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Elise Bultel, Didier Gascuel, Frédéric Le Manach,  
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Email: [elise.bultel@gmail.com](mailto:elise.bultel@gmail.com)

## Catch reconstruction for the French Atlantic coast, 1950-2010

Elise Bultel<sup>a</sup>, Didier Gascuel<sup>b</sup>, Frédéric Le Manach<sup>a,c</sup>, Daniel Pauly<sup>a</sup> and Kyrstn Zylich<sup>a</sup>

<sup>a</sup>*Sea Around Us Project, Fisheries Centre, University of British Columbia,  
2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada*

<sup>b</sup>*Université Européenne de Bretagne, UMR ESE 985, INRA – Agrocampus Ouest,  
65 rue de St Briec, CS 84215, 35042 Rennes, France*

<sup>c</sup>*Institut de Recherche pour le Développement; UMR212 Ecosystèmes Marins Exploités;  
Avenue Jean Monnet, BP 171, Sète cedex 34203, France*

[elise.bultel@gmail.com](mailto:elise.bultel@gmail.com); [didier.gascuel@agrocampus-ouest.fr](mailto:didier.gascuel@agrocampus-ouest.fr); [f.lemanach@fisheries.ubc.ca](mailto:f.lemanach@fisheries.ubc.ca); [d.pauly@fisheries.ubc.ca](mailto:d.pauly@fisheries.ubc.ca); [k.zylich@fisheries.ubc.ca](mailto:k.zylich@fisheries.ubc.ca)

### ABSTRACT

Catch statistics of France's Atlantic fisheries, from the English Channel in the North to the Gulf of Gascony in the South, were improved for the 1950-2010 time-period using a catch reconstruction approach. This produced an estimate of total fisheries catches for all industrial, artisanal and recreational sectors - including associated discards - of 11.3 million t in the EEZ, i.e., 1.5 times the official data reported to ICES, which was deemed to be caught inside the EEZ (i.e., 7.4 million t). Major landed taxa were Clupeidae (12%), Gadidae (11%), marine Crustacea (8%) and Bivalvia, Pectinidae and Merlucciidae (7% each). The industrial sector was the major component within the French Atlantic coast EEZ (51% of the total catch), while the artisanal and recreational sectors were estimated to contribute 44% and 5%, respectively.

### INTRODUCTION

France is the third largest fishing country in Europe in terms of value of the official landings, after Spain and Italy (Daurès *et al.* 2011). The French fleet operating in the Northeastern Atlantic, the English Channel and the North Sea represents over 70% of the national mainland fleet in terms of vessels and almost 80% in terms of fishers (Daurès *et al.* 2011).

The French Northeast Atlantic area, which belongs to the Food and Agriculture Organization of the United Nations' (FAO) fishing area 27, extends from the border with Spain in the south to the border with Belgium in the north (Fig. 1). It is characterized by a wide continental shelf covering over half of the 246,000 km<sup>2</sup> Exclusive Economic Zone (EEZ; [www.seaaroundus.org](http://www.seaaroundus.org)).<sup>1</sup>

Overall, the number of fishing vessels in France has declined more than fourfold since the late 1940s, but the power of their engine has increased by a factor of five between the early 1950s and the late 1980s, which, along with other technical improvement, has led to increased fishing efficiency of the fleet (IFREMER *et al.* 2009; Guénette and Gascuel 2012). The French fleet is described as mostly coastal (71%), with the two main gears being nets and trawls (IFREMER *et al.* 2009). Reported catches increased from the post WWII area until the 1970s, then plateaued and started to decrease in 2003 in terms of weight and value (IFREMER *et al.* 2009). However, these data include tropical tuna catches, without which a significant decrease occurs between the mid-1970s and the late 1990s (about 100,000 t). Moreover, substantial catches remain underreported, notably from artisanal fisheries, which are known to sell part of their catch through unmonitored direct sales (Fontaine and Seck 1987; Bolopion *et al.* 2000; Anon. 2010). Also, national fisheries statistics do not include discards or recreational catches.

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<sup>1</sup> The Atlantic EEZ of France was declared in 1977. See [https://www.un.org/depts/los/LEGISLATIONANDTREATIES/PDFFILES/FRA\\_1977\\_Decree.pdf](https://www.un.org/depts/los/LEGISLATIONANDTREATIES/PDFFILES/FRA_1977_Decree.pdf)

Based on concepts presented by Pauly (1998) and implemented via a methodology developed in Zeller *et al.* (2007), Zeller and Pauly (2007) and later applied worldwide (e.g., by Zeller and Harper (2009), Harper and Zeller (2012), and Harper *et al.* (2012)), this report aims to reconstruct total marine fishery removals by the French mainland fishers and fleets, within and outside the French EEZ along the French Atlantic coast. It is hoped that this reconstruction will improve catch data baselines and inform appropriate management measures.

