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ESTIMATES OF TOTAL FISHERIES REMOVAL FOR THE BALEARIC ISLANDS (1950-2010)

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Abstract

For effective fisheries management to be able to act, realistic fisheries removal data are needed, so as to assess exploitation levels and the impact of fisheries on the ecosystem. Unfortunately, official statistics underestimate catches in most countries and regions. In the Balearic Islands (Western Mediterranean), where artisanal fishing and industrial bottom trawling are the most important fishing activities, unreported catches are common. They consist of landings at 'black markets', subsistence fishing, recreational fishing, locally unreported mainland fleet catches and discards. Here, we developed the first estimates of actual total fisheries removals from 1950 to 2010 for the Balearic Islands. We gathered all available official landings data (from national and regional agencies and fishers sales notes) and unreported catch data using grey literature and interviews with fishers and fisheries experts. We paid particular attention to those species of high economic importance to bottom trawling and artisanal fleets. We estimated a total catch of over 570,500 t over the 1950-2010 time period, where official landings represent 44% (around 248,000 t), followed by 'black market' (unreported commercial catches) (24%), discards (18%), recreational landings (10%) and subsistence fishing (4%). The total reconstructed catch of 570,500 t is 2.3 times the assumed official reported landings of 248,300 t. Further studies are needed to obtain more accurate estimates of total fisheries removals from the Balearic Islands, especially for those species targeted by the artisanal fleet. Furthermore, additional insight into the taxonomic composition of the various catch components, including discards and subsistence/recreational catches is required.

Introduction

Catch statistics are important for fisheries management, as they are fundamental for assessing the status of exploited species. In addition, if the true impacts of fisheries are to be evaluated, data of total removals of marine organisms are needed (Pauly 1998; Pitcher *et al.* 2002). Unfortunately, official landings data in most countries are deficient (Pauly 1998) and frequently underestimated (Zeller and Pauly 2007; Wielgus *et al.* 2010). Furthermore, Illegal, Unreported and Unregulated (IUU) catches (Bray 2000) occur to a greater or lesser extent in all fisheries (Doulman 2000), and this catch misreporting can lead to unwise investment decisions in the fishing sector and prevents effective management (Watson and Pauly 2001). Recreational fishing (Zeller *et al.* 2008) and discarding (Zeller and Pauly 2005), though often legal, are two examples of a global problem of unreported catches and unaccounted fishing mortality. Artisanal fisheries, though socially and economically important, have historically been marginalized (Pauly 2006) and are also a common source of misreported catches (Chuenpagdee *et al.* 2006; Zeller *et al.* 2006).

The *Sea Around Us* (www.seaaroundus.org) is an international project created in 1999 whose main goal is to assess, document and communicate impacts of fishing on the world's marine ecosystems (Pauly 2007). One of the problems that the project is working on is estimating the real fisheries extractions from marine ecosystems, including reported and unreported landings and discards at sea, the goal being to reconstruct marine fisheries extractions for all countries in the world from 1950 to 2010, while taking all fisheries sub-sectors into account (see e.g. Zeller *et al.* 2006; Zeller *et al.* 2007; Zeller and Pauly 2007; Zeller and Harper 2009; Wielgus *et al.* 2010; Harper and Zeller 2011; Zeller *et al.* 2011a; Zeller *et al.* 2011b; Le Manach *et al.* 2012; Trujillo *et al.* 2012). This includes estimating total extractions by the fisheries in the Spanish Mediterranean Sea and Gulf of Cadiz regions (Coll *et al.* 2014b), here complemented by the catch reconstruction of the Balearic Islands.

The Balearic Islands, composed of four main islands – Mallorca, Menorca and the Pitiusas (Ibiza and Formentera) – are located in the Western Mediterranean (Figure 1). From a geomorphologic point of view, the Balearic archipelago consists of the Balearic promontory, which reaches depths between 1,000 and 2,000 m and is separated from the Spanish mainland by 90 to 220 km (Acosta *et al.* 2001).

The waters surrounding the Balearic Islands are treated as an independent fisheries management unit because of their unique characteristics (Massutí 1991; Quetglas *et al.* 2012a), and were recognized as such by FAO (as sector 37.1.6). Since 2007, they are treated as a Geographical Subarea (GSA05) of the General Fisheries Commission for the Mediterranean (GFCM).[1]

Quetglas *et al.* (2012b) have shown that the fleet and stock dynamics of bottom trawl fisheries in the Balearic Islands have followed the same general increasing trend in fishing effort and declining trend in catches as has been observed globally since the 1950s (Pauly *et al.* 2002; Myers and Worm 2003). The main sources of misreported catches are discards from the bottom trawling fleet (Carbonell *et al.* 1999; Moranta *et al.* 2000; Guijarro and Massutí 2006), under-reported catches from artisanal (Llabrés and Martorell 1984; Iglesias *et al.* 1994), recreational fishing (Morales-Nin *et al.* 2005; Grau 2008; Morales-Nin *et al.* 2010), and catches by vessels with home ports on the Spanish mainland that partially conduct their activity in Balearic Islands fishing grounds (Massutí 1958; Oliver 1983; Massutí 1994; García-Rodríguez and Esteban 1999; Quetglas *et al.* 2012a). Under-reporting appears to be more pronounced in the smaller islands of the archipelago (Menorca and the Pitiusas Islands of Ibiza and Formentera) than in Mallorca. This is mainly due to the absence of *lonjas* (fish markets) on the smaller islands, which cause statistical data collection to be conducted only by the *Cofradías de Pescadores* (fishermen brotherhoods), which are more difficult to control (Massutí 1989).

In this study, we estimate for the first time all fisheries removals from 1950 to 2010, in the Balearic Islands. This work aims to provide the basis for improved management of the Balearic Islands and Spanish Mediterranean Sea fisheries, and also contribute to the estimation of the global fisheries catches by *Sea Around Us*.

2. Fisheries in the Balearic Islands

2.1 Commercial fishing

Commercial fishing in the Balearic Islands represents only 0.1% of the Gross Domestic Product (GDP) of this 'Autonomous Community' (A.M. Grau, personal communication). Nevertheless, fishing is a historically deeply-rooted economic activity, which is also of great social and cultural importance. Artisanal fishing in its different modalities and bottom trawling are the most important fishing activities in the area. Artisanal fishing is the most traditional and accounts for 85% of the 408 fishing vessels in the area, while bottom trawlers make up only 12% of the fleet (Anon. 2010). Purse seiners and longliners

1) Resolution GFCM/31/2007/2 on the establishment of Geographical Sub-Areas in the GFCM Area.

together represent 3% of the fleet (Anon. 2010) and lack historical relevance in the Balearic Islands (Massutí 1989; Velasco 1992).

In addition to the Balearic fleet, 70 bottom trawling vessels from the Spanish mainland, specifically from Northern Spain GSA06, are allowed to fish on the continental slope of the Pitiusas Islands with a limit of 40 vessels fishing simultaneously. This represents a significant fishing effort, close to the number of bottom trawlers operating from Balearic ports (50 vessels), and four times the Pitiusas bottom trawling fleet of 10 vessels. The fleet from the mainland has always been an obstacle to estimating real fishery catches in the Baleares because catches are landed on the Spanish mainland, without reporting in Balearic landings statistics (Massuti 1973; FAO 1980; Oliver 1983; Massutí 1989; Garcia 2003; Quetglas *et al.* 2012a).

In recent years, nominal landings in the Balearic Islands average 3,340 $t \cdot year^{-1}$ and bring in approximately €21 million in ex-vessel value (Anon. 2010). The bottom trawling fleet contributes 60% of the total landings in weight, and 65% in ex-vessel value. It is followed by the artisanal fleet (18% of landings and 28% of ex-vessel value), the purse seiners (20% of landings and 5% of ex-vessel value), and the longline fishing fleet (2% of both landings and ex-vessel value), as can be inferred from data of the *Direcció General de Pesca del Govern de les Illes Balears* (DGPGIB).

Surface longlining has not developed in the Balearic Islands, although the southern waters of the Balearic Islands are an important area for reproduction for several tuna species and is an important area for tuna fisheries (Alemany *et al.* 2010). Longline vessels fishing in these waters are home-ported on the Spanish mainland, and traditionally target tuna and other species including shortfin mako (*Isurus oxyrinchus*) and blue sharks (Velasco 1992). In recent decades, industrial purse seiners also fish tuna in the area (Alemany *et al.* 2010). Finally, vessels from the northeastern Spanish mainland coast (i.e,GSA06), operate on the upper slopes of Mallorca and Menorca using traps, mainly targeting the caridean shrimp *Plesionika edwardsi* (García-Rodríguez and Esteban 1999).

Main target species

a) Bottom trawling fleet

Bottom trawling in the Balearic Islands is carried out over a wide bathymetric range (50-800 m), and constitutes a multi-species fishery with more than 100 commercial species being caught (Massuti *et al.* 1996; Moranta *et al.* 2008b). Four fishing tactics are practiced, sometimes during the same day, for targeting different species of economic interest (Palmer *et al.* 2009). Surmullet (*Mullus surmuletus*) and European hake (*Merluccius merluccius*) are targeted on shallow and deep shelf grounds, respectively, while Norway lobster (*Nephrops norvegicus*) is targeted on the upper slope and red shrimp (*Aristeus antennatus*) on the intermediate slope (Moranta *et al.* 2008b).

Red shrimp is the most valuable target species of the bottom trawling fleet, contributing 6.8% of the total weight landed, and 25% of the ex-vessel value in the Balearic Islands (Anon. 2010). This fishery began in 1948, and became, within a few years, the most important crustacean resource in the area (Massutí 1958).

In terms of weight, other important species or groups include picarel or *gerret* (*Spicara smaris*), common octopus (*Octopus vulgaris*) and '*morralla'* (a composite of different fish species), originating from the continental shelf, and blue whiting (*Micromesistius poutassou*) from the continental slope (Alemany and Alvarez 2003).

b) Artisanal fleet

The Balearic Islands artisanal fleet is engaged in a large number of seasonally alternating fisheries (Iglesias *et al.* 1994), similar to other Mediterranean fisheries. The seasonal change in target species, gears and habitats are closely linked to the biological cycles of the targeted species, in particular their reproduction and feeding (Mallol and Goñi 2004). In the Balearic Islands, three fisheries make up a large fraction of the artisanal fishing effort: the seine-net fishery targeting transparent goby *(Aphia minuta*), the trammel net fishery targeting spiny lobster *(Palinurus elephas*), and the seine-net fishery targeting common dolphinfish *(Coryphaena hippurus*) (Iglesias *et al.* 1994; Mallol and Goñi 2004). Catches of these species are of high economic value, especially for local consumption (Iglesias *et al.* 1994).

The relative importance of these fisheries differs by island. In Mallorca, transparent goby and common dolphinfish fisheries are very important, both economically (13% and 11% of the total artisanal ex-vessel value, respectively), and in terms of biomass landed (8.5% and 25% of total artisanal landings, respectively), according to DGPGIB data for 2009. These fisheries do not occur around the islands of Menorca and the Pitiusas, and it is the spiny lobster fishery which is of primary importance there, representing 18% of the total ex-vessel value of all fleets on Menorca (Anon. 2010).

Other important target species of the Balearic artisanal fisheries include cuttlefish (*Sepia officinalis*), surmullet, common seabream (*Pagrus pagrus*), common dentex (*Dentex dentex*), greater amberjack (*Seriola dumerilii*), red scorpionfish (*Scorpaena scrofa*) and black scorpionfish (*Scorpaena porcus*), caught mainly using trammel nets, gillnets and longlines (Iglesias *et al.* 1994; Mallol and Goñi 2004; Merino *et al.* 2008; Morales-Nin *et al.* 2010).

2.2 Recreational fishing

There are approximately 70,000 recreational fishers in the Balearic Islands and it is estimated that they catch 1,200 t per year, or 25% of total official landings around the Balearic Islands (Morales-Nin *et al.* 2005; Grau 2008). Recreational fishing is becoming more important and it is believed that a transition is taking place from artisanal to recreational fishing in coastal areas (Morales-Nin *et al.* 2010). Recreational fishing is greatest at the peak of the tourist season. It has been estimated that in 2009, 211,500 tourists (2.35% of all tourists that year) caught 296 t of fish using recreational fishing methods on Mallorca (Cardona 2009).

Recreational fishers catch a great variety of species (approximately 80 fish species and 4 cephalopod species), but some are more predominant than others, depending on the fishing method (Grau 2008). Some examples of species that stand out are razorfish (*Xyrichtys novacula*), painted comber (*Serranus scriba*), comber (*Serranus cabrilla*) and annular seabream (*Diplodus annularis*) (García *et al.* 2003). Some species, mainly those targeted by underwater spear fishing, are also of great economic importance to the commercial fishing industry, such as the dusky grouper (*Epinephelus marginatus*) (Coll *et al.* 2004).

