sources: Gordoa *et al.* 2004; Franquesa 2006; Gaudin and de Young 2007).

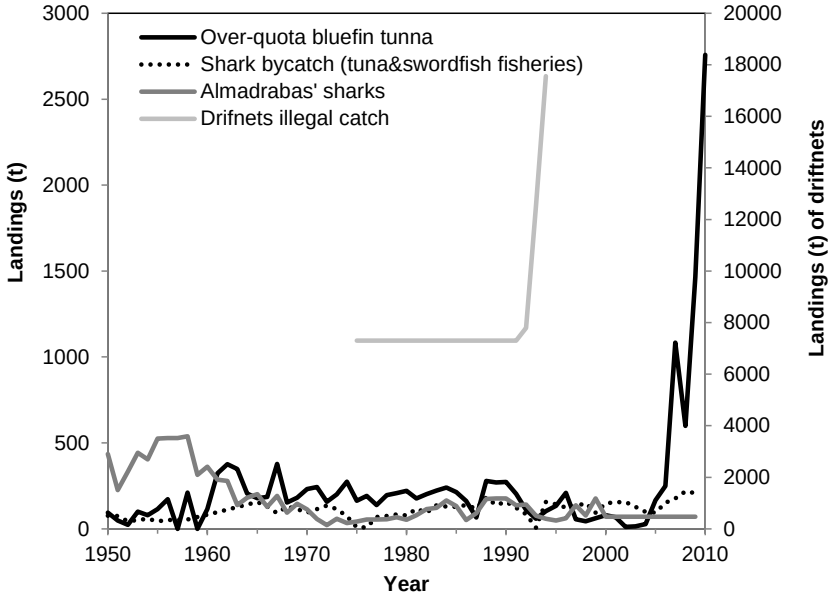


Figure 10. Illegal catch or non-reported catch of vulnerable species (t) (Sources: Raymarkers and Lynham 1999; Silvani *et al.* 1999; ATRT 2006, 2010; Mielgo Bregazzi 2011).