## METHODS

### *Baseline data*

Baseline catch data for marine fisheries from 1950 to 2010 were extracted from ICES (International Council for the Exploration of the Sea) Historical Nominal Catches (1950-2010) dataset.<sup>2</sup> Catches related to the taxa not considered in this study were removed, i.e., seaweeds, freshwater fishes, mammals and aquatic plants. Furthermore, catches related to the taxa listed in ICCAT data were also removed from the baseline (i.e., Scombridae, Istiophoridae, Xiphiidae and sharks), as these were treated separately as part of a worldwide reconstruction of tuna, billfishes and associated catches by the *Sea Around Us* (Le Manach *et al.* in press). Catch data from the Food and Agriculture Organization of the United Nations (FAO) was also extracted for comparison purposes.

Additionally, the catch of blue mussels, Pacific cupped and European flat oysters reported to ICES were extremely variable and appeared to be very similar to that of aquaculture production prior to 1984 (Fig. 2). For these species, the following adjustments were performed:

- For blue mussels, the catch reported to ICES was used as is after 1984, as they appeared to be substantially different from the aquaculture data and very similar to the ones reports to FAO (Fig. 2). However, no ICES data were available in 2007 and 2008, so we interpolated the percentages of the ICES area allocation between 2006 and 2009 and applied them to the FAO catch. From 1950 to 1983, where catches were much higher than for the later period and close to FAO aquaculture production data, we estimated the marine catch by applying the average 1984-2010 ICES reported data/FAO aquaculture ratio to the total data reported to ICES between 1950 and 1983. We calculated the average ICES area allocation percentages from 1984 to 1993 and applied it to the newly estimated catch;
- For Pacific cupped and European oysters, the data from 1984 onward was kept as is (very small catches) and no reconstruction was done as the amount would have been negligible.

As a result, most of the catch for these species before 1984 was re-allocated to aquaculture, instead of marine wild capture fisheries.

For the other taxa, annual catches were available by ICES Division, whose geographical precision greatly varied. For catches simply reported as belonging to 'ICES Area', we considered that they came from outside the EEZ, except for 1999 which only contained catch from 'ICES Area'. A strike occurred that year in the France's fisheries statistical office which prevented the catch to be reported by ICES divisions (Guénette and Gascuel 2012). For this year, we interpolated the ICES allocation percentages by taxa between 1998 and 2000 and applied them to the total taxa catch. Then, the catches from divisions which did not overlap with the French EEZ were allocated outside the EEZ. Finally, catches from divisions overlapping the French EEZ were allocated within or outside the EEZ, using the following approach:

- Firstly, we considered that fishing was homogeneous throughout the divisions for the 1980-2010 period. Thus, we split the catch proportionately to the percentage of EEZ surface area within each division (the rest being allocated to outside the EEZ);

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<sup>2</sup> <http://www.ices.dk/marine-data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx> [Version 30-11-2011 of the 'Historical Nominal Catches 1950-2010' dataset utilized]

- Secondly, we assumed that 100% of the catch was taken inside the EEZ in 1950 and linearly decreased to the level reached in 1980 for each division. However, many fishing vessels were already fishing far away from the shore in the 1950s in the Celtic Sea and North Sea divisions (i.e., division VII + subdivision VII a-k and division IV + subdivisions IV a-c, respectively; D. Gascuel, unpublished data). Thus, the split between 'within EEZ' and 'outside EEZ' was done differently: for the Celtic Sea, we considered that only 2/3 of the catch (i.e., 67%) was taken inside the EEZ in 1950; for the North Sea, since the estimated catch inside the EEZ was only 1% in 1980, we assumed that it was the same throughout the time-period.

In addition, all catches of Bivalvia (notably Pectinidae) and Echinodermata (sea urchins) were assigned exclusively to the EEZ. Indeed, less than 0.1% of their total catch came from divisions exclusively outside the EEZ and we considered it was unlikely that these catches came from the High Seas at all given the gears generally used to target such taxa (i.e., mostly small dragged gear). Catches from within the EEZ and outside the EEZ are analyzed separately in this report.

## **French catch within the EEZ**

### *Gear allocation of taxon-specific catch*

Information on the French fishing fleet of the Atlantic, English Channel and North Sea was available from reports published by the *Système d'Informations Halieutiques* (SIH; Fisheries Information System), based on data collected from 2006 to 2010 (Leblond *et al.* 2008; Leblond *et al.* 2009; Leblond *et al.* 2010; Leblond *et al.* 2011; Leblond *et al.* 2012). SIH reported 12 fleet types, which we grouped in nine gear types: trawls, nets, longlines, seines, mixed gear, small dragged gear, fyke nets with rings, other small gear and divers (Table 1).