The sale of recreational catches is forbidden in the Balearic Islands and normally the recreational catches are eaten by the fishers and their families, despite the fact that illegal selling, mainly by spear fishers, is common. For that reason, this activity could be considered as subsistence fishing. However, it is more likely that subsistence fishing (a need to fish to provide protein) in the earlier years has now transformed more into truly recreational fishing (catching and eating for pleasure, not out of financial or economic necessity).

2.3 Stock status

The fisheries resources of the Balearic Sea, or GSA05, are in a relatively healthy state when compared to those along the Mediterranean coast of Spain (Quetglas *et al.* 2012a). It is believed that this difference mainly stems from the fact that the density of trawlers operating on Balearic fishing grounds is 4-8 times lower than along the coast of the nearby Spanish mainland (Massutí and Guijarro 2004). Nevertheless,

according to the GFCM, all species targeted by bottom trawlers that were assessed in 2010 in the GSA05, i.e., European hake, surmullet, red mullet (*Mullus barbatus*), Norway lobster, red shrimp, and the deepwater rose shrimp (*Parapenaeus longirostris*), were found to be overexploited (GFCM 2010).

Unfortunately, there are few studies on the exploitation status of the species targeted by artisanal fisheries and none on those targeted by recreational fisheries (Morales-Nin *et al.* 2010). The only study on artisanal fishing in the area, which addresses four species targeted by trammel net fisheries, shows that red scorpionfish, surmullet and cuttlefish are near maximum sustainable yield (MSY), and hence at relatively safe levels of exploitation, whereas black scorpionfish is considered to be suffering from increasing overfishing (Merino *et al.* 2008). Studies focusing on spiny lobster – a species also targeted by trammel net fisheries - also indicate signs of overfishing (Goñi *et al.* 2003; Quetglas *et al.* 2004). Regarding species targeted by recreational fishing, Coll *et al.* (2004) point out that spear fishing has had a strong impact on the sub-littoral rocky zone species between 0 and 40 m, and specifically on dusky grouper, which shows signs of overexploitation.

2.4. Marine 'protected' areas and marine reserves

In the Balearic Islands, the main form of protection as part of fisheries management are marine reserves (MR), i.e., "…areas that given their special characteristics are deemed adequate for the regeneration of fishing stocks"[2] and "… marine areas where the exploitation of live marine resources is limited in one way or another, either to increase the fish nursery and to promote the proliferation of marine species subject to exploitation, or to protect marine ecosystems with differentiated ecological characteristics".[3]

In addition to the waters of the National Marine-Land Park of the Cabrera Archipelago, with a marine area of 8,678 ha, seven marine reserves exist in the Balearic Islands: five in Mallorca, one in Menorca and one between Ibiza and Formentera. The seven marine reserves comprise approximately 63,600 ha of coastal waters subject to fisheries management for the explicit purpose of regenerating fish stocks, which amounts to 2.2% of waters of the Balearic promontory, upon which the Balearic Islands sit. Of these, 4,250 ha (0.2% of the waters of the Balearic promontory) are completely closed to any fishing activity (no-take). Most extractive activities are prohibited in the reserves and recreational and commercial fishing are regulated more strictly than in areas open to fishing. However, in Mallorca one 'reserve' allows bottom trawling and three allow spear fishing is allowed.

3. Materials and methods

3.1 Fisheries removal estimation

To estimate total fisheries removals from the Balearic Islands, we followed the catch reconstruction approach of Zeller and Pauly (2007) and Zeller *et al.* (2007), the methodology used for other island fisheries (Zeller and Harper 2009; Harper and Zeller 2011) and, in particular, the protocol developed for the Spanish Mediterranean Sea and Gulf of Cádiz regions (Coll *et al.* 2014b). We adapted this methodology to the local conditions of the Balearic Islands and followed six general steps:

1. Gathered all available reported landing time series from national agencies (*Ministerio de Agricultura, Alimentación y Medio Ambiente*: MAGRAMA, known in the past as MAPA and MARM; and other government bodies), regional agencies (Direcció General de Pesca del Govern de les Illes Balears: DGPGIB), research institutes (Instituto Español de Oceanografía, Centre Oceanografic de les Balears: IEO-COB) and sales notes from fishery producer organization Opmallorcamar (earlier called FICOPEMA);

2) Ley 3/2001, de 26 de marzo de pesca marítima del Estado (Cap. III, art. 14).

3) Decreto 91/1997, de 4 de julio, de protección de los recursos marinos de la CAIB.

2. Identified missing data, including sectors, time periods and/or species that could have resulted in unreported catches;

3. Gathered alternative information on any missing data using literature searches and secondary data sources (informal interviews with fishers and fisheries experts, final project reports, grey literature);

4. Developed anchor points in time between which missing catches could be interpolated;

5. Estimated total fisheries catch time series as the sum of total reported landings and unreported catches.

To determine total fisheries removals (TR), we used a modification of the equation used by Coll *et al.* (2014b) for the Spanish Mediterranean Sea and Gulf of Cadiz regions:

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

where *TR* is the sum of total fisheries landings (*TL*) and total discards (*TD*) for *S* caught species and *F* number of fishing fleets.

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

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

OL refers to official landings and *UL* to unreported landings. *UL* includes catches that are caught legally, but sold on the black market (*BM*), subsistence fishing (*SF*), which refers to the personal consumption of fishing products by fishers and their families, and recreational catches (*RC*), which are not reported in official landings. For the Balearic Islands, we also estimated catches from the mainland fleets, i.e., of those fleets that fish in waters of the Balearic Islands, but land their catches elsewhere. In particular, we took into account the bottom trawlers from subarea GSA06 of the Spanish mainland, which exploit the Pitiusas Islands slope, but we excluded the longliners and industrial purse seiners focused on tuna species and the caridean shrimp fishery (see Section 2.1). Catches from the mainland fleet are a separate estimate and are not included in the reconstructed total catch estimate for the Balearic Islands.

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

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

where *D* refers to direct boat-based discards from fishing activities (Kelleher 2005) and *GF* to the ghost fishing mortality of those specimens that die due to lost or abandoned gear (Brown *et al.* 2005; Macfadyen *et al.* 2009).[4] We will consider as unreported removals, or IUU catch, all the elements of *TR* that are not included in *OL*.

[4] The *Sea Around Us* project will exclude ghostfishing discards from the dataset they use for global application, as this aspect of discarding has not been covered globally for all countries for which catches have been reconstructed.

As part of the methodology, interviews were conducted with local fishers. The main objectives of the interviews with fishers were to: (a) verify the existence of unreported catches and identify principal sources of non-reporting, (b) quantify, by fishing fleet and target species, the unreported catch, and how this may have changed over time, and (c) collect additional information on discarding. Therefore, we used the information retrieved from interviews with fishers to estimate unreported catches from the commercial sector by island, fleet and main species. Fishers interviewed were chosen based on our confidence in the validity of their responses and previous working relationships. A total of seventeen fishers were interviewed: seven from Menorca Island and ten from Mallorca Island. Six were bottom trawl fishers and the other eleven were artisanal fishers.

3.2 Main fleets and species

We focused on total removals and removals of major species, paying particular attention to those which are of high economic importance to bottom trawling fleets and artisanal fisheries, and for which data on official landings, unreported landings and discards were available. Thus, we focused on red mullets (*Mullus surmuletus* and *Mullus barbatus barbatus*), European hake (*Merluccius merluccius*), Norway lobster (*Nephrops novegicus*) and red shrimp (*Aristeus antennatus*), which are important to bottom trawlers, and three artisanal species which were common dolphinfish (*Coryphaena hippurus*), transparent goby (*Aphia minuta*) and spiny lobster (*Palinurus elephas*). We also included species and groups with enough official landings data to make the catch reconstruction, despite us not having unreported landings and discards data, and thus having to make assumptions. These species are picarel (*Spicara smaris*), European sardine (*Sardina pilchardus*) and '*bastina'* a local name to describe a group that includes demersal elasmobranches, mainly cat sharks (*Scyliorhinus canicula* and *Galeus melastomus*) and skates. Information on total removals was utilized to estimate the total catch of the non-major species. Additional information was used to assign this catch to taxonomic categories. Because of this, some additional species may be under- or overestimated by our reconstruction.

3.3 Landings

3.3.1 Official landings

We collected official landings data from publications by national and local agencies, and sales notes from Opmallorcamar, who manage Palma *lonja* (as gathered by IEO-COB), on total landings and by major species (Appendix Table A1). When faced with more than one data option for the same year, we selected the one that came from a longer, consistent time series; if the series were of the same length, we selected the higher value. We observed that for bottom trawling species, most of the data refer only to Mallorca Island (from the Palma *lonja*). The IEO-COB bases its bottom trawl species stock assessments on landings from sales notes from the Palma *lonja,* which tracks all official landings in Mallorca. The reason is that the Palma *lonja* represents most of the official landings from the largest island, in the Balearic archipelago, where the information is more reliable. Thus, data from 1965 to 2001 for red mullets, from 1950 to 2006 for European hake, from 1986 to 2001 for Norway lobster and from 1950 to 2002 for red shrimp refer only to Mallorca (Appendix Table A1). Regarding the main artisanal species, there was a scarcity of available information, especially for common dolphinfish (Appendix Table A1).

It should be noted that in cases where linear interpolations were done between known data points, these catches were also considered reported. We assumed that there were reported data which we did not have access to in those years, in order to remain conservative in our estimate of unreported catches.

3.3.2 Unreported landings

Literature research and informal interviews with fishers and experts were carried out in 2011. When we had more than one data source for the same year, we used what appeared to be the most reliable information, but if they were similar and both reliable, we averaged them. With this information, we developed anchor points, which took various historical clues into account (Appendix Table A2). When unreported landings estimates were not available, we interpolated linearly between intermediate periods, or assumed proportionality (Appendix Table A3). We also gathered information on the total number of vessels, the total official power of the fleet (in hp) and the number of fishers in order to get an idea of the evolution of fishing effort (Appendix Table A4).

Black market and subsistence fishing

Black market (unreported commercial catches) and subsistence fishing were combined because the interview results, the IEO-COB data and the literature always referred to them jointly. However, we separated numerically subsistence fishing by assuming that its value was the same as the one estimated for the Spanish Mediterranean Sea and Gulf of Cadiz (Coll *et al.* 2014b), i.e., each fisher brings home 1 $kg \cdot day^{-1}$. We used the number of fishers per year found in several references (see Appendix Table A4 for anchor points) and we estimated the number of fishers for the other years using the number of fishers per vessel. We also assumed that from 1950 to 1969, fishers worked fewer days than from 1970 to 2010 (180 and 220 days, respectively) in order to take into account the improvement over time of vessel capacity. Note that for the Balearic Islands, subsistence fishing refers to take-home catch by the industrial and artisanal fishers only.

Fisher interviews

Unreported landings from commercial fishing occur mainly because of black market sales. Fifteen of the seventeen interviewed fishers admitted to the existence of unreported landings, one of them denied their existence and one either did not answer or did not know. One of the main reasons given for not declaring landings was the fact that fishers do not pay taxes on fish that they do not declare. On Menorca, it is easier not to declare landings because of the lack of *lonja,* which implies that there is much less control. Also, artisanal fishers tended to declare a smaller fraction of their landings than bottom trawl operators, possibly because the smaller amounts being involved make it easier to escape controls.

Sources of unreported landings (Figure 2a), based on cases where fishers provided more than one reason, were as follows: nine fishers stated that it was due to direct sales to individual consumers; eight to family consumption (i.e., subsistence fishing); six to direct sales to various businesses (mainly restaurants); five to family businesses (such as fishmongers); two to local industries; and one to central markets (note that these answers do not add up to seventeen, the number of fishers interviewed, because more than one response was allowed).

According to fishers' interviews, unreported landings average 25% of official landings. By fleet (Figure 2b), longliners had the highest rate of non-reporting (26%), followed by the artisanal fleets (25%; considering all artisanal gears), purse seiners (24%), bottom trawlers (22%), and gillnets (20%; a gear considered as being artisanal). Results by species indicated that the highest rate of non-reporting (according to the fishers) occurred for dusky grouper and Mediterranean slipper lobster (*Scyllarides latus*; 40%). Red shrimp also were associated with an important rate of non-reporting (35%), followed by red mullets (34%), cuttlefish (32%), monkfish (30%) and spiny lobster (20%). The lowest rates of non-reporting were associated with common dolphinfish (4%), Norway lobster and European hake (both at 10%; Figure 2c). Regarding trends of non-reporting, 10 fishers interviewed opined that they have been decreasing, 3 that they have been increasing, while 4 did not answer.

a) Industrial fisheries

For bottom trawling, in addition to interviews with fishers and literature searches, we used data obtained from the Spanish National Data Collection Program, carried out by IEO-COB (Appendix Table A3). IEO-COB compared actual landings of bottom trawlers, verified by on-board observers, and sales notes to quantify the proportion of landed catch that was not reported between 2001 and 2010. This data showed that 11% of trawl catches were sold outside of the *lonja* and went unrecorded. These data also indicate that the most non-reported species was red shrimp (18%), followed by Norway lobster (16%), while the least non-reported was European hake (7%; Figure 3). We compared this with the data from the interviews to get an average for the final percentage of unreported bottom trawling landings (Appendix Tables A3 and A5).