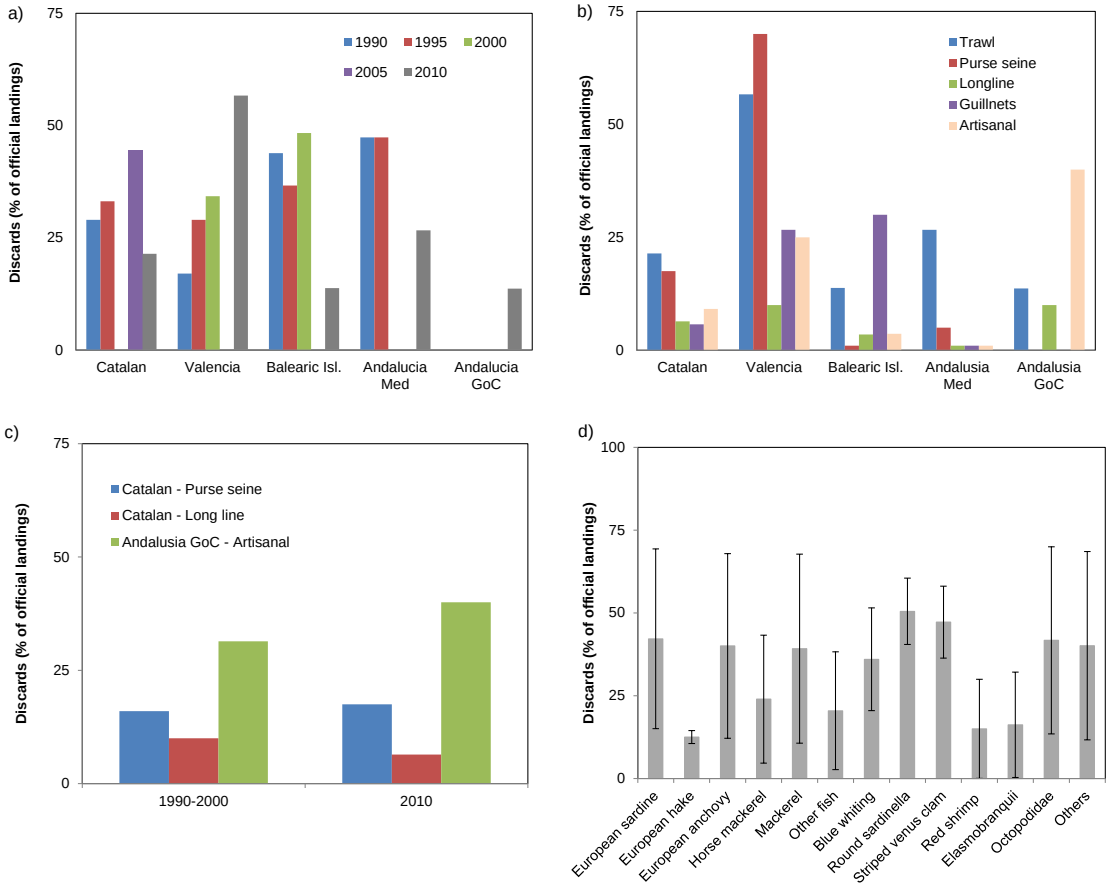


Figure 11. Total discards as % of official landings: a) from trawling in different time periods, b) by region and fleet in late 2000s, c) of purse seine, long line and artisanal in different time periods, and d) by main caught species (Sources: Table 5 and fishers' interviews in 2009-2011).