The likelihood of a taxon to be targeted by a particular gear was then assumed based on the species reported in the English Channel by the 'Fisheries Atlas'<sup>3</sup>, the reviews performed by the SIH on the English Channel, North Sea and Atlantic's fleets<sup>45</sup> (Leblond *et al.* 2012) and the study carried out by IFREMER on French fisheries' discards, which also described the different fleet types and targeted species (Guéroux *et al.* 2010). When a reported taxon was not mentioned in these studies, we based our decision on information found in the FAO Species Identification sheets (Ebert and Stehmann 2013), a report on Mediterranean small-scale fisheries (Guillou *et al.* 2002), or habitat descriptions found in FishBase ([www.fishbase.org](http://www.fishbase.org)). For the entire time-period, the catch of a given taxon was then equally allocated to each gear assumed to be catching it, except for '*métiers de l'appât*' (mixed gear) and '*plongée sous-marine*' (divers), for which we only allocated 5% of the total catch, because of the low catch for '*métiers de l'appât*' and the low catch efficiency for '*plongée sous-marine*' compared to the other gear types.

### *Sectorial allocation of gear types (industrial and artisanal)*

Once catches were allocated to gear types, they were further assigned to either the industrial or artisanal sector. A fishing gear was considered to be used by the industrial sector (i.e., large-scale) if it involved an active type of fishing (Martín 2012), e.g., was towed from a boat such as a trawler. Thus, a fishing gear was considered to belong to the artisanal sector (i.e., small-scale), if only passive fishing methods were used, e.g., fyke nets and other small gears. For fishing nets, longlines, '*casier*' and '*drague*', which greatly vary in terms of size and use, we assumed an equal allocation to both sectors. However, since '*tamis*' are only used to catch glass eel and operate very locally without scraping the bottom, they were considered here as exclusively artisanal. Finally, '*métiers de l'appât*' was labelled as mixed gear since the targeted species (mainly sand lances and shrimps) are targeted by '*chalut*'<sup>6</sup>, '*drague*'<sup>6</sup>, '*senne*' and '*casier*' (D. Gascuel, unpublished data). This category was allocated equally among both sectors.

<sup>3</sup> [http://sirs.agrocampus-ouest.fr/CHARM\\_V2/index.php](http://sirs.agrocampus-ouest.fr/CHARM_V2/index.php)

<sup>4</sup> <http://sih.ifremer.fr/Publications/Syntheses/Synthese-des-flottilles-de-peche/2011/Atlantique>

<sup>5</sup> <http://sih.ifremer.fr/Publications/Syntheses/Synthese-des-flottilles-de-peche/2011/Mer-du-Nord-Manche>

<sup>6</sup> [http://sih.ifremer.fr/content/download/8916/60254/file/FICH\\_FLOTTILLE\\_2009\\_ZAT\\_51\\_AT\\_2\\_2011\\_11.pdf](http://sih.ifremer.fr/content/download/8916/60254/file/FICH_FLOTTILLE_2009_ZAT_51_AT_2_2011_11.pdf)

**Table 1:** Sectorial allocation (%) of reported catches per gear type from 1950 to 2010.

<i>Gear (French)</i>	<i>Gear (English)</i>	<i>Sector</i>	
		<i>Industrial</i>	<i>Artisanal</i>
<i>Chalut</i>	Trawls	100	0
<i>Filet</i>	Nets	50	50
<i>Drague</i>	Small dragged gear	50	50
<i>Tamis</i>	Other small gear	0	100
<i>Métiers de l'appât</i>	Mixed gear	50	50
<i>Verveux</i>	Fyke nets with rings	0	100
<i>Plongée sous-marine</i>	Divers	0	100
<i>Rivage</i>	Other small gear	0	100
<i>Casier</i>	Other small gear	50	50
<i>Palangre</i>	Longlines	50	50
<i>Ligne à main</i>	Other small gear	0	100
<i>Senne</i>	Seines	100	0

### *Unreported catches*

Once the reported baseline was established and catches were allocated to gears and sectors, unreported catches were estimated. As a general rule, landings from the artisanal fleets are known only in part, because of unmonitored direct sales (Fontaine and Seck 1987; Bolopion *et al.* 2000). Also, the limited facilities at landing sites, especially along the English Channel, and numerous points of sale located far away from fish markets on the Atlantic coast can lead to bias in catch statements (Bolopion *et al.* 2000), i.e., to underestimation of artisanal landings. Moreover, a recent official report underlined that there are financial incentives that may result in under-reporting, as subsidies are provided to fishers who do not sell their catch at official auctions (Anon. 2010). Therefore, we considered that the unreported artisanal data accounted for half of the reported catch of the artisanal sector for the 1950-1980 period. However, since controls and sanctions have increased in the recent decades, we considered that only a third of the artisanal reported tonnages was unreported in 2010 and from 1981 to 2009, we applied the interpolated ratio.