For the main bottom trawling species, we calculated the mean from available data for the 2000-2010 time period which came out to 8.4% for European hake, 21.5% for red shrimp, 12.1% for red mullets and 13.2% for Norway lobster (Table 1 and Appendix Table A5). For hake, the only trawl species for which we had information before 2000s, this proportion was 35.3% in 1989 (Appendix Table A5).

Table 1. Commercial unreported landings (black market and subsistence fishing) of the trawling fleet (2001-2010) by major species.

Source	European hake	Red shrimp	Red mullets	Norway lobster
Interviews	10.0	25.0	10.0	10.0
IEO data	6.8	18.0	14.2	16.5
Mean[a]	**8.4**	**21.5**	**12.1**	**13.2**

[a]As used for the reconstruction.

As previously mentioned, the official landings of the main bottom trawling species that are used by IEO-COB for its stock assessments, originate from the Palma *lonja,* which monitors landings of Mallorca Island. Using these data, combined with ancillary data found in various publications, we estimated the periods during which the small islands' (Menorca and Pitiusas islands') landings were misreported (Appendix Table A6). The fact that there is no *lonja* in Menorca and that the *lonja* in Ibiza only controls 40% of the landings mean there is little statistical information about landings in these islands (Llabrés and Martorell 1984; Iglesias and Martorell 1988; Massutí 1994).

We also extracted species and groups with enough official landings to make a catch reconstruction. For the industrial fishery this included purse seine caught European sardine (*Sardina pilchardus*) and trawler caught picarel (*Spicara smaris*; also caught by the artisanal fleet but that is not included here). We assumed the same unreported landings as common dolphinfish for both (see 'artisanal fisheries' below).

b) Artisanal fisheries

We acquired less information on artisanal than on bottom trawl landings (Appendix Table A3). For overall artisanal landings, we obtained the black market and subsistence fishing rates from interviews. In the case of spiny lobster, we assumed that the unreported rate during 1950-1969 was the same. In 1970, spiny lobster stopped being exported to Barcelona, on the Spanish mainland, causing an increase in unreported landing data, because it was sold in local (Balearic) restaurants, without statistical controls (Appendix Table A2). It has been shown in other areas of the Mediterranean, that statistical series are more reliable when the species is exported for foreign consumption (Quetglas *et al.* 2004). In the Balearic Islands, estimates of the increase in non-reporting were made by crosschecking official landings with the estimate of actual landing (190 t) between 1986 and 1988 (Iglesias and Martorell 1988; Iglesias *et al.* 1994) (Appendix Table A3). We also obtained an estimate of 100 t in 2003-2004 (Quetglas *et al.* 2004) and we assumed the same unreported catch percentage from 2004 for 2005-2010 (Appendix Table A3).

Of the major species targeted by the artisanal fishery, spiny lobster had the highest fraction of unreported landings, estimated at 1,710% (the results include take-home subsistence catch) in 1986-1988, and decreasing to 232.1% in 2005-2010 (Appendix Table A5). This fraction was 40% between 1981 and 1991 in common dolphinfish, decreasing to 3.8% in 2001-2010 (obtained the 2001-2010 unreported landings data from interviews with fishers; Appendix Table A3). For transparent goby, we assumed the same non-reporting rate as for Norway lobster for 2001-2010, i.e., 13.2%, (Appendix Table A5). This was due to the lack of information and because both species have a similar market price (currently: 16.9 €•kg-1 and 16.0 €•kg-1, respectively; Anon. 2010).

c) *Bastina* fishery

We also had enough information to estimate the *bastina* (demersal elasmobranches) fishery. Information on industrial trawl caught *bastina* from daily sale bills from Palma *Lonja* for 1965-2008. Information on total *bastina* catches was available for 2007-2010 from the local agency (DGPGIB). The two overlapping years of data allowed us to estimate the industrial catch from the other two smaller islands and the artisanal catch for the years prior to 2007 (approximately 70% of the industrial landings at Palma *Lonja*). After raising the Palma *Lonja* landings to the total catch, the 1965 total was carried back unaltered to 1950. Additional information indicated that the artisanal *bastina* catch was 17% of the total. Catch from the two smaller islands as well as the artisanal catch was considered unreported, except for the years 2007-2010 when all catches were considered reported. Also, all catches from 1950-1964 are considered unreported.

d) Non-major species catch

Total landings data were collected and then data for the specific major species collected above (including the less commercially important picarel, European sardine, and *bastina*) were subtracted from the total to give the amount of non-major species catch. Additional information was used to separate this catch into molluscs, crustaceans and various fish families. For total landings in 1950, we used the results of the interviews of older fishers, and interpolated linearly to the first available anchor point (Appendix Table A3), which was 1994. The anchor points used to estimate the proportion of unreported landings over official landings over time were 84.2% in 1950 for all landings and species, and 54.3% for all landings in 1994 (Appendix Table A5). Catches were then interpolated to the next anchor point in 2001. Out of all the information gathered for the period 2001-2010 (interviews, IEO-COB, literature and official data), the mean of the estimate was based on the average of the DGPGIB data for 2009 and 2011, and the informal interviews with fishers. For the unreported part of all landings (all species and all fleets combined), we calculated a 29.6% non-reporting rate (Table 2, Appendix Table A5). Also of note was that for the two main Balearic fleets (trawl fleet and artisanal fleet), we selected the average between available data (interviews and IEO-COB data) for bottom trawlers (16.7%) and the only data available for the artisanal fleet that came from fisher interviews (25.0%; Table 2).

Table 2. Commercial unreported landings (black market and subsistence fishing) by fleets 2001-2010.

Source	Trawl fleet	Artisanal fleets	All landings
Interviews	22.3	25.0	24.9
IEO data	11.2	-	-
2009 DGPGIB	-	-	37.5
2011 DGPGIB	-	-	26.4
Mean[a]	**16.7**	**25.0**	**29.6**

[a]As used for the reconstruction.

In order to disaggregate the catches into more informative taxonomic categories, the catch was first split into crustaceans, molluscs and fish for both the industrial and artisanal sectors. We used the composition for the mainland Spanish fleet fishing in the Mediterranean Sea (Coll *et al.* 2014b) as a baseline. We then made adjustments to this composition in order to better reflect the fisheries of the Balearic islands using additional data and records (Oliver 1983; Massutí 1994; Massutí *et al.* 2007; Anon. 2007-2010; and data from the DGPGIB). This modified species breakdown was applied to the non-major species catch (reported and unreported) of the industrial sector in order to disaggregate it into higher resolution taxonomic categories. For the artisanal catch we used information provided by Llabrés and Martorell (1984) to disaggregate the non-major species catch into higher resolution taxonomic categories. Species and species groups included in Llabrés and Martorell (1984) were sorted into fish, crustaceans and molluscs and re-proportioned in order to apply the breakdowns the totals we had estimated for each of these groups. In the fish category the shark and ray information was removed before the proportions were calculated. This information was used separately to disaggregate the estimated *bastina* catches (both industrial and artisanal).

Recreational fishing

All publications related to catch estimates for recreational fishing by the Balearic local population (Morales-Nin *et al.* 2005; Grau 2008) are based on a 2000-2002 study that estimates a total recreational catch of 1,200 t for those years (Morales-Nin *et al.* 2002). To obtain an estimate of these catches for other years, we assumed that the data from the 2000-2002 study could be made proportional to the official population census of the Balearic Islands (Appendix Table A7). Similarly, we assumed that the estimated 296 t total catch by recreational fishing by tourists in 2009 (Cardona 2009) could be made proportional to the number of tourists visiting the Balearic Islands (Appendix Table A7) since the start of tourism development in the 1960s (Appendix Table A2).

The taxonomic breakdown of the recreational catches was derived from Morales-Nin *et al.* (2005), who describe the total number and weight of species most commonly taken during recreational fishing competitions. Catch composition was provided for boat-fishing, shore-fishing, and spear-fishing, which accounted for 62.9%, 33.4%, and 3.6% of recreational fishers, respectively. As we did not have any information on the percentage of catch that comes from each fishing type, as a proxy we used the percentage composition of fishers using each method to represent the amount of catch from each method. Using the catch composition data provided for each fishing method, we determined the percentage breakdown by weight and applied this to the proportion of the recreational catch accounted for by each method to determine a total taxonomic breakdown for the recreational catch (see Table 3 for overall breakdown). Further study on this sector is needed in the future.

Table 3. Overall taxonomic breakdown applied to the recreational catches of the Balearic Islands, 1950-2010.

Taxon	Percentage
Serranus cabrilla	25.34
Serranus scriba	14.79
Diplodus annularis	14.02
Sarpa salpa	13.28
Lithognathus mormyrus	6.52
Coris julis	4.43
Symphodus tinca	3.98
Diplodus vulgaris	3.78
Pagellus acarne	3.35
Diplodus sargus	2.83
Spondyliosoma cantharus	1.62
Pagellus erythrinus	1.51
Umbrina cirrosa	1.19
Muraena helena	0.90
Thalassoma pavo	0.68
Boops boops	0.52
Mugilidae	0.38
Sciaena umbra	0.28
Dactylopterus volitans	0.20
Scorpaena scrofa	0.18
Labrus viridis	0.14
Labrus merula	0.08

Mainland fleet

We estimated bottom trawler landings from the Spanish mainland fleet (i.e., subarea GSA06) that operate on the upper and middle slope of the Pitiusas Islands, as a separate estimate not included in the reconstructed total catch estimate for the Balearic Islands . Because they land their catches on the mainland, they are not included in the official landing statistics of the Balearic Islands. Total landing estimations of this fleet by major species are available from 1976 to 2000 (Garcia 2003). Given the lack of data for other years, we assumed that, from 1950 to 1975, the mainland fleet landed the same proportion of catches relative to official landing of Balearic Island shrimp as in 1976, and the same proportion in 2001 to 2010 as in 2000 (Appendix Table A7).

Spanish mainland bottom trawlers exhibited particularly high levels of activity in the 1970s, when this fleet was three times larger than was officially registered (Massuti 1973). In 1980, the fleet was two-times larger (Oliver 1983). For this reason, and due to us missing data on fishing effort, we multiplied total landings and landings by species in those decades by three and two, respectively (Appendix Table A7).

We did not estimate catches from other mainland fleets (see Section 2.1) because there is no information available specific to the study area, and therefore we could not determine the level of activity with the Balearic Islands' waters. However, these catches are included in the fisheries withdrawals of the Spanish Mediterranean Sea and Gulf of Cadiz regions (Coll *et al.* 2014b).

3.4 Discards

We followed the same methodology for discards that we used to estimate unreported landings (see Section 3.3.2). We gathered available data on discards in the literature and informal interviews with fishers (Appendix Table A8).

Almost all fishers interviewed (i.e., 16 of 17) admitted that discards occurred in their fishery, and only one did not answer. Also, seven said that there was a season when discarding was higher, while nine said that discard proportion remained the same throughout the year (again, one did not answer). Of the fishers that said that there was a 'discarding season', three said it was spring, three answered summer and one indicated around Christmas. The reasons given were that recruitment of many species takes place in spring, and there are more undersized individuals in catches, and that the spiny lobster fishery occurs in summer, whose trammel-nets generate much of the by-catch of the artisanal fisheries.

Regarding trends, seven of the fishers interviewed said that discards decreased over time, six said that they remain the same, three said that they increased, and one did not answer. The main reasons given for the increase in discards was that in recent times there are more minimum landing size obligations and forbidden species regulations that force them to discard, while the major reason given for the alleged decrease of discards was that there are now more regulations designed to improve gear selectivity, such as changing from diamond to square mesh trawl cod-ends or bigger mesh sizes in gill or trammel nets.

As with unreported landings, we selected the most credible percentages, or, in cases where we had more than one credible value, we took an average.

There is no data on the proportion of discards by the fleet as a whole, only by each fleet segment. Thus, in order to estimate overall discards, we averaged the proportion of official landings by fleet for 2002-2009 from the DGPGIB data: bottom trawling 63.2% of total landings, artisanal fishery 17.7%, purse seiners 16.9% and long liners 2.2%. Using these proportions, we were able to estimate the proportion of discards by each fleet, and thus estimate the proportion of discards for all catches.

Discarding was highest in trawlers (31.3%), followed by trammel and gillnets (jointly 30%), all artisanal fleets (17.0%), longline (4.0%) and purse seine (1.0%). Total discards were estimated to be 24.6% of total landings (reported plus unreported, not including recreational catches). In addition to calculating overall total discards, target discards were calculated for the major species that were reconstructed separately using species specific information. These discards were then subtracted from the overall total and the remaining discards were assigned to taxonomic groups using additional information.

Bottom trawling fleet

We used data obtained from the Spanish National Data Collection Program, carried out by IEO-COB using on-board observers on bottom trawlers between 2001 and 2010. On-board observers verified catches and discards, by species. In our final removal estimation, we took into account the discards of the major commercial groups: fish, molluscs and crustaceans.