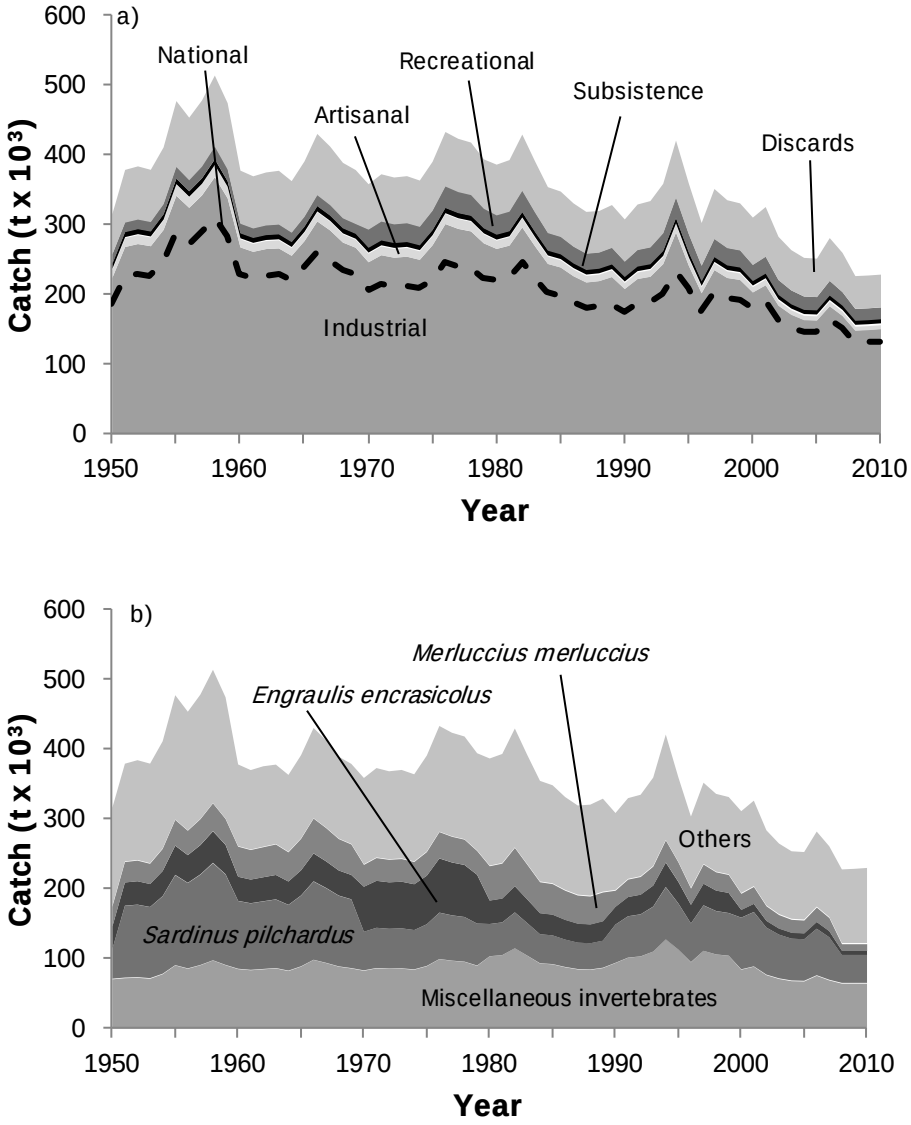


Figure 12. Total reconstructed fisheries removals (t) in the Spanish Mediterranean Sea and Gulf of Cadiz regions (1950-2010): a) Main sources of removals (industrial, artisanal, subsistence, recreational and discards), including adjusted national data baseline and b) total reconstructed removals by major taxa.

Table 1. Population and fisheries related information by Autonomous regions of the study area (Franquesa *et al.* 2004; MAPA 2007; JA 2011; MARM 2011).

Autonomous Regions	Population (2010)	Nº Harbours	Nº *Cofradias*	Nº *Lonjas*	Nº Vessels	Power (Kw)	Total Gross Tonnage	Vessel mean Length (m)	Nº Professional fishers
Catalonia	7,504,881	29	29	19	1,040	128,449	27,267	13	4500
Balearic Islands	1,106,049	16	16	7	432	24,111	3,931	9	770
Valencia Community	5,111,706	23	23	17	697	104,695	28,028	15	760
Region of Murcia	1,424,063	4	4	5	221	17,108	4,224	11	480
Andalusia	8,370,975	23	23	25	1,750	179,230	63,020	12	6745*
Total	23,517,674	95	95	73	4,140	453,593	126,470	12	13255

*2010 Junta de Andalucia.

Table 2. Number of boats by fleet from the Spanish Mediterranean Sea and Gulf of Cadiz regions in 2006 (MAPA 2007).

Nº of Boats	Bottom trawls	Purse seiners	Long liners	Tuna fleet	Artisanal fleet
Spanish Mediterranean	971	334	133	6 seiners & *Almadrabas*, and artisanal fleet	2577
Spanish Gulf of Cadiz	215	113	–	–	527
Total	24.3%	9.2%	2.7%	0.1%	63.7%

Table 3. Sources of official landings from the Spanish Mediterranean region and Gulf of Cadiz regions.

	Official landings							
Year	**FAO Capture Production data**	**ICCAT & *Almadrabas***	**National statistics**	**Catalonia**	**Valencia**	**Balearic Islands**	**Murcia**	**Andalusia**
1950 - 1960	(FAO 2011a, 2011b)	(MAPA 1940-1972 1973-1986)	(MAPA 1940-1972 1973-1986)	(MAPA 1940-1972 1973-1986; DAAR 1986-2010; Garrido and Alegret 2006)	(MAPA 1940-1972 1973-1986; CAPA 2011).}	(VVAA 1989; Massutí 1994; IBESTAT 2011)		(IDAPES 2011; IECA 2011; JA 2011)
1961							(Esteve Selma *et al.* 2003; RM 2011)	
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Table 4. Anchor points or historic and anecdotal clues to develop the reconstruction of total fisheries removals.