### *Discards*

Discard data were available from a study on the French fleet in different fishing areas (Guérineau *et al.* 2010). For nets and trawls, we used the average discard rate in these different areas in order to obtain a discard rate per gear. Longline, traps and dredges were considered to produce negligible discards (Morizur *et al.* 1996; Guérineau *et al.* 2010), but are reported to be efficient, especially dredges for invertebrates (Kelleher 2005). Thus, for longlines, we used the average data from the aforementioned synthesis (Guérineau *et al.* 2010) and from a study on discards in the French ICES areas VII and VIII (Melnychuck *et al.* 2001). The discard rate for seines was also obtained from the latter study. For small dragged gear (including dredges), we used the Italian discard rate published by Vassilopoulou (2012), as we did not find any specific values for France. Divers, other small gear and fyke nets with rings were considered to generate no discards, as the targeted species are generally caught more selectively and/or are released in good condition. Lastly, for mixed gear, we used the same discard rate as trawls as most of the catch is likely to come from their activity.

Then, we used the taxa reported as usually discarded for trawls and nets in Guérineau *et al.* (2010) to allocate the discarded catch calculated estimated above. Higher percentages were applied to the taxa which were reported as constituting most of the discards in terms of weight (i.e., for trawls and mixed gear, the 7 following taxa were allocated 7% of the discard catches each – Osmeriformes, Carangidae, marine Crustacea, Gadidae, Macrouridae, Merlucciidae and Pleuronectidae – and the 15 others, 3.4% each, in order to attain 100%. For nets, the 3 following taxa were allocated 16% of the net's discard catch each – marine Crustacea, Gadidae and Pleuronectidae – and the 16 remaining taxa 3.25% each, in order to reach 100%. However, we realize that not all discarded taxa are accounted for, since we focused on the major discarded taxa. As for the other gears, discarded percentages were equally distributed among the taxa likely to be caught.

## Recreational sector

Recreational fishing in France is defined as non-commercial fishing for consumption purposes (Pawson *et al.* 2008) and thus includes what may otherwise be called subsistence fishing. As such, subsistence fisheries consist in sharing and consuming caught fish (or other marine resources) directly with the family and kin of the fishers ([www.fao.org/fishery/topic/12306/en](http://www.fao.org/fishery/topic/12306/en)). However, recreational fishing is also further defined as motivated by fun, pleasure or sport, and not by a dependence on fish for food (Gaudin and De Young 2007), which would exclude subsistence fishing. Nevertheless, Pawson *et al.* (2008) explained that the term subsistence fishing in France is based more on the “cultural” element of traditional fishing activities rather than on the survival aspect, and most of the hand-picking activities on the exposed intertidal are documented to be traditional and recreational (Lagenette 2001). Moreover, France being a rich country, true subsistence fishing to complement available food supply should be small to non-existent. Therefore, cultural subsistence fishing, widely carried out on the French Atlantic coasts, is included as part of recreational fishing. Another methodology was applied to the French Mediterranean catch (Pauly *et al.* 2014; Bultel *et al.* 2015) in order to fit the local situation.

Quantifying recreational fishing in French marine waters is difficult because this activity does not require a permit, unlike freshwater recreational fishing, leading to few available data (Bolopion *et al.* 2000; Levrel 2011). However, it is known that this sector contributes substantial catches, and that Atlantic shores have the highest concentration of occasional and regular recreational fishers in France (Levrel 2011).

Our reconstruction is mainly based on one set of studies carried out between 2006 and 2008 (Levrel *et al.* 2009; Levrel 2011; Herfaut *et al.* 2013). These studies were based on a combination of phone and on-site surveys about leisure fishing habits, taking into account handpicking, shore fishing, spearfishing and line fishing, and conducted in collaboration with the French Research Institute for the Exploitation of the Sea (IFREMER) and a market research institute (BVA). A total of 15,000 households were surveyed and their results were scaled up to be representative of the entire country. Results show that 5.1% of the metropolitan French population beyond 15 years of age is fishing recreationally, i.e., there are 2.45 million recreational fishers in France. An overwhelming majority of these recreational fishers are males between 25 and 64 years of age, who actively fish 13 weeks per year on average. It also appears that most fisher live in the coastal area (Levrel *et al.* 2009).

These studies, which documented that most fishers feel that the marine resources have been declining over the past years, also yielded evidence that the French recreational fishery has been rapidly expanding for the last 30 years, and is currently catching around 24,000 t of fish·year<sup>-1</sup>, as well as 5,200 t·year<sup>-1</sup> of Mollusca, Crustacea and Cephalopoda (Herfaut *et al.* 2013). Out of these totals, two third are estimated to be caught outside of the French Mediterranean Sea, i.e., along the Atlantic coast (Levrel 2011). The most targeted species are seabass (*Dicentrarchus labrax*), Atlantic mackerel (*Scomber scombrus*), and various species of Sparidae and Gadidae (e.g., *Sparus* spp., *Pagrus* spp., *Diplodus* spp., *Pollachius* spp.) (Levrel *et al.* 2009; Levrel 2011; Herfaut *et al.* 2013), although Mugilidae, Carangidae, Sciaenidae and Clupeidae make up most of the recreational catch in terms of abundance in the South Atlantic (Morandeau 2009, 2011a, 2011b, 2011c, 2012). Sepiidae, Labridae, Triglidae and Soleidae are also reported to be commonly caught by recreational fishers in Morbihan (Peronnet *et al.* 2003). All these species were already reported in 1912 by Cunisset-Carnot (1912) as recreational catches.