There are many studies on discards from bottom trawling in the Balearic Islands that provided yields ($kg \cdot hour^{-1}$) and amounts, for various depths (Appendix Table A8). For example, an IEO report evaluating discards in the Balearic Islands (Massutí *et al.* 2005) estimates the following proportions: a) 55-70% discards originate from areas less than 150 m deep; b) 45-60% from 150 to 350 m; and c) 15-20 % from 350 to 800 m. Thus, we chose discard results from the Spanish National Data Collection Program described above, for all bottom trawl landings and by main species as the most reliable data and we assumed the same proportion for the entire time period for all species, with the exception of European hake (Appendix Table A9).

European hake has increasingly suffered from overfishing since the 1980s (Oliver 1993; Guijarro *et al.* 2010b) and immature individuals became a more important proportion of the catch (Martin *et al.* 2001; Hidalgo *et al.* 2011). To take this into account, we assumed two anchor points: one in 1950 with discards assumed to be a third of those in 2001-2010, and the other in 1980 with discards assumed to be half of those in 2001-2010 (Appendix Table A9).

Discards of red mullets, Norway lobster and red shrimp were negligible (estimates from Spanish National Data Collection Program carried out by IEO-COB of 0.5%, 0.5% and 0.1%, respectively). Due to a lack of data, we assumed the same proportion for the entire time period for all these species.

For demersal elasmobranches (both industrial and artisanal fisheries), we assumed the same discard rate as for European hake, in order to take into account an increase in discard with time due to less interest in this species in the population (fisher's personal communication). For European sardine, we used the discard rate for purse seiners which was determined from the interviews with fishers (1%).

We also calculated discard proportions for some non-commercial groups, such as seaweeds, ascidians, echinoderms and polychaetes, to obtain an idea of the overall impact of fisheries on the ecosystem. If we take these into account the discard proportion increases from 31.3% to 42.7% for this gear and from 24.6 to 33.8% for overall catches. These discard proportions and their results were not included here as they are not part of the *Sea Around Us* Project estimate.

Artisanal and other fleets

To take into account discards from artisanal, purse seiners and the longline fleet, we used the proportion we calculated based on interviews with fishers (Appendix Table A8).

For the artisanal fleet, we obtained an average by using the two most common gears: nets (gillnets and trammel nets) and longlines. For the main species, we also compared information given by fishers and available information in the literature (Appendix Table A8). We assumed that for all major artisanal species, the same discarding rate applied over time, except for spiny lobster. For this species, we know that in the 1950s, baited traps were the most commonly used gear (Massutí 1958). Baited traps have almost no discards of non-targeted species and do not cause any spiny lobster mortality (Goñi *et al.* 2003). Since the 1960s, there has been a progressive increase of the use of trammel net to catch this species (Massutí 1989; Goñi *et al.* 2003) and since 2003, it is the only gear used to catch spiny lobster (based on interviews with fishers). Trammel nets cause a higher mortality of spiny lobsters than traps, mainly because they are generally soaked for longer than allowed (more than 48 hours). In the Balearic Islands, 7.5% of spiny lobsters are damaged by stress or by predators (Quetglas *et al.* 2004), mainly by octopuses, and 13% of individuals are under the legal landing size (Goñi et al, unpublished data). Consequently, if fishers followed the minimum landing size regulation, the percentage of this species that would need to be discarded would be 13%, which would increase to 20.5% if they also discarded all damaged lobsters. In the case of crustaceans, undersized individuals are almost always still alive. For that, we selected the discard proportion related to dead lobsters and those most like to not survive which corresponds to 7.5% (Appendix Table A9). Also, to take into account the increase in discards due to the transition from traps to trammel nets, we assumed that in 1950, spiny lobster discards amounted to 5%, as proposed in the catch reconstruction for Corsica (Riutort, unpub. data in Le Manach *et al.* 2011), where traps were also the main gear used (Appendix Table A9).

For common dolphinfish and transparent goby, we assumed zero discards for the entire time period, based on literature and interviews with fishers (Appendix Tables A8 and A9).

Finally, we used the same proportion of underwater discarding (ghost fishing) as in Coll *et al.* (2014b), estimated as an additional 1% over official landings, based on a study on European waters (Brown *et al.*

2005). These results were not included in this paper as underwater discarding (ghost fishing) is not analyzed by *Sea Around Us*.

4. Results and discussion

4.1 Landings

4.1.1 Official commercial landings

Official reported landings ranged from a minimum 2,880 t in 1952 to a maximum of 5,720 t in 1969, with an average during the study period of 4,070 t·year^{-1}. The highest period of official landings was registered from 1963 to 1995, with landings averaging 4,670 t·year^{-1}. Before and after that period, official landings were roughly constant, averaging around 3,340 t·year^{-1} from 1950 to 1962 and 3,380 t·year^{-1} from 1996 to 2010.

The most important species, when considering overall official landings was picarel (*Spicara smaris*), whose official landings during the 1950s to mid-1960s amounted to 41-57% of all landings, but which declined in 1970 to 11% and 7% in the 2010. This high decrease is attributed to cultural reasons (A.M Grau and fishers' personal communications). Whereas in the past this species was highly appreciated (Anon. 1921; Llabrés and Martorell 1984)**,** today it is difficult to sell. Thus, there is a fixed quota of 15 kg per fisher and day that seems to be followed and it is rarely an under-reported species (fisher's personal communication). On the other hand, there was an increase in the proportion of the main commercial species (red mullets, European hake, Norway lobster, red shrimp, spiny lobster, transparent goby and common dolphinfish) over time, from 10% in 1950 to 23% in 2010. Fish decreased in official landings (from 78% in 1950 to 62% in 2010), and invertebrates increased (from 22% in 1950 to 38% in 2010).

Reported landings of European pilchard (*Sardina pilchardus*) followed an interesting pattern, fluctuating to a peak of 540 t in 1976 before decreasing to a low of 70 t in 2007 before rapidly increasing to a secondary peak of 380 t in 2009. However, the period from 1987 to 2007 was interpolated due to a data gap and so most likely fluctuations continued during that period. The low of 68 t is probably just one of the many down points in a fishery which exhibits large fluctuations from year to year.

For red mullets (*Mullus* spp.), maximum reported landings of 409 t occurred in 1961, with a minimum, of 113 t in 1989. From 1978 to 2010, official landings fluctuated between 113 t·year^{-1} and 207 t·year^{-1}. European hake showed highly fluctuating landings, with the most important peak in 1977 (270 t) and the minimum in 1960 (34 t). From 1982 to 2010, the height of the peaks became progressively less important. Overall, the fluctuating landings of Norway lobster increased over time, from 2.7 t in 1950 to 34 t in 1996, similar to red shrimp, which had its minimum landing of 54 t in 1950, and its maximum of 365 t in 1990. Official records for spiny lobster landings were difficult to find for much of the study period, thus an estimated baseline was determined which ranged from 74 t in 1955 to a minimum of 11 t in 1986. Official landings in recent years (2003-2010) oscillate around 30 t·year^{-1}. Common dolphinfish official landings showed an increasing, though a strongly fluctuating, trend, ranging from 2 t in 1984 to 174 t in 2003. Finally, data on transparent goby indicated an important period from 1972 to 1996 with two peaks in 1983 and 1991 of 73 t and 70 t, respectively.

4.1.2 Unreported landings

Commercial fleets

Black market decreased along the entire time series, from 2,190 t (industrial 1,820 t and artisanal 370 t) in 1950; to 850 t (industrial 645 t and artisanal 205 t) in 2010. The black market catches ranged from a minimum 760 t (595 t industrial and 165 t artisanal) in 2007 and a maximum 3,825 t (3,160 t industrial

and artisanal 665 t) in 1969. The total black market catches were 134,925 t (108,035 t industrial and 26,890 t artisanal).

From the most important commercial species, spiny lobster was most important in the black market. Along the entire time period, there have been more black market than official landings (4,485 t and 1,920 t respectively, 2.3 times more). The minimum black market landings were in 1950 with 11 t; and the maximum was in 1986 with 155t.

Subsistence fishing (take home catch by commercial fishers) decreased along the time period, from 885 t in 1950 to 140 t in 2010. That decrease was related with the decrease of the number of fishers (see section 4.3). The total subsistence landings were 27,380 t.

Recreational fishing

Catches taken by local recreational fishers followed the evolution of the Balearic population, which grew from approximately 420,000 inhabitants in 1950 to 1,106,000 in 2010. Thus, we calculated the relationship between local population and recreational catch and observed an increasing trend during the time period studied, with a minimum in 1950 of 550 t and the maximum in 2010 of 1,450 t (Figure 4a).

We also took into account the recreational catches of tourists. The number of tourists to the Balearic Islands grew from approximately 400,000 in the 1960s, when the industry began to develop, to a maximum 14,283,000 in 2010, which allowed calculating a minimum recreational catch of 8 t in 1961 and a maximum of 300 t in 2010 (Figure 4a).

Overall, recreational catches thus rose from 550 t in 1950 to 1,750 t in 2010, i.e., 3.2 times, with the local component declining from 100% of the total in 1950 to 83% in 2010.

Mainland bottom trawlers

Estimated catches from the Spanish mainland bottom trawlers operating on the Pitiusas slope increased from 22 t in 1950 to a peak of 353 t in 1970 and 1976, and declined thereafter with an average of 72 $t \cdot year^{-1}$ in the 2000s (Figure 4b). Landings made up 80% of the mainland bottom trawlers catch with discards contributing the remaining 20%. These catches have been accounted for by the reconstruction for the Spanish mainland fleet fishing in the Mediterranean and Gulf of Cadiz (Coll *et al.* 2014b) but have been included here to show the complete picture of removals from Baleares Islands' waters. These totals are not included in any other results within this paper.

Of the major species targeted by bottom trawlers, the most important were red shrimp, which accounted for 23.0% of all the catch (landings and discards), followed by Norway lobster (7.2%) and European hake (6.5%), with these three species exhibiting the same general trend (Figure 4b). Minimum and maximum catches were 5 t in 1950 and 81 t in 1970 for red shrimp, 2 t in 1950 and 24 t in 1970 for Norway lobster and 1 t in 1950 and 22 t in 1970 for European hake.

4.2 Discards

All discards along the entire time series were 100,970 t, with an average per year of 1,655 t. The maximum was in 1969, with 2,450 t, and the minimum was in 2007 with 985 t.

Overall it was estimated that the largest contributor to discards was picarel accounting for 6% of the discards. That was mainly because this species was the most important in catches.

European hake was the most important commercial species with the highest discard rate (percentage of total catch of the species). However, in the overall results these only amounted to 1.2% of the total reconstructed discards. It should be noted that these only represent the target discards of that fishery

and that there may be additional discards of these species from the other fisheries which are either grouped under their family or in a pooled group.

4.3 Fleet evolution

Fleet data from 1950 to 2010 shows an increase in total official engine power, from 6,360 hp to 29,561 hp, and a decrease in vessel numbers from 1,265 to 408 (Figure 5), implying an increase in mean vessel engine power from 5.0 hp to 72.5 hp. The most important power increase took place between 1969 and 1986, when official data suggest power increased by 4.4 fold; slightly declining thereafter. The maximum fleet size was 1,322 units, in 1973.

The number of fishers has declined drastically from 4,976 in 1950 to 673 in 2010 (Figure 5), and the mean number of fishers per vessel has decreased from 3.9 to 1.6.

4.4 Total fisheries removals vs. official landings

While the official landings show a certain stability at around 4,000 t, the reconstructed total catches tend to decline, after a peak in 1969 (13,200 t) and in 1976-1977 (12,500 t), and reached a minimum in 2007 with 6,700 t (Figure 6a). As with official landings, fisheries removal trends can be divided into three time periods (within the time series). The most productive period appears to have been from 1963 to 1995 with average catches per year of 10,740 t. The other two periods: from 1950 to 1962 and from 1996 to 2010, showed a more consistent pattern, the difference being that the first period had a higher mean annual catch (8,300 t) and a slightly increasing tendency, and the second period had a lower mean catch (7,200 t) and a slightly decreasing tendency.

If we analyze the evolution throughout the time-series, from 1950 to 2010, the official landings proportion has increased (from 39% to 47%), black market and subsistence has decreased (from 36% to 14%), recreational fishing has increased (from 6% to 24%), and discards have decreased (19% to 15%). Fisheries removal estimation is 2.5 times the assumed official landings in 1950 and 2.1 times in 2010.

We estimated total catch of over 570,500 t over the entire period, where official landings would represent 44%, followed by black market and subsistence (28%), then discards (18%), and recreational landings (10%). All reconstructed catches combined equal 2.3 times the amount of official landings.