Anchor points	Historic or anecdotal clues	Source
Before 1950	Hardy any catch was declared to the government	Fishermen interviews & C. Bas. Institute of Marine Science of Barcelona, personal communication
1950s	Catch was not weighted, data is only indicative. But everything was used (very little discarding) and quantities were low	C. Bas. Institute of Marine Science of Barcelona, personal communication
1950-1960	Trawl fishing is still very small. Although there was lots of discarding of small fish, including mackerel and horse mackerel, bogue, *Spicara* spp. and blue whiting	C. Bas. Institute of Marine Science of Barcelona, personal communication
1960s	Fishing activity from Cadiz harbour in Mauritania started during the 1960s and continues today in low quantities	I. Sobrino personal observation
End of 1960s	The catch starts to be weighted when landed. Spain officially starts fishing in Mauritania	C. Bas. Institute of Marine Science of Barcelona, personal communication
Mid 1960s to 1990s	Large development of fishing capacity and fishing economic incentives	C. Bas & F. Sarda. Institute of Marine Science of Barcelona, personal communications
Mid 1980s	The use of driftnets in the Alboran Sea starts in the 1980s	(Silvani *et al.* 1999; Tudela *et al.* 2005)
1992	Driftnets are banned. However, this activity continues until 1994 in Spanish waters. Large amounts of by-catch of sunfish and other pelagic organisms are reported	(Silvani *et al.* 1999)
1996	Fishing activity in Morocco, whose catches are landed in the Spanish Gulf of Cadiz and started at the end of the XIX century, finish at the end of 1996	(Sobrino *et al.* 1994)
1999	Spain and Gibraltar sign an agreement so Spanish fishing vessels (4 at a time) can fish in the English area, operating at a distance of 250 meters from the coast minimum. This regularized a "de facto" situation.	Annex 1. Newspapers
Early 2000	Official data is more reliable	J. Rodon. *Generalitat de Catalunya*, personal communication
1990s-2000s	Availability of studies reporting discarding in the study area	Table 5
	Availability of studies characterizing the importance of recreational fisheries	Table 6
1990s-2000s	Incidental catch reported for large pelagic sharks from fishing activities targeting tuna and swordfish	(Silvani *et al.* 1999; Macías *et al.* 2004; Megalofonou *et al.* 2005; Hareide *et al.* 2007)
1998-2010	Atlantic bluefin tuna is highly unreported in official statistics	(Raymarkers and Lynham 1999; ATRT 2006, 2010; Mielgo Bregazzi 2011)
2007	A special report by the European Court of Auditors highlights many deficiencies and failures of control, inspection and sanction systems of 6 European countries, including Spain. Spain may un-report 40% of total catches	(Court of Auditors 2007)
2000s-2010	Spain is the second largest exporter of shark fins to the Hong Kong market after China and shark finning is a profitable activity for Spanish fisheries	(Hareide *et al.* 2007; OCEANA 2008; Lack and Sant 2011)
2008-2009	The *Instituto Español de Oceanografía* (IEO) conducts comparisons of landing declarations and sale notes to cross-checked declared information and quantifies the proportion of landed catch that is not declared in the sales.	I. Sobrino & M. Torres, personal observation
2008-2010	Economic crisis: black market is highlighted in the media as important in Spanish harbors	Annex 1. Newspapers
2008 onwards	Direct selling of catch to tourists and visitors is frequent in several harbors	E. Morote & M. Coll, personal observations
Through the years	Due to low prices, sardines and anchovies go off board frequently	C. Bas & A. Rillo. Institute of Marine Science of Barcelona and fisher, personal communication

Table 5. Sources of data on recreational fisheries from the Spanish Mediterranean and Gulf of Cadiz regions.

Regions	Recreational fisheries	
	Coastal	**Open sea**
Catalonia	2000-2004: (Franquesa and Bellini 2006) Ebro Delta area 2002-2006: (Gordoa 2009) All region 2004: (Soliva 2006) All region 2004-2007: (Anonymous 2008) All region 2006: (Lloret *et al.* 2008b) MPA 2007: (Lloret *et al.* 2008a) MPA 2007-2008: (Ribalta 2009) Southern Catalan Sea	1990s-2000s: (Gordoa 2003) Mediterranean 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean
Valencia		1990s-2000s: (Gordoa 2003) Mediterranean 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean
Balearic Islands	1975-2001: (Coll *et al.* 2004) Balearic islands 2001: (Morales-Nin *et al.* 2005)	1990s-2000s: (Gordoa 2003) Mediterranean 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean
Murcia		1990s-2000s: (Gordoa 2003) Mediterranean 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean
Andalusia-Mediterranean		1990s-2000s: (Gordoa 2003) Mediterranean 2004: (TRAGSATEC 2005) Mediterranean 2005-2006: (Franquesa 2006) Mediterranean
Andalusia-Gulf of Cadiz	no information found	no information found

Table 6. Sources of data on direct boat-based discards from the Spanish Mediterranean and Gulf of Cadiz regions.