In spite of this century-old tradition, we considered that the recreational sector truly started to take off in 1976 (i.e., 30 years before the 2006 study), and that the ratio of recreational fishers in 1976 was 1/4<sup>th</sup> of that in 2006, i.e., 0.01. We also considered that this ratio had only doubled between 1950 and 1975 (i.e., although growing previously, the sector only expanded after 1975). Furthermore, we considered that the catch per unit of effort in 1976 was twice that of 2006 (and following years), and stable prior to that, as fishers have been noticing a decline in fish per unit of effort.

For the taxonomic breakdown, we allocated 70% of the total catch to the most reported families (Moronidae, Scombridae, Sparidae, Gadidae, Mugilidae, Carangidae, and Sciaenidae) and distributed the remaining percentage equally among the other families (i.e., Clupeidae, Sepiidae, Labridae, Triglidae, Soleidae), as well as a ‘marine fishes’ category.

For the non-fish catch, we allocated 5% to Echinodermata, i.e. sea urchins (Nadaud 1955) and the proportions given by Levrel (2011) to the remaining 95%, i.e., Bivalvia and Gastropoda (36%), marine Crustacea (30%), and Cephalopoda (29%).

In the context of the *Sea Around Us* database, where 'subsistence' fishing is kept separate from recreational fishing, we suggest that 50% of the recreational catch presented here should be allocated to line fishing, as well as other forms of sport fishing, and the other half to 'subsistence'.

### **French catch from outside the EEZ**

As described in the 'Baseline data' section, we allocated the reported catches within and outside the French EEZ depending on the ICES areas they were reported in. However, the gear allocation for catches outside the EEZ was performed differently. Indeed, we divided the catch among the four gears thought to represent classes in which High Seas vessels are dominant in the area, i.e., trawls, longlines, seines and nets (Le Guilloux and Pauly 2010). Furthermore, all catches were considered to be industrial (i.e., artisanal fishing is restricted to the EEZ, i.e., near-shore areas).

### **Tunas**

The baseline for 'Tunas' (containing Scombridae, swordfish and shark catches) came from the data published by ICCAT, as their taxonomic resolution was better than the more generic FishStat data. These data were treated and will be published separately (Le Manach *et al.* in press).

## **RESULTS**

### **Inside the EEZ**

#### *Industrial catch – landings, unreported catch and discards*

Industrial total catches for the 1950-2010 period amounted to almost 5.8 million t. Catches were close to 70,000 t·year<sup>-1</sup> in the early 1950s and increased throughout the time period to reach 123,000 t in 2010 with a substantial drop in 1982 to 63,000 t (Fig. 3a; Appendix 1).

Unreported catch consisted of Bivalvia only and occurred mostly in the two first decades where they averaged almost 570 t·year<sup>-1</sup> and then 1,500 t·year<sup>-1</sup> in 2007 and 2008.

The major taxa caught in the industrial landings were Clupeidae (16%), Gadidae (11%), Merlucciidae (9%), as well as Engraulidae (8%). The remaining catch represented 56% and included 49 other taxa.

Overall, the discards followed the same trend as the total catch (due to the methodology used here). They amounted to about 1.3 million t and mostly consisted of Gadidae, marine Crustacea and Pleuronectidae (7% each), as well as Osmeriformes, Carangidae and Elasmobranchii (5% each). The remaining catch (63%) included 21 other taxa.

#### *Artisanal catches – landings, unreported catch and discards*

Artisanal landings and unreported catches amounted to almost 5 million t over the whole time period. Their evolution over the time-period is quite similar to that of industrial catch. The first two decades were stable in terms of catch with an average of about 54,000 t·year<sup>-1</sup> before the catch increased and almost doubled in the 2000s, with a significant drop to 67,800 t in 1981 (Fig. 3a; Appendix 1). However, the catch in the 1990s had mostly a declining trend.

The artisanal landings added up to 4.2 million t and were mostly composed of the following taxa: Clupeidae and Gadidae (12% each), Pectinidae, marine Crustacea, and Bivalvia (11% each), as well as Merlucciidae (7%) and Congridae (5%). The remaining taxa (36) constituted 41% of the total catch.

The artisanal discards catch amounted to 748,000 t and were mostly composed of Gadidae (9%), marine Crustacea and Pleuronectidae (8% each), as well as Soleidae (6%) and Elasmobranchii (5%). The remaining taxa (22) represented 64% of the total discards.