Total fisheries removals in the Balearic Islands were mainly due to industrial sector landings (Figure 6a), which accounted for 57% of reconstructed total catches from 1950 to 2010 (72% if discards included). Discards (regardless of sector) followed with 18% of the total catch, then artisanal landings, recreational and subsistence fishing with 10%, 10% and 5%, respectively (Figure 6a). The artisanal sector increases to 12% if discards are included. Subsistence fishing decreased from 10% (around 900 t), to 2% (around 140 t; Figure 6a) as the number of fishers decrease drastically (Figure 5). Recreational fishing is the fraction that has increased the most along the time series, and in 2010 it was higher than artisanal fishing (24% and 13%, respectively) (Figure 6a).

The top contributor to the reconstructed total catch is picarel (*Spicara smaris*) with 15% of the overall catch (Figure 6b). This is followed by blue whiting (4.8%), *bastina* (sharks and rays; 4.1%), European pilchard (3.4%), red mullets (3.4%), and red shrimp (3.3%; Figure 6b). Invertebrates as a group (not including red shrimp) are also an important part of the catch with a combined estimate of 17.8% of the catch.

5. Conclusions

Based on our reconstruction of total removals from the Balearic Islands from 1950 to 2010, we observed that there is an important difference between reported landings and our estimates of total catches. We

estimated that total catches for the whole area are 2.3 times what it is officially reported.[5] This proportion is more important than in the Spanish mainland Mediterranean Sea (excl. the Balearic Islands) and Gulf of Cadiz region, 1.7 times (Coll *et al.* 2014b), but lower than for the Mediterranean island of Corsica, where real catches were estimated to be five times higher than official catches (Le Manach *et al.* 2011). This may be explained by the lower enforcement in small islands (Quetglas *et al.* 2012a).

Although unreported catches (unreported landings and discards) have decreased in the Balearic Islands, from 61% in 1950 to 53% in 2010, there are still more unreported than reported catches. Thus, it is important to enforce regulations to reduce unreported catch in the area in order to improve fisheries management.

Spiny lobster is the species with the greatest percentage of unreported landings, especially from the 1970s to the 1990s. The high price that spiny lobster brings in, which today ranges from 40 to 50 €/kg (Anon. 2010) and the historical low enforcement of artisanal fishery regulations, are probably behind the high levels of unreported landings. The economic importance of the lobster fishery in the Islands is evidenced by the high proportion of the artisanal fleet involved annually in this fishery, which ranges from 30% to 77% of the vessels depending on the island (De Pablo 1992; Quetglas *et al.* 2004).

Red shrimp is the most important species in terms of revenues in the Balearic Islands accounting for a quarter of the total amount (Anon. 2010). It has also a high market value, 24-33 €/kg (Anon. 2010), and is the second most valuable species after the spiny lobster. Red shrimp, like spiny lobster, is also sold frequently on the black market.

Variations in landings and total catches by species can depend on several factors. In addition to fishing pressure, environment, cultural changes and other human factors are also important. For example, high variation in catches on red shrimp (Carbonell *et al.* 1999; Maynou 2008a, 2008b), Norway lobster (Maynou and Sardà 2001), European hake (Hidalgo *et al.* 2011; Quetglas *et al.* 2012b), common dolphinfish (Massutí and Morales-Nin 1995) and transparent goby (La Mesa *et al.* 2005) are also related to environment factors. Fluctuations in Norway lobster catches are related also to commercial causes (Merella *et al.* 1998), as occurs with picarel (A.M. Grau and fishers' personal communications).

The high proportion of red algae and maërl beds on the Balearic shelf leads to a greater proportion of discards from the Balearic Islands bottom trawlers than those from the Spanish mainland: up to 55-70% compared with 23-48% on continental shelf in each area, respectively (Carbonell *et al.* 1998; Sánchez *et al.* 2004). Despite the fact that maërl beds are protected by European Union against bottom trawling,[6] this fleet continues operating on this habitat in the Balearic Islands.

It seems that the important increase in vessels engine power that took place during the studied period, especially since 1969, is linked to the increased landings between the 1960s and 1990s. Despite the dramatic decrease in vessel numbers from the 1970s and on, catches have not followed a similarly decreasing trend. It was estimated that the power average of the bottom trawlers engines in the Balearic Islands has increased 6 times between 1965 and 2008 (Quetglas *et al.* 2012b). Bottom trawlers in the Balearic Islands have a much higher power than what appears in the official register (Morales-Nin 2003; Coll *et al.* 2014a), as happens in all Mediterranean Sea trawl fleets (Sanchez 2002), usually

[5] Reported baseline includes assumed interpolations for data gaps where official data could not be obtained.

6) Council Regulation (EC) No 1967/2006 of 21 December 2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, amending Regulation (EEC) No 2847/93 and repealing Regulation (EC) No 1626/94.

surpassing the established legal limit of 500 hp (Quetglas *et al.* 2012b). Vessel power can be double the permitted legal power (Guijarro *et al.* 2010a; Guijarro *et al.* 2010b; Guijarro *et al.* 2010c), whereas official data puts the average between 150 to 320 hp. This extra fishing effort in bottom trawlers needs to be factored in if we want to assess the real impact on marine resources.

In the artisanal fleet there are also indications that fishing effort has increased – in some cases with regards to net length. It is common to use nets longer than what is permitted by law (2,000 m per person and 5,000 m maximum per vessel), and in some cases net sizes reached 10,000 m, considerably increasing the effective fishing effort (Iglesias and Martorell 1988; Massutí 1989; Goñi *et al.* 2003). One retired fisherman we interviewed said that when he began fishing in 1971, he used 750 m of net and usually caught one smooth-hound (*Mustelus* spp.) of 25 kg, four European spider crabs (*Maja squinado*), 9 kg of cuttlefish and 8 kg of mixed fish. Now his son uses 3,000 m of net, four times more than he used to use, and catches only 5 kg of cuttlefish and 6 kg of mixed fish (smooth-hounds have greatly decreased and European spider crabs have disappeared from the area; Coll *et al.* 2014a).

The increase in the fishing capacity throughout time has been a substitute of an important number of fishers.

Landings from recreational fisheries increased with time and in 2010 they are greater than those from artisanal fishing (around 1,700 t and 800 t respectively). Thus, this sector should be included in landing statistics to improve fisheries management.

Despite being responsible for one percent of the total removals in the Balearic Islands (if included in the calculation), the mainland fleet (coming from the Spanish coast) should be taken into account so as to have more accurate and effective management for highly commercial species. The mainland fleet, for example, catches 37% of all Norway lobster and 9% of all red shrimp in the Balearic Islands.

Our study also highlights that further studies are needed to obtain a more accurate estimate of total removals from the Balearic Islands. For example, it would be useful to compare reported landings with reliable data from fishers' personal logbooks. Also there is the need to link total removals with total fishing effort in order to get information on the yield evolution.

However, catch reconstructions, where unreported catches are estimated and combined with reported landings data, are a critical first step since it is misleading and inefficient to continue assessing target species that are known to be misreported (Pauly 1998). This study thus presents the first attempt to estimate total removals from the Balearic Islands from 1950 to 2010 and represents a substantial improvement for fisheries management.

Acknowledgements

The authors would like to thank *Sea Around Us* for giving them the opportunity to participate, through this contribution, in their effort to reconstruct global fisheries catches. We are very grateful to those fishers that have kindly participated in our informal interviews, to Beatriz Guijarro for helping us with landings data and to Angela Pauly for the initial round of English editing. Finally, the authors would like to acknowledge the historical work conducted by Miquel Massutí. Marta Coll was supported by a research contract of the *Ramon y Cajal* program of the Spanish Government, and Andrea Au, Kyrstn Zylich and Daniel Pauly acknowledge support from *Sea Around Us,* a scientific collaboration between The University of British Columbia and The Pew Charitable Trusts.

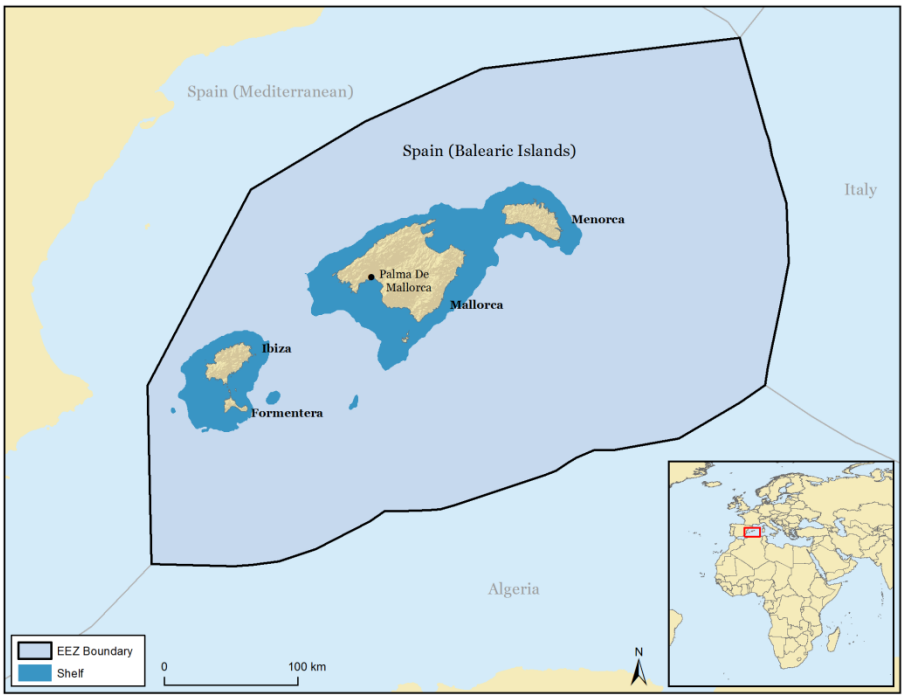
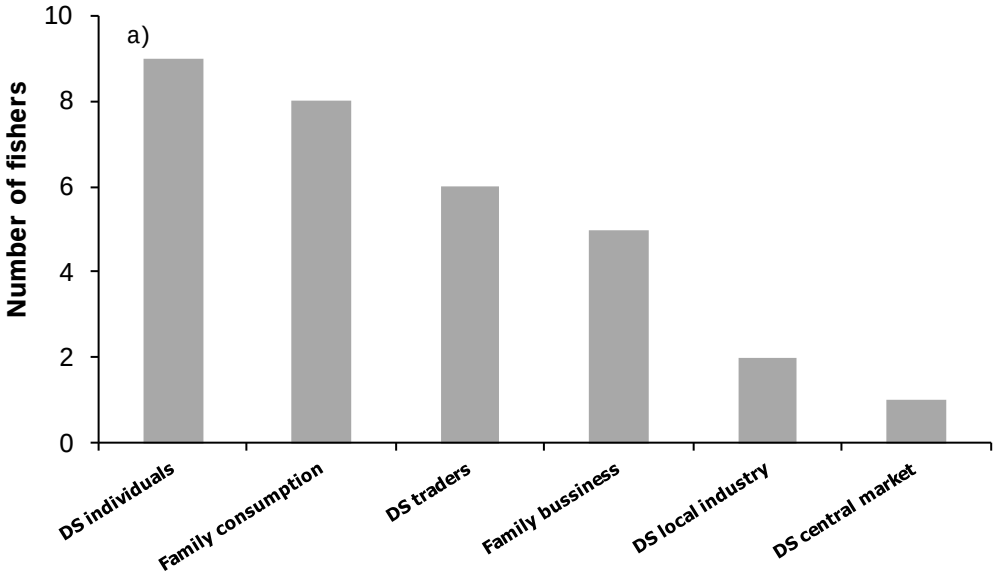


Figure 1. The Balearic Islands in the western Mediterranean Sea, showing the Exclusive Economic Zone (EEZ, boundary to Spanish mainland EEZ was derived arbitrarily), and the 200 m depth contour shelf waters.