	Direct boat-based discards: available data			
Regions	**Trawling**	**Purse seine**	**Long line**	**Gillnets & Artisanal**
Catalonia	1990: (Carbonell 1997) Villanova i la Geltru 1995-1996: (Sánchez *et al.* 2004) Villanova i la Geltru 1995-1996: (Carbonell *et al.* 1998) Villanova i la Geltru 1996-1997: (Carbonell 1997) Villanova i la Geltru 2001: (Martin *et al.* 2001) Villanova i la Geltru 2002-2003: (Sanchez *et al.* 2007) Sant Carles de la Rapita 2010-2011: Fishers interviews	1997-1999: (Arcos and Oro 2002a; Arcos and Oro 2002b; Arcos *et al.* 2002) Ebro delta region 2010-2011: Fishers interviews	1988-1995: (Camiñas and De la Serna 1995) Western Mediterranean 2010-2011: Fishers interviews	2010-2011: Fishers interviews
Valencia	1990: (Carbonell 1997) Valencia and Santa Pola 1995-1996: (Carbonell *et al.* 1998) Valencia and Santa Pola 1998-1999: (Soriano 2000) (Soriano and Sánchez-Lizaso 2000) Alacant 2001: (Martin *et al.* 2001) Santa Pola 2010-2011: Fishers interviews	2010-2011: Fishers interviews	1988-1995: (Camiñas and De la Serna 1995) Western Mediterranean 2010-2011: Fishers interviews	2010-2011: Fishers interviews
Balearic Islands	1995-1996: (Carbonell *et al.* 1998) Palma de Mallorca and Alcudia 1995-1996: (Carbonell *et al.* 2003) Mallorca (demersal sharks) 1995-1996: (Moranta *et al.* 2000) Palma de Mallorca 1996-1997: (Carbonell 1997) Palma de Mallorca and Alcudia 2001: (Martin *et al.* 2001) Palma de Mallorca 2002-2003: (Ordines *et al.* 2006) Mallorca 2002-2003: (Massutí *et al.* 2005) Mallorca 2008-2009: IEO Mallorca Project Discards (*Plan Nacional*) 2010-2011: Fishers interviews	2010-2011: Fishers interviews	1988-1995: (Camiñas and De la Serna 1995) Western Mediterranean 2010-2011: Fishers interviews	2010-2011: Fishers interviews

Table 6. Sources of data on direct boat-based discards from the Spanish Mediterranean and Gulf of Cadiz regions.

Direct boat-based discards: available data				
Regions	**Trawling**	**Purse seine**	**Long line**	**Gillnets & Artisanal**
Murcia	1998-1999: (Martínez Baños 2000) Anguilas, Mazarron, Carragena y San Pedro		1988-1995: (Camiñas and De la Serna 1995) Western Mediterranean	
Andalusia-Mediterranean	1995-1996: (Carbonell *et al.* 1998) Fuengirola 1996-1997: (Carbonell 1997) Fuengirola 2010-2011: Fishers interviews	2010-2011: Fishers interviews	1988-1995: (Camiñas and De la Serna 1995) Western Mediterranean 2010-2011: Fishers interviews	2010-2011: Fishers interviews
Andalusia-Gulf of Cadiz	1994-2007 (Jardim *et al.* 2010) Gulf of Cadiz - European hake 2008-2009: IEO Cadiz Project Discards (*Plan Nacional*) 2010-2011: Fishers interviews	2010-2011: Fishers interviews	2010-2011: Fishers interviews	1990-2000: (Goncalves *et al.* 2007) Gulf of Cadiz 2010-2011: Fishers interviews

Appendix Table A1. Total catches in Spanish Mediterranean and Gulf of Cadiz by sector, including adjusted national baseline, 1950-2010.