### *Recreational catches*

Recreational catches amounted to almost 600,000 t from 1950 to 2010. They represented about 3,000 t-year<sup>-1</sup> in the early 1950s and increased to reach 20,000 t in 2010 (Fig. 3a; Appendix 1). They were mainly composed of Carangidae, Gadidae, Moronidae, Mugilidae, Sciaenidae, Scombridae and Sparidae (9% each), with 11 taxa accounting for the remaining 36% of catch.

### *Overall*

Within the EEZ, French catch evolved similarly to artisanal and industrial catch but started in 1950s at almost 127,000 t and reached 247,000 t in 2010 (Fig. 3a). The main taxa represented were Clupeidae (12%), Gadidae (11%), marine Crustacea (8%), as well as Bivalvia, Pectinidae and Merlucciidae (7% each), with 51 taxa accounting for the remaining 48% (Fig. 3b).

### **Outside the EEZ**

All catches were considered to be industrial outside the French EEZ and their landings amounted to 17 million t from 1950 to 2010, with FAO Area 27. In 1950, they represented 125,000 t and increased until they reached their highest catch in 1973 at nearly 500,000 t (Appendix 2). Since then, they gradually decreased to reach 151,000 t in 2010. Discards amounted to about 3.4 million t over the whole study period and followed a trend similar to that of the total catch.

Most of the catch outside the EEZ was made up by Gadidae (42%), Clupeidae (10%), Merlucciidae and marine Crustacea (5% each) with 51 other taxa representing 39% of the remaining catch (Appendix 4).

### **Overall**

The French catches from the total FAO 27 area showed a similar trend to that of the catches outside the French EEZ. Indeed, catches started at nearly 252,000 t in 1950 and peaked at 678,000 in 1973 before they decreased to 398,000 t in 2010 (Fig. 4). The taxonomic composition was also characterised by Gadidae (29%), Clupeidae (11%), marine Crustacea (6%) and Merlucciidae (5%). The remaining 48% were constituted by 54 other taxa.

## DISCUSSION

This report is a first attempt to estimate the total marine fishery catches for the French Atlantic coast by combining reported data with estimates of unreported catches (including discards) for all fisheries sectors, to improve national data reported to ICES (as well as the FAO) from 1950 to 2010 based on independent estimates. The reconstructed catch from the French fisheries within and outside the EEZ is 1.3 times the official data (i.e., 28 million t vs 21 million t), which shows the discrepancy between the reported catch and the amount of marine taxa likely removed from the sea. Of the total reconstructed catch, unreported industrial catches, unreported artisanal catches and recreational catches represented 16% (almost all discards), 7% (2.6% discards, 4.6% unreported catch) and 2%, respectively. Predominant taxa in the overall catch were Gadidae (29%), Clupeidae (11%), marine Crustacea (6%) and Merlucciidae (5%).

Within the EEZ only, the situation was quite similar since the estimate of total fisheries catches for all sectors added up to 11.3 million t in the EEZ, which is 1.5 times the official data reported to the ICES and assumed (i.e., 7.4 million t). Major landed taxa were Clupeidae (12%), Gadidae (11%), marine Crustacea (8%), Bivalvia, Pectinidae and Merlucciidae (7% each). Within the EEZ, the industrial sector was also the major component of this marine fisheries catch reconstruction for the French Atlantic coast (51% of the total catch), while the artisanal and recreational sectors were estimated to contribute 44% and 5%, respectively.



The disparity between the quality of data on artisanal versus industrial fisheries is common throughout the world, as many countries have not even begun to comprehensively account for their artisanal fishing sector. This sector is only partially monitored in France (Fontaine and Seck 1987; Bolopion *et al.* 2000), and due to incentives to under-report, its catch is higher than what is reported. In this study we estimated that this sector represented 86% of the industrial sector in terms of tonnages within the EEZ.

The main estimated taxa caught are consistent with the fact that trawls contributed to 2/3 of the catch in 2008 (Bivalvia, Gadidae, Clupeidae, marine Crustacea, Merlucciidae), as described in IFREMER *et al.* (2009). However, while this report stated that French catches were mostly coastal, we found that catches outside the EEZ were 1.5 times larger than the catch within the EEZ (17 million vs 11.3 million t). This is largely due to the catches taken in the North Sea, a traditional fishing area for France, even though it does not belong to the French EEZ.

Overall, the French Northeast Atlantic fisheries show a declining trend since the early 1970s, when a maximum of 678,000 t was attained in 1973 before declining to 398,000 t in 2010. This trend is similar to the one observed for fish stock biomass, which has been shown to have declined by 80% since the industrialization of fisheries (Cardinale *et al.* 2012; Gascuel *et al.* In press). Le Gall (1949) had already reported a distinct depletion of fish stocks on the European continental shelf and, nowadays, it is acknowledged that many fish stocks are overexploited by the French fisheries (IFREMER *et al.* 2009). If catches seem to have remained at the same level over the last 30 years, it is not because of the sustainability of the fisheries, but on the contrary, because of increases of fishing pressure (i.e., fishing effort) and changes in species composition and fishing grounds (Guénette and Gascuel 2012).