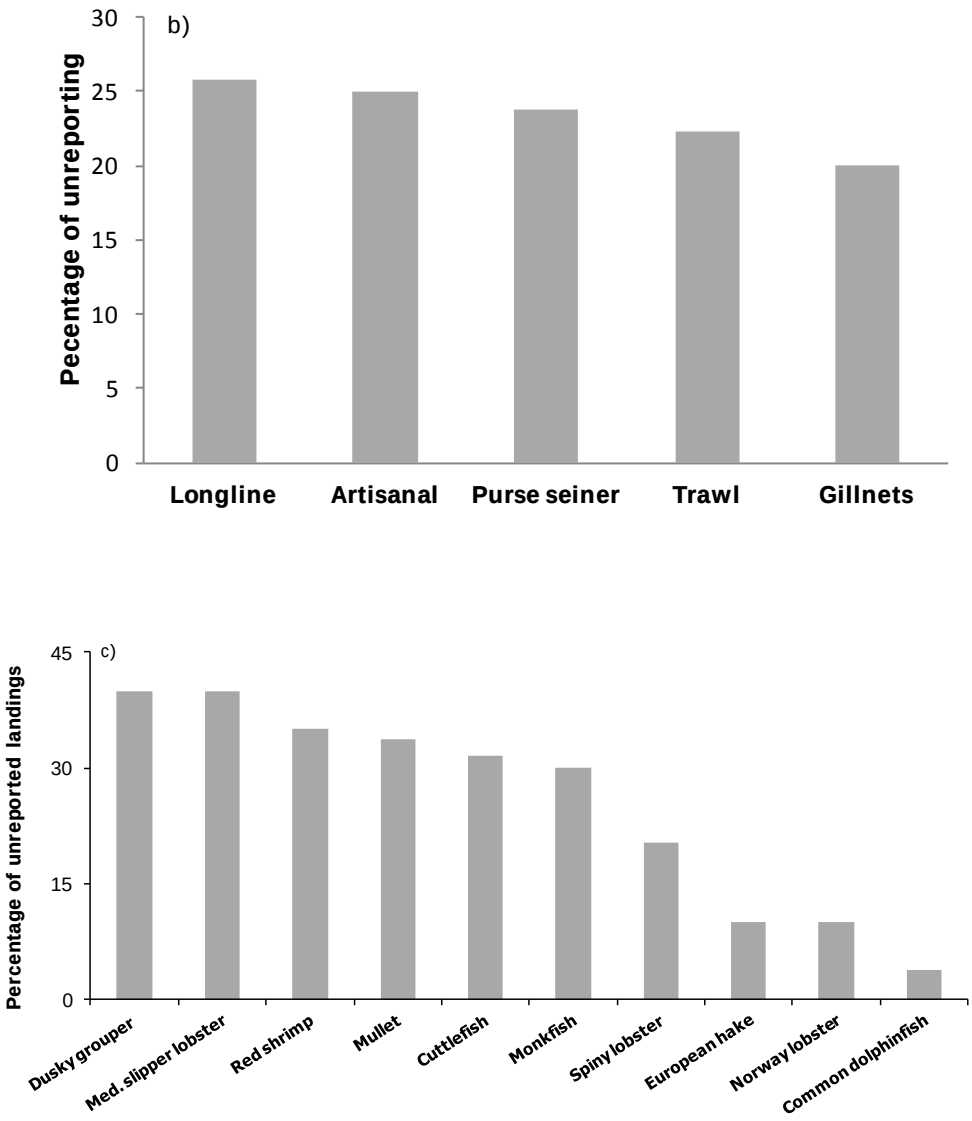


Figure 2. Results of interviews: a) number of fishers answers about sources of non-reported catch (DS means "direct selling"), b) percentage of unreported landings by gear, and c) percentage of unreported landings by species.

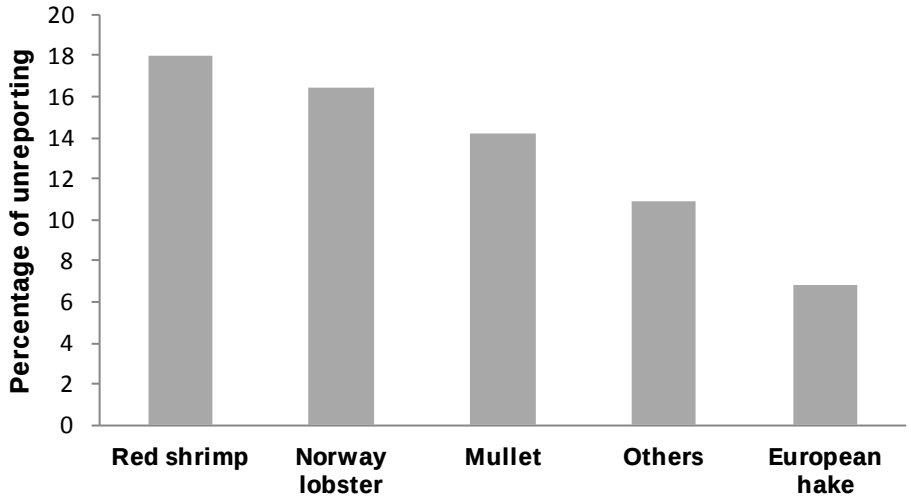
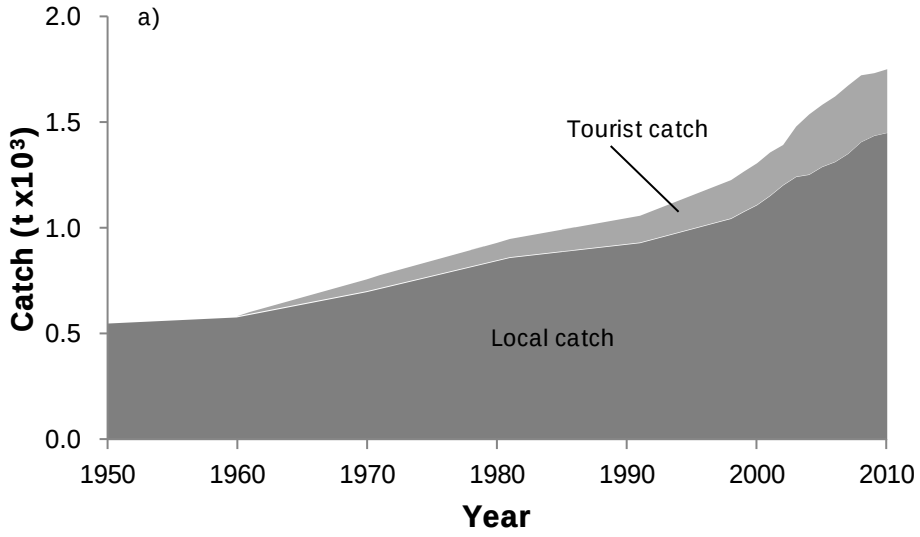


Figure 3. Unreported landings (%) from the Spanish National Data Collection Program carried out by IEO-COB, with observers on board trawlers during 2001-2010.



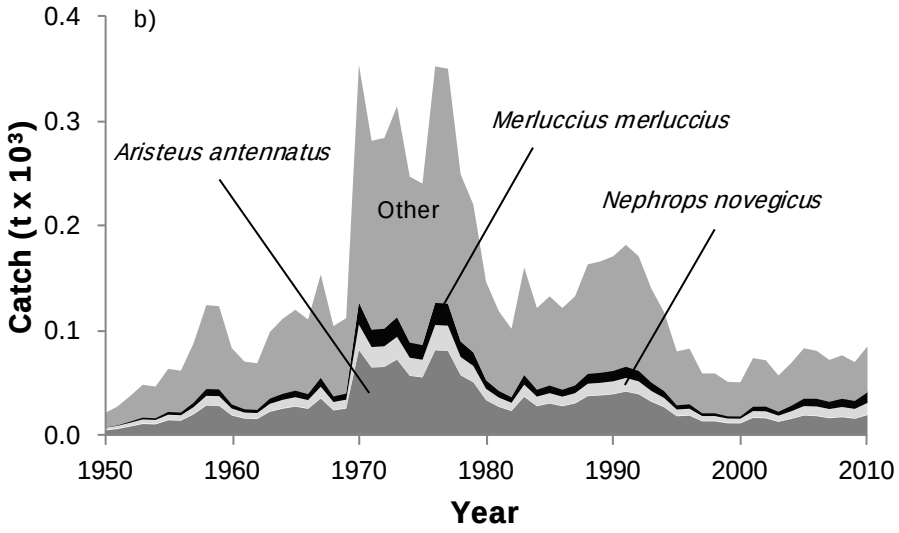


Figure 4. Estimated catches in the Balearic Islands by a) recreational fishers (local population and tourists) and b) Spanish mainland bottom trawlers from GSA06.

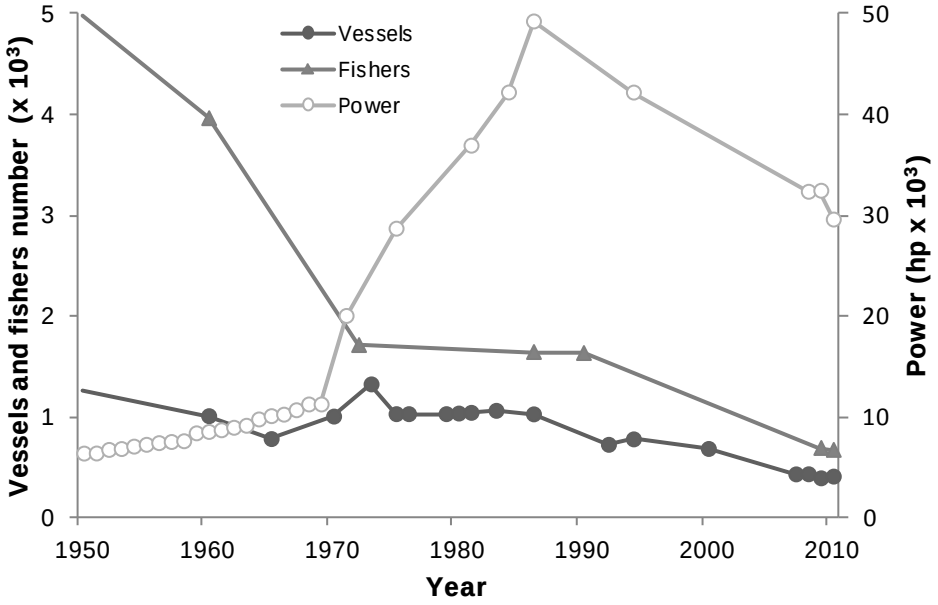


Figure 5. Trends in the Balearic fleet: vessels number, total official engine power; and fishers' number.

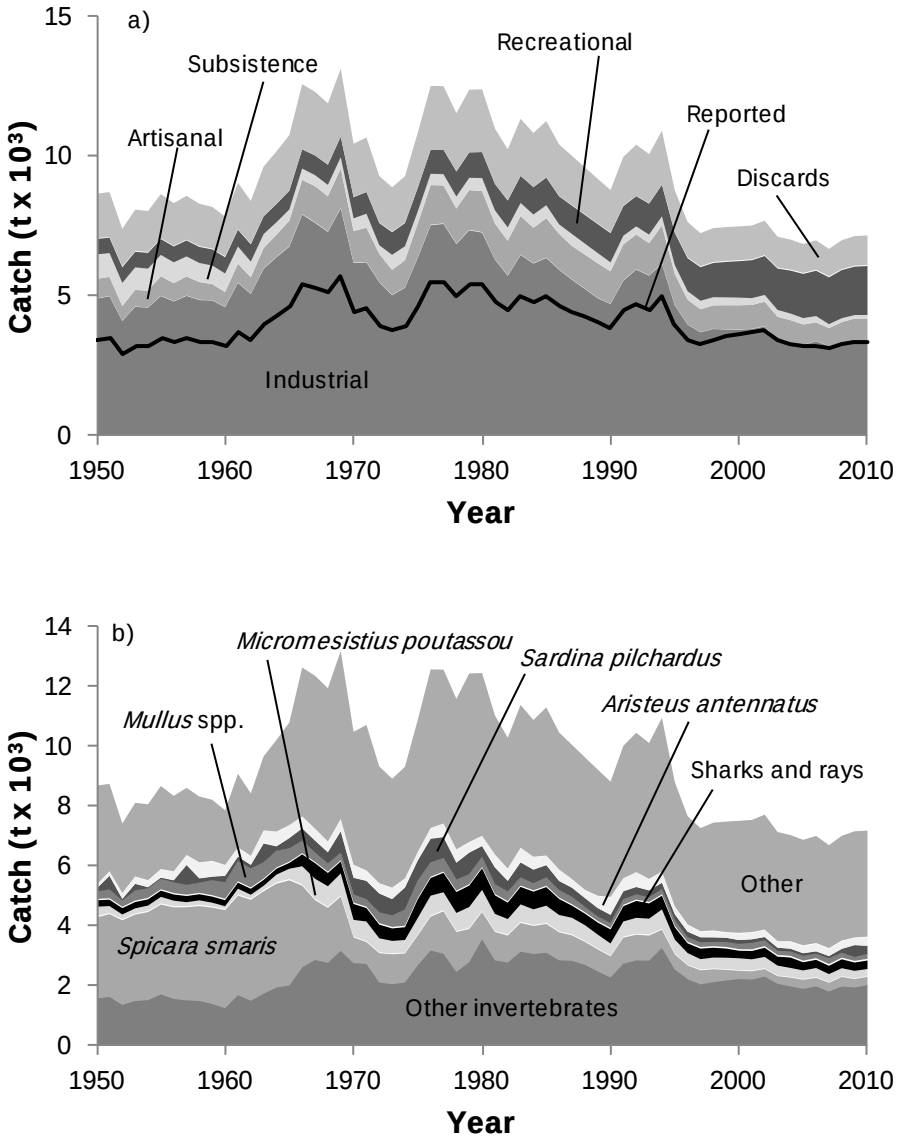


Figure 6. Total fisheries removals in the Balearic Islands (1950-2010): a) by sector with comparison to official landings (discards shown separately); b) by major taxonomic groups. "Other" contains 64 additional taxonomic groups.

Appendix Tables

Appendix Table A1. Sources of fisheries landings data in the Balearic Islands.