Year	FAO landings	Total reconstructed catch	Industrial	Artisanal	Subsistence	Recreational	Discards
1950	187,000	315,530	224,000	14,400	11,030	8,000	58,100
1951	226,000	378,920	268,000	14,600	12,520	8,000	75,800
1952	230,000	384,790	273,000	14,800	12,590	8,000	76,400
1953	228,000	378,920	269,000	14,500	12,320	8,000	75,100
1954	247,000	411,860	293,000	15,800	13,360	8,000	81,700
1955	287,000	478,540	342,000	18,300	15,440	8,000	94,800
1956	273,000	454,000	324,000	17,400	14,600	8,000	90,000
1957	288,000	478,990	342,000	18,400	15,390	8,000	95,200
1958	309,000	514,580	368,000	19,800	16,480	8,000	102,300
1959	284,000	475,110	338,000	18,400	15,310	8,000	95,400
1960	229,000	378,430	268,000	14,700	11,430	8,000	76,300
1961	224,000	369,580	261,000	14,500	11,180	8,000	74,900
1962	227,000	375,120	265,000	14,700	11,320	8,000	76,100
1963	228,000	377,640	266,000	14,900	11,440	8,000	77,300
1964	219,000	363,330	256,000	14,300	10,930	8,000	74,100
1965	237,000	391,810	277,000	15,400	11,710	8,000	79,700
1966	261,000	430,990	305,000	17,000	12,890	8,000	88,100
1967	250,000	412,770	292,000	16,300	12,270	8,000	84,200
1968	236,000	389,680	275,000	15,400	11,580	8,000	79,700
1969	230,000	378,710	267,000	15,000	11,210	8,000	77,500
1970	206,000	359,180	247,000	26,800	12,080	8,000	65,300
1971	214,000	373,430	257,000	27,900	12,530	8,000	68,000
1972	211,000	368,260	253,000	27,600	12,360	8,000	67,300
1973	213,000	369,780	254,000	27,700	12,380	8,000	67,700
1974	209,000	363,920	250,000	27,300	12,120	8,000	66,500
1975	220,000	391,180	271,000	28,900	12,780	8,000	70,500
1976	245,000	433,550	301,000	32,100	14,150	8,000	78,300
1977	240,000	423,780	294,000	31,400	13,780	8,000	76,600
1978	237,000	418,920	291,000	30,900	13,520	8,000	75,500
1979	223,000	394,780	274,000	29,100	12,680	8,000	71,000
1980	219,000	387,180	266,000	28,600	11,680	8,000	72,900
1981	223,000	393,020	270,000	29,100	11,820	8,000	74,100
1982	245,000	429,780	296,000	31,800	12,880	8,000	81,100
1983	223,000	391,140	269,000	28,900	11,640	8,000	73,600
1984	203,000	354,300	244,000	25,900	10,400	8,000	66,000
1985	198,000	348,030	239,000	25,600	10,230	8,000	65,200
1986	188,000	331,540	227,000	24,500	9,740	8,000	62,300
1987	181,000	319,270	218,000	23,700	9,370	8,000	60,200
1988	183,000	320,570	220,000	23,500	9,270	8,000	59,800
1989	187,000	328,310	225,000	24,200	9,510	8,000	61,600
1990	174,000	307,760	208,000	22,300	8,660	8,000	60,800
1991	186,000	330,000	223,000	24,100	9,300	8,000	65,600
1992	188,000	334,620	226,000	24,500	9,420	8,000	66,700
1993	199,000	359,310	244,000	26,100	10,010	8,000	71,200
1994	233,000	421,350	289,000	30,300	11,550	8,000	82,500
1995	208,000	360,090	242,000	26,800	10,190	8,000	73,100
1996	176,000	302,750	202,000	22,600	8,550	8,000	61,600
1997	203,000	351,560	235,000	26,500	9,960	8,000	72,100
1998	194,000	335,670	224,000	25,300	9,470	8,000	68,900
1999	192,000	330,880	221,000	24,900	9,280	8,000	67,700
2000	180,000	310,300	203,000	23,400	7,800	8,000	68,100
2001	189,000	326,260	214,000	24,500	8,160	8,000	71,600
2002	164,000	283,560	185,000	21,300	7,060	8,000	62,200
2003	153,000	264,350	172,000	19,900	6,550	8,000	57,900
2004	147,000	252,750	164,000	19,000	6,250	8,000	55,500
2005	146,000	251,280	163,000	18,900	6,180	8,000	55,200
2006	164,000	281,570	184,000	21,100	6,870	8,000	61,600
2007	152,000	260,060	170,000	19,400	6,260	8,000	56,400
2008	133,000	226,580	149,000	16,800	5,780	8,000	47,000
2009	133,000	227,580	150,000	16,800	5,780	8,000	47,000
2010	133,000	228,580	151,000	16,800	5,780	8,000	47,000

Appendix Table A2. Primary taxa caught in Spanish Mediterranean and Gulf of Cadiz fisheries, 1950-2010.