Interestingly, the catch inside the EEZ remained stable in the 1960s, and even declined in the 1970s due to the decrease in Clupeidae catch (Binet 1986), which suggests that the increase in catch between 1950 and 1970 mostly occurred outside of the EEZ, probably as a result of the development of subsidized industrial fisheries at the time (Mesnil 2008).

On the other hand, the recreational catch did not show the same declining trend, probably because participation in this sector is still growing, which may have masked the declining catch per unit of effort noticed by many surveyed fishers (Levrel *et al.* 2009). Noteworthy, Herfaut *et al.* (2013) noted that the recreational sector may represent a major part of the total catch for some species, e.g., equivalent to the commercial landing of European sea bass, and 19% and 44% of the landing of Atlantic mackerel and sea bream, respectively. Compared to Le Goff *et al.* (2012), who reported recreational catch for the entire French mainland in 2011, our estimate of Mollusca and marine Crustacea catches are lower (525 t in 2010 vs 1000 t for Crustacea and 315 t in 2010 vs 4800 t). However, for Echinodermata and Cephalopoda, the estimates are quite close.

It is also noteworthy to state that we did not estimate bycatch and bait catches related to recreational fisheries. However, these could constitute significant amounts in handlines and the fisheries using bait, and should be monitored (Gaudin and De Young 2007).

Also, our discard allocation was done by gear type and not by fleet type, and more specific work could be done at a larger scale, i.e., at the regional scale with the fleet information provided. Since the ICES data did not allow us to link the catch directly to the fleet type, we assumed it would be simpler to allocate the catch among gear types reported in French fleets and then estimate the discard species and rates using approximations calculated from fleet-type data.

We believe that our reconstructed catch estimates for the French North Atlantic marine fisheries provide a more comprehensive, yet conservative, baseline of total fishery removals for the 1950-2010 period, notably since it identified major discrepancies between the reported catch and independent estimates and anecdotal evidence about all fisheries sectors. We hope that these preliminary estimates will be improved by focusing on the aforementioned weaknesses, and that they will serve as a basis of future management decisions accounting for all sectors, and therefore reducing the impact we have on the marine resources.

## ACKNOWLEDGEMENTS

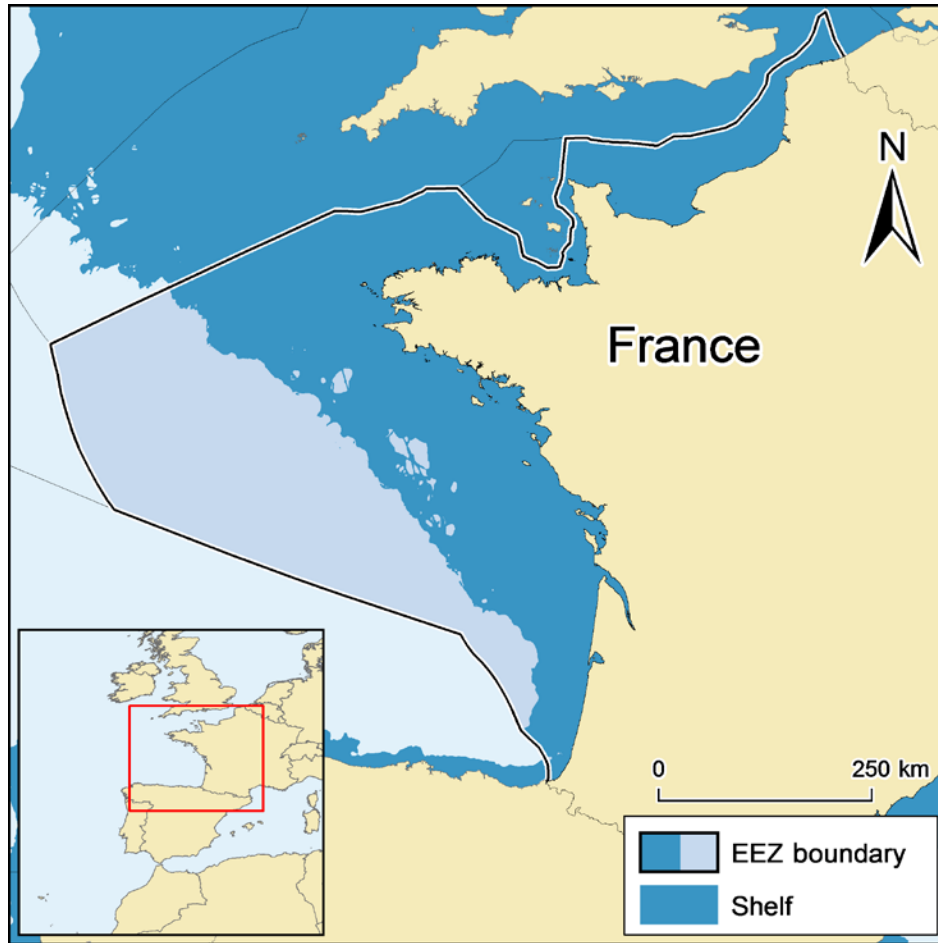
We acknowledge the support of the *Sea Around Us*, a scientific collaboration between the University of British Columbia and The Pew Charitable Trusts. We are also grateful to Jérôme Guitton (AgroCampus), Christopher Hoornaert (*Sea Around Us*), Céline Vignot (IFREMER), Amelia Curd (IFREMER) and Emilie Leblond (IFREMER) for their help during the reconstruction process.