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Total</th><th colspan="4">Major species from the trawl fishery</th><th colspan="3">Major species from the artisanal fisheries</th></tr>
<tr><th>Red mullets</th><th>European hake</th><th>Norway lobster</th><th>Red shrimp</th><th>Spiny lobster</th><th>Transparent goby</th><th>Common dolphinfish</th></tr>
<tr><td>1950-1956</td><td rowspan="10">MAPA (1940-1972)</td><td rowspan="3">Massutí (1989)</td><td rowspan="19">Oliver (1991)</td><td rowspan="4">Anon. (1950-1970)</td><td rowspan="19">Sales notes from Palma lonja</td><td>Massutí (1958)</td><td>Anon. (1950-1970)</td><td rowspan="19">Linear interpolation from 1920 data (Anon. 1921)</td></tr>
<tr><td>1957-1961</td><td rowspan="2">Anon. (1950-1970)</td></tr>
<tr><td>1962-1964</td><td rowspan="3">Linear interpolations</td></tr>
<tr><td>1965-1966</td><td rowspan="9">Sales notes from Palma lonja</td></tr>
<tr><td>1967</td><td>Linear interpolations</td><td>Linear interpolations</td></tr>
<tr><td>1968-1969</td><td rowspan="3">Anon. (1950-1970)</td><td>Anon. (1950-1970)</td></tr>
<tr><td>1970</td><td>MAPA (1940-1972)</td><td rowspan="5">Massutí (1975)</td></tr>
<tr><td>1971</td><td>MAPA (1971-1986)</td><td>MAPA (1971-1986)</td></tr>
<tr><td>1972</td><td>Linear interpolations</td><td>Linear interpolations</td></tr>
<tr><td>1973</td><td rowspan="5">MAPA (1973-1986)</td><td>MAPA (1971-1986)</td><td>MAPA (1971-1986)</td></tr>
<tr><td>1974-1975</td><td>Linear interpolations</td><td>Linear interpolations</td></tr>
<tr><td>1976</td><td>MAPA (1971-1986)</td><td>MAPA (1971-1986)</td><td rowspan="3">Linear interpolations</td></tr>
<tr><td>1977-1979</td><td>Linear interpolations</td><td>Linear interpolations</td></tr>
<tr><td>1980</td><td>MAPA (1971-</td><td>MAPA (1971-</td></tr>
</table>

1981				1986)		1986)	Massutí (1989)	*Iglesias et al. (1994)*
1982				*Linear interpolations*		*Linear interpolations*		
1983				MAPA (1971-1986)		MAPA (1971-1986)		
1984-1985				*Linear interpolations*		*Linear interpolations*		
1986				Anon. (1971-1986)		Anon. (1971-1986)		
1987	*Linear interpolations*			Sales notes from Palma *lonja*		*Linear interpolations*		
1988							Massutí (1994)	*Massutí (1993)*
1989								
1990-1993	Massutí (1994)		Sales notes from Palma *lonja*					
1994	Massutí (1995)						*Linear interpolations*	*Lleonart et al. (1999)*
1995	DGPGIB data						Iglesias and Miquel (1998)	
1996								
1997-1998							*Linear interpolations*	*Linear interpolations*
1999-2001	*Linear interpolations*							
2002-2006	DGPGIB data	DGPGIB data		DGPGIB data	DGPGIB data	DGPGIB data	DGPGIB data	*DGPGIB data*
2007-2010			DGPGIB data					

Appendix Table A2. Anchor points or historic and anecdotal clues to develop the reconstruction of total fisheries removals in the Balearic Islands.

Anchor points	Historic or anecdotal clues	Source
1940-1965	Landings in Mallorca have a complete historical data from 1940, but its confidence has increased from the middle of 1960s.	Oliver (1983)
1950-1969	Almost all spiny lobsters from Menorca are exported to Barcelona.	Guinard and Ramis (2009)
1950-2010	Trawlers from the Spanish mainland have been fishing in the Balearic Islands waters for decades.	P. Oliver (pers. comm.)
1948	Beginning of shrimp fisheries around Mallorca island.	Massutí (1989)
1958	Beginning of shrimp fisheries around Menorca island.	Massutí (1958, 1959), Oliver (1983)
1958	Spiny lobsters are caught mainly with traps.	Massutí (1958)
1961	Beginning of the tourism development in Mallorca.	Garcia and Martorell (2007)
1965-1970s	Trawling fishing effort increases 2.5 fold because a rapid increase in vessels number, whose power also increases.	Quetglas *et al.* (2012b)
1970	Beginning of the tourism development in Menorca. Spiny lobsters are sold in the island (mainly to restaurants) and their export to Barcelona cease. The under-reporting of landings increases.	Guinard and Ramis (2009)
1970s	Trawlers catch immature hakes and sell them.	Massutí (1989)
1970-1978	Statistical landing data gap by the Palma *lonja*, covered partially by IEO.	Massutí (1989)
1976-2000	Statistical landing data by trawlers from the Spanish mainland operating around Pitiusas Islands.	Garcia (2003)
1979	Palma *lonja* reorganization, due to the start of data computerization.	Massutí (1989)
1980s	Overexploitation in species targeted by trawlers, particularly on the shelf, less so on the slope.	Oliver (1983)
1980s	Hake begins to show signs of growth overfishing, as the population increasingly consists of young individuals.	Oliver (1993), Hidalgo *et al.* (2011)
1986	Important unreported landings of spiny lobster in Mallorca.	Massutí (1989)
1986	A quota of 50-60 $kg \cdot vessel^{-1} \cdot day^{-1}$ of transparent goby is introduced, due to increasing exploitation, itself due to the high market value of transparent goby.	Iglesias and Martorell (1988)
1989	A new inspection system is created which helped report more caches of spiny lobster throughout the Palma *lonja*. Menorca is where landings are most underreported followed by the Pitiusas Islands.	Massutí (1989)
1991	This year is considered the shrimp year, with high sale values for environment reasons (not fishing reasons), as hydrographic and substrate characteristics and trophic resources.	Massutí (1994), Guijarro *et al.* (2008)
1989	The *Conselleria d'Agricultura i Pesca* create a statistical informant network throughout the secretaries of the *cofradías*.	Massutí (1994)
2000-2010	Reduction of bottom trawl fishing effort on shelf due to the its moving to greater depths.	Moranta *et al.* (2008a)
2000-2002	A study is published which evaluates the impact of recreational fishing by the local population in the Balearic Island.	Morales-Nin *et al.* (2002)

2001-2010	IEO-COB carries out the Spanish National Data Collection Program and estimates, with observers on trawl vessels, discards and landed catches that are not declared in sales notes.	E. Massutí and T. Quetglas (pers. comm.)
2002	Founding of the fish producers' organization Opmallorcamar.	Local law[1]
2003	Spiny lobster traps are phased out and this species is only fished using trammel nets.	Fishers (pers. comm.), Quetglas *et al.* (2004)
2006	Improvement in the selectivity of trawling (using square-meshed netting). Increases spiny lobster legal minimum size, from 80 mm to 90 mm.	REGULATION (EC) No 1967/2006[2]
2006-2007	Introduction of the electronic auction in the Palma *lonja.*	Maynou *et al.* (2013)
2009	A study is published which evaluates the impact of recreational fishing by tourists in the Balearic Island	Cardona (2009)
2010	Effective change to square-meshed netting in trawlers nets.	E. Massutí (pers. comm.)
Present vs. past times	Important decrease on picarel landings attributed to cultural reasons: people don't like this species nowadays.	A.M Grau and fishers (pers. comm.)

[1] Resolución del Consejero de Agricultura y Pesca de 14 de junio de 2002, por la que se reconoce a la entidad Opmallorcamar como organización de productores pesqueros.

[2] Council regulation (EC) No 1967/2006 of 21 December 2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea.

Appendix Table A3. Sources of unreported fisheries landings in the Balearic Islands. Note that areas of 'linear interpolation' may actually have been determined through assumed proportionality.

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Total</th><th colspan="4">Major species in the trawl fishery</th><th colspan="3">Major species in the artisanal fishery</th></tr>
<tr><th>Red mullets</th><th>European hake</th><th>Norway lobster</th><th>Red shrimp</th><th>Spiny lobster</th><th>Transparent goby</th><th>Common dolphinfish</th></tr>
<tr><td>1950</td><td>Informal interviews with fishers</td><td>Informal interviews with fishers</td><td>Informal interviews with fishers</td><td>Informal interviews with fishers</td><td>Informal interviews with fishers</td><td rowspan="2">Informal interviews with fishers</td><td>Informal interviews with fishers</td><td>Informal interviews with fishers</td></tr>
<tr><td>1951-1969</td><td rowspan="8">Linear interpolations</td><td rowspan="9">Linear interpolations</td><td rowspan="4">Linear interpolations</td><td rowspan="9">Linear interpolations</td><td rowspan="9">Linear interpolations</td><td rowspan="9">Linear interpolations</td><td rowspan="2">Linear interpolations</td></tr>
<tr><td>1970-1980</td><td>Linear interpolations</td></tr>
<tr><td>1981-1985</td><td rowspan="7">Massutí and Morales Nin (1991)</td></tr>
<tr><td>1986-1988</td><td>Iglesias and Martorell (1988), Iglesias et al. (1994)</td></tr>
<tr><td>1989</td><td>Oliver (1991)</td><td rowspan="6">Linear interpolations</td></tr>
<tr><td>1990-1991</td><td rowspan="4">Linear interpolations</td></tr>
<tr><td>1992-1993</td><td rowspan="3">Linear interpolations</td></tr>
<tr><td>1994</td><td>Massutí (1995)</td><td rowspan="2">Linear interpolations</td></tr>
<tr><td>1995-2000</td><td>Linear interpolations</td><td>Linear interpolations</td></tr>
<tr><td>2001-2002</td><td rowspan="3">Mean of 2009 & 2011 data from DGPGIB & informal interviews with fishers</td><td rowspan="3">Mean of Spanish National Data Collection Program cross-checked with sales notes & informal interviews with fishers</td><td rowspan="3">Mean of Spanish National Data Collection Program cross-checked with sales notes & informal interviews with fishers</td><td rowspan="3">Mean of Spanish National Data Collection Program cross-checked with sales notes & informal interviews with fishers</td><td rowspan="3">Mean of Spanish National Data Collection Program cross-checked with sales notes & informal interviews with fishers</td><td rowspan="2">Quetglas et al. (2004)</td><td rowspan="3">Assumed same unreported % as in Norway lobster</td><td rowspan="3">Informal interviews with fishers</td></tr>
<tr><td>2003-2004</td></tr>
<tr><td>2005-2010</td><td>Assumed same unreported % as Quetglas et al. (2004) as in 2004.</td></tr>
</table>

Appendix Table A4. Fishing fleet evolution in the Balearic Islands sources.						
Year	**Number of vessels**	**Sources**	**Total vessels power (hp)**	**Sources**	**Number of fishers**	**Sources**
1950	1,265	*Linear interpolations from 1940 data* (Velasco, 1992)	6,360	Massutí (1989)	4,976	We have assumed the same number of fishers per vessel than in 1960
1951	1,239		6,370		4,874	
1952	1,213		6,725		4,773	
1953	1,188		6,811		4,671	
1954	1,162		7,051		4,570	
1955	1,136		7,231		4,468	
1956	1,110		7,397		4,367	
1957	1,084		7,510		4,265	
1958	1,059		7,585		4,164	
1959	1,033		8,369		4,062	
1960	1,007	Velasco (1992)	8,507		3,961	Massutí (1989)
1961	962	*Linear interpolations*	8,674		3,640	*Linear interpolations*
1962	916		8,920		3,332	
1963	871		9,119		3,038	
1964	825		9,746		2,758	
1965	780	Velasco (1992)	10,073		2,490	
1966	825	*Linear interpolations*	10,220		2,511	
1967	869		10,658		2,518	
1968	914		11,231		2,512	
1969	958		11,231		2,492	
1970	1003	Velasco (1992)	15,619	*Linear interpolations*	2,460	
1971	1109	*Linear interpolations*	20,006	Velasco (1992)	2,556	
1972	1216		22,169	*Linear interpolations*	1,712	Massuti (1973)
1973	1322	MAPA (1971-1986)	24,332		2,844	*Linear interpolations*
1974	1175	*Linear*	26,494		2,522	

		interpolations				
1975	1027	Velasco (1992)	28,657	Velasco (1992)	2,200	
1976	1027	MAPA (1971-1986)	30,029	*Linear interpolations*	2,196	
1977	1027	*Linear interpolations*	31,400		2,191	
1978	1027		32,772		2,187	
1979	1027	MAPA (1971-1986)	34,143		2,182	
1980	1033		35,515		2,190	
1981	1040		36,886	Velasco (1992)	2,200	
1982	1050	*Linear interpolations*	38,643	*Linear interpolations*	2,217	
1983	1060	MAPA (1971-1986)	40,401		2,233	
1984	1048	*Linear interpolations*	42,158	Velasco (1992)	2,204	
1985	1037		45,679	*Linear interpolations*	2,174	
1986	1025	MAPA (1971-1986)	49,200	MAPA (1971-1986)	1,643	Velasco (1992)
1987	975	*Linear interpolations*	48,319	*Linear interpolations*	2,040	*Linear interpolations*
1988	924		47,438		1,935	
1989	874		46,556		1,829	
1990	824		45,675		1,633	Massutí (1994)
1991	773		44,794		1,634	*Linear interpolations*
1992	723	Velasco (1992)	43,913		1510	
1993	750	*Linear interpolations*	43,031		1,548	
1994	777	Massutí (1995)	42,150	Massutí (1995)	1,585	
1995	761	*Linear interpolations*	41,448	*Linear interpolations*	1,534	
1996	745		40,745		1,484	
1997	730		40,043		1,435	

1998	714		39,340		1,386	
1999	698		38,638		1,338	
2000	682	Morales-Nin *et al.* (2010)	37,935		1,291	
2001	646	*Linear interpolations*	37,233		1,207	
2002	646		36,530		1,192	
2003	646		35,828		1,176	
2004	646		35,125		1,160	
2005	646		34,423		1,144	
2006	646		33,721		1,129	
2007	430	Anon. (2010)	33,018		741	
2008	431		32,316	Data provided by MAGRAMA	732	
2009	391		32,417		692	Anon. (2009, 2010)
2010	408		29,561		673	

Appendix Table A5. Unreported landings percentages (%) (black market and subsistence fishing) anchor point years used for the catch reconstruction considering all landings, main trawl species; and main artisanal species.