Year	Miscellaneous inverts	*Sardina pilchardus*	*Merluccius merluccius*	*Engraulis encrasicolus*	Others
1950	69,800	43,100	32,700	28,700	140,500
1951	71,400	104,200	33,500	29,300	140,000
1952	72,000	105,100	33,700	29,600	143,000
1953	70,600	103,100	33,100	29,000	142,600
1954	77,000	112,400	36,100	31,600	153,400
1955	89,400	130,500	42,000	36,700	178,100
1956	84,700	123,800	39,800	34,800	169,900
1957	89,700	131,000	42,100	36,900	178,100
1958	96,500	140,900	45,400	39,700	191,000
1959	89,800	131,200	42,200	36,900	173,700
1960	84,200	98,300	34,700	43,100	116,700
1961	82,600	96,500	34,100	42,400	113,500
1962	83,900	98,000	34,600	43,000	114,900
1963	85,200	99,500	35,100	43,700	113,400
1964	81,500	95,300	33,600	41,800	109,900
1965	87,700	102,500	36,200	45,000	118,900
1966	97,200	113,500	40,100	49,800	129,000
1967	92,700	108,400	38,300	47,600	124,700
1968	87,700	102,500	36,100	45,000	117,000
1969	85,100	99,600	35,100	43,700	114,400
1970	81,900	56,000	65,000	31,300	123,200
1971	85,300	58,300	67,800	32,700	127,600
1972	84,400	57,800	67,000	32,300	125,500
1973	84,800	58,000	67,300	32,500	126,400
1974	83,300	57,000	66,100	31,900	124,400
1975	88,300	60,400	70,000	33,800	137,100
1976	98,300	67,200	78,100	37,600	151,000
1977	96,000	65,700	76,200	36,700	148,000
1978	94,500	64,700	75,000	36,200	146,700
1979	88,900	60,800	70,400	34,000	139,000
1980	102,400	46,700	33,900	49,300	153,300
1981	104,000	47,500	34,400	50,100	156,100
1982	113,900	52,000	37,800	54,900	170,100
1983	103,100	47,100	34,100	49,800	156,000
1984	92,100	42,200	30,500	44,500	144,000
1985	91,000	41,700	30,100	44,000	140,400
1986	86,800	39,800	28,600	42,000	132,900
1987	83,800	38,400	27,600	40,500	127,600
1988	83,100	38,100	27,400	40,200	130,300
1989	85,700	39,300	28,200	41,500	133,100
1990	92,800	55,500	25,700	23,200	109,900
1991	100,400	59,900	27,800	25,000	115,300
1992	102,100	61,000	28,300	25,500	116,500
1993	109,100	65,100	30,300	27,200	126,300
1994	126,900	75,600	35,200	31,600	150,700
1995	112,000	66,800	31,000	27,900	120,600
1996	93,800	56,100	26,800	23,400	101,700
1997	110,200	65,900	31,200	27,500	115,900
1998	105,000	62,900	29,500	26,200	111,000
1999	103,200	61,800	29,000	25,800	110,300
2000	83,400	74,900	11,300	23,200	117,100
2001	87,600	78,800	11,800	24,400	122,400
2002	75,700	68,200	9,800	21,100	107,500
2003	70,300	63,500	9,000	19,600	101,000
2004	67,200	60,700	8,800	18,800	96,700
2005	66,700	60,300	8,700	18,700	96,600
2006	74,800	67,500	9,900	20,900	107,500
2007	68,200	61,700	9,000	19,100	101,300
2008	63,700	40,800	6,400	9,700	105,500
2009	63,700	40,800	6,400	9,700	106,300
2010	63,700	40,800	6,500	9,700	107,600