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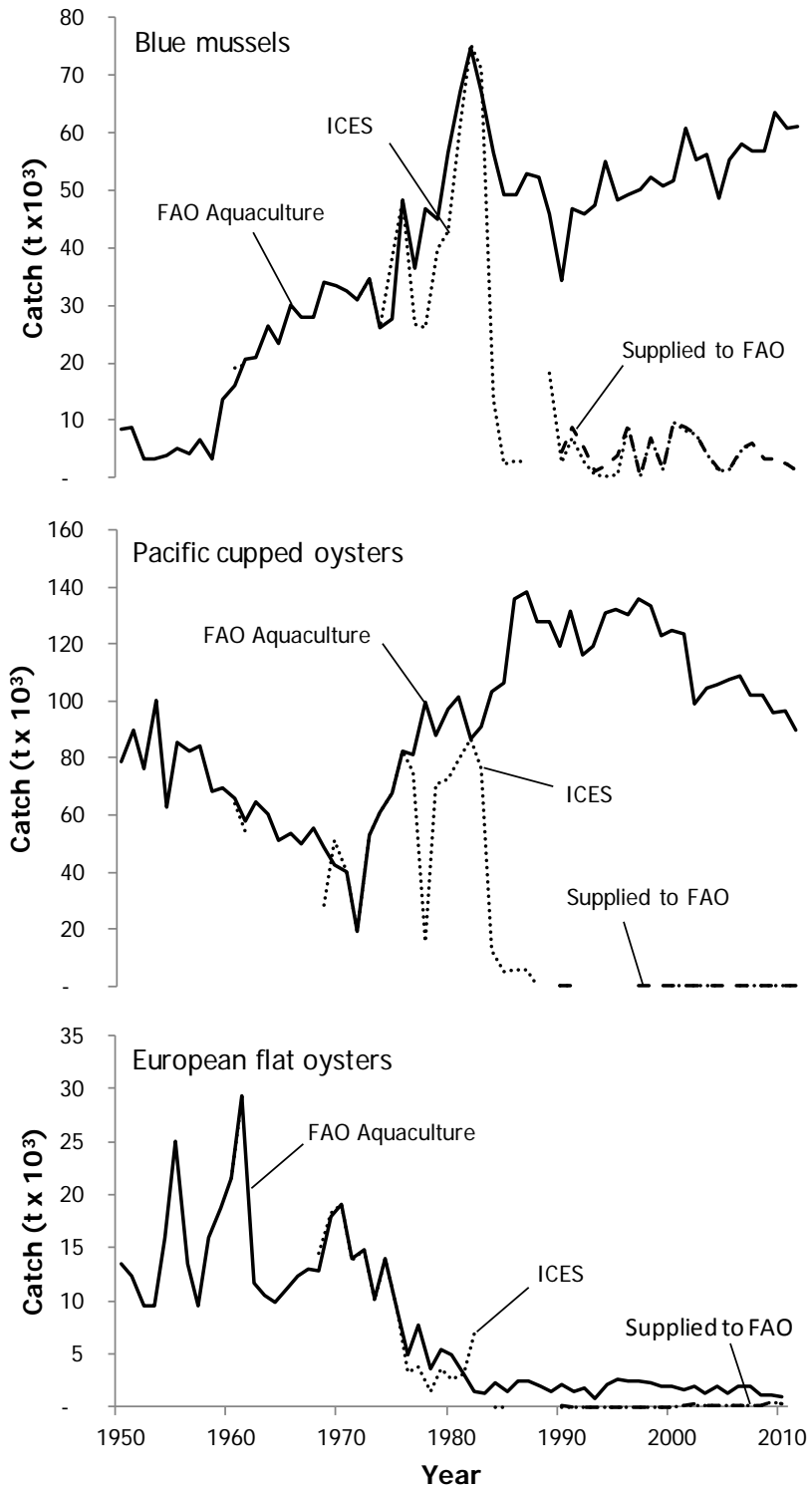
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