<table>
<tr><th>Year</th><th>All landings</th><th>European Hake</th><th>Red shrimp</th><th>Red mullets</th><th>Norway lobster</th><th>Spiny lobster</th><th>Common dolphinfish</th><th>Transparent goby</th></tr>
<tr><td>1950</td><td>84.2</td><td>84.2</td><td>84.2</td><td>84.2</td><td>84.2</td><td rowspan="2">84.2</td><td>84.2</td><td>84.2</td></tr>
<tr><td>1951-1968</td><td rowspan="9">Linear interpolations</td><td rowspan="5">Linear interpolations</td><td rowspan="9">Linear interpolations</td><td rowspan="9">Linear interpolations</td><td rowspan="9">Linear interpolations</td><td rowspan="2">Linear interpolations</td><td rowspan="2">Linear interpolations</td><td rowspan="9">Linear interpolations</td></tr>
<tr><td>1969</td></tr>
<tr><td>1970-1980</td><td rowspan="2">Linear interpolations</td></tr>
<tr><td>1981-1985</td><td rowspan="4">40.0</td></tr>
<tr><td>1986-1988</td><td>1,709.5</td></tr>
<tr><td>1989</td><td>35.3</td><td rowspan="6">Linear interpolations</td></tr>
<tr><td>1990-1991</td><td rowspan="4"></td></tr>
<tr><td>1992-1993</td><td rowspan="3">Linear interpolations</td></tr>
<tr><td>1994</td><td>54.3</td></tr>
<tr><td>1995-2000</td><td>Linear interpolations</td></tr>
<tr><td>2001</td><td rowspan="5">29.6</td><td rowspan="5">8.4</td><td rowspan="5">21.5</td><td rowspan="5">12.1</td><td rowspan="5">13.2</td><td></td><td rowspan="5">3.8</td><td rowspan="5">13.2</td></tr>
<tr><td>2002</td><td></td></tr>
<tr><td>2003</td><td>295.8</td></tr>
<tr><td>2004</td><td>232.1</td></tr>
<tr><td>2005-2010</td><td>232.1</td></tr>
</table>

Appendix Table A6. Sources of unreported landings by major trawl species in small Balearic islands (Menorca and Pitiusas).

<table>
<tr><th rowspan="2">Year</th><th colspan="2">Red mullets</th><th colspan="2">European hake</th><th>Norway lobster</th><th>Red shrimp</th></tr>
<tr><th>Menorca</th><th>Pitiusas</th><th>Menorca</th><th>Pitiusas</th><th>Menorca</th><th>Menorca</th></tr>
<tr><td>1950-1957</td><td rowspan="5">Data included in official landings</td><td rowspan="5">Data included in official landings</td><td rowspan="11">% of landings estimated as the same than 1989</td><td rowspan="11">% of landings estimated as the same than 1989</td><td>No Norway lobster fishing (Massutí 1958, 1959)</td><td>No red shrimp fishing (Massutí 1958, 1959)</td></tr>
<tr><td>1958</td><td rowspan="10">Data included in official landings</td><td>% of landings estimated as the same than 1959</td></tr>
<tr><td>1959-1963</td><td>Difference between Balearic island estimation Fernández González (2009) and Mallorca data</td></tr>
<tr><td>1964</td><td rowspan="2">Oliver (1983)</td></tr>
<tr><td>1965-1967</td><td rowspan="2">Oliver (1983)</td><td>% of landings estimated as the same than 1968</td></tr>
<tr><td>1968</td><td rowspan="3">FAO (1980)</td></tr>
<tr><td>1969</td><td rowspan="3">% of landings estimated with Mallorca and Pitiusas landings and total landings of 1970, 1980 and 1986 (MAPA 1940-1972, 1973-1986)</td><td>Difference between Balearic island estimation Fernández González (2009) and Mallorca data</td></tr>
<tr><td>1970-1976</td><td rowspan="2">% of landings estimated as the</td></tr>
<tr><td>1977-1979</td><td>Oliver (1983)</td></tr>
</table>

<table>
<tr><td></td><td rowspan="15"></td><td rowspan="3"></td><td rowspan="15"></td><td rowspan="15"></td><td rowspan="3"></td><td>same than 1969</td></tr>
<tr><td rowspan="2">1980</td><td>% of landings estimated with Mallorca landings and total landings of 1980 (MAPA 1971-1986)</td></tr>
<tr><td rowspan="2">1981-1985</td><td rowspan="2">% of landings estimated as the same than 1980</td></tr>
<tr><td rowspan="4">1986</td><td rowspan="12">% of landings estimated with Mallorca landings and total landings of 1986 (MAPA 1971-1986)</td><td rowspan="4">% of landings estimated with Mallorca landings and total landings of 1986 (MAPA 1971-1986)</td></tr>
<tr><td rowspan="12">% of landings estimated with Mallorca landings and total landings of 1970, 1980 and 1986 (MAPA 1940-1972, 1973-1986)</td></tr>
<tr><td>1987-1988</td></tr>
<tr><td>1989</td><td>Oliver (1991)</td><td>Oliver (1991)</td></tr>
<tr><td>1990-1994</td><td rowspan="5">% of landings estimated as the same than 2007</td><td rowspan="5">% of landings estimated as the same than 2007</td><td rowspan="2">% of landings estimated as the same than 1986</td></tr>
<tr><td>1995-1996</td><td rowspan="4">% of landings estimated with Mallorca landings and total landings 2002</td></tr>
<tr><td>1997-2001</td><td rowspan="3">% of landings estimated as the same than 2002</td></tr>
<tr><td>2002-2006</td><td rowspan="2">Data included in official landings</td><td rowspan="2">Data included in official landings</td><td rowspan="2">Data included in official landings</td><td rowspan="2">Data included in official landings</td><td rowspan="2">Data included in official landings</td></tr>
<tr><td>2007-2010</td></tr>
</table>

Appendix Table A7. Sources of unreported landings by recreational fishing and Spanish mainland trawlers from GSA06.

<table>
<tr><th rowspan="2">Year</th><th colspan="2">Recreational fishing</th><th colspan="2">Mainland trawlers</th></tr>
<tr><th>Local population</th><th>Tourists</th><th>Landings</th><th>Special period</th></tr>
<tr><td>1950-1960</td><td rowspan="12">Catches related to local population (IBESTAT and Fundación BBVA, 2008) and catch estimation of 2002</td><td>Negligible catch assumed</td><td rowspan="5">Landings assumed to be the same proportion as in Balearic Islands shrimp official landing for 1976</td><td rowspan="2">-</td></tr>
<tr><td>1961</td><td>Catches related to number of tourists for this year (Garcia and Martorell 2007) and tourist catches and number of tourists for 2009</td></tr>
<tr><td>1962-1969</td><td rowspan="2"></td></tr>
<tr><td>1970</td><td rowspan="4">Landings assumed to be tree-fold because real fleet was three-fold the official data (Massuti 1973)</td></tr>
<tr><td>1971</td><td>Catches related to number of tourists for this year (Garcia and Martorell 2007) and tourist catches and number of tourists for 2009</td></tr>
<tr><td>1972-1975</td><td rowspan="2">Linear interpolations</td></tr>
<tr><td>1976-1979</td><td rowspan="5">Garcia (2003)</td></tr>
<tr><td>1980</td><td>Catches related to number of tourists for this year (Garcia and Martorell 2007) and tourist catches and number of tourists for 2009</td><td rowspan="2">Landings assumed to be two-fold because real fleet was two-fold the official data (Oliver 1983)</td></tr>
<tr><td>1981-1989</td><td rowspan="2">Linear interpolations</td></tr>
<tr><td>1990</td><td rowspan="2">-</td></tr>
<tr><td>1991</td><td>Catches related to number of tourists for this year (Garcia</td></tr>
</table>

		and Martorell 2007) and tourist catches and number of tourists for 2009		
1992-2000		*Linear interpolations*		
2001		Catches related to number of tourists for this year (Garcia and Martorell 2007) and tourist catches and number of tourists for 2009	Landings assumed to be the same proportion as in Balearic Islands shrimp official landing for 2000	
2002	Morales-Nin *et al.* (2002)			
2003	Catches related to local population and catch estimation of 2002	*Linear interpolations*		
2004-2008		Catches related to number of tourists for these years (Botín *et al.* 2010) and tourist catches and number of tourists for 2009		
2009		Cardona (2009)		
2010		Catches related to number of tourists for this year (Botín *et al.* 2010) and tourist catches and number of tourists for 2009		

Appendix Table A8. Sources of discards data in the Balearic Islands fisheries.

Trawling	Purse seine and long line	Artisanal gears
1995-1996: Carbonell *et al.* (1998) Palma de Mallorca and Alcudia	2011: informal interviews with fishers	Spiny lobster 1950 (Riutort, unpub. data in Le Manach *et al.* 2011)
1995-1996: Carbonell *et al.* (2003) Mallorca (demersal sharks)	-	Spiny lobster: Trammel net and traps (Quetglas *et al.* 2004)
1995-1996: Moranta *et al.* (2000) Palma de Mallorca	-	Transparent goby (Brunet-Quetglas 2004; La Mesa *et al.* 2005)
2001: Martin *et al.* (2001) Palma de Mallorca	-	2011: informal interviews with fishers
2002-2003: Ordines *et al.* (2006) Mallorca	-	-
2002-2003: Massutí *et al.* (2005)	-	-
2001-2010: results of Spanish National Data Collection Program carried out by IEO-COB	-	-
2011: informal interviews with fishers	-	-

Appendix Table A9. Sources of discards by major species in the Balearic Islands fisheries.

<table>
<tr><th rowspan="2">Year</th><th colspan="4">Major species in the trawl fishery</th><th colspan="3">Major species in the artisanal fisheries</th></tr>
<tr><th>Red mullets</th><th>European hake</th><th>Norway lobster</th><th>Red shrimp</th><th>Spiny lobster</th><th>Transparent goby</th><th>Common dolphinfish</th></tr>
<tr><td>1950</td><td rowspan="4">Assumed: the same % than in 2001-2010</td><td>Assumed: a third of the discard rate in 2001-2010</td><td rowspan="4">Assumed: the same % than in 2001-2010</td><td rowspan="4">Assumed the same % than in 2001-2010</td><td>Assumed: the same as Riutort (unpubl. data in Le Manach et al. 2011)</td><td rowspan="4">We have assumed the same % than in 2001-2010</td><td rowspan="4">We have assumed the same % than in 2001-2010</td></tr>
<tr><td>1951-1979</td><td>Linear interpolations</td><td rowspan="3">Linear interpolations</td></tr>
<tr><td>1980</td><td>Assumed: a half of the discard rate in 2001-2010</td></tr>
<tr><td>1981-2000</td><td>Linear interpolations</td></tr>
<tr><td>2001-2010</td><td>Spanish National Data Collection Program carried out by IEO-COB</td><td>Spanish National Data Collection Program carried out by IEO-COB, confirmed by (Martin et al. 2001)</td><td>Spanish National Data Collection Program carried out by IEO-COB, confirmed by Carbonell et al. (1998)</td><td>Spanish National Data Collection Program carried out by IEO-COB, confirmed by Carbonell et al. (1998)</td><td>Assumed % of individuals damaged by trammelnets as estimated by Quetglas et al. (2004)</td><td>Discard % from informal interviews with fishers and literature</td><td>Discard % from informal interviews with fishers</td></tr>
</table>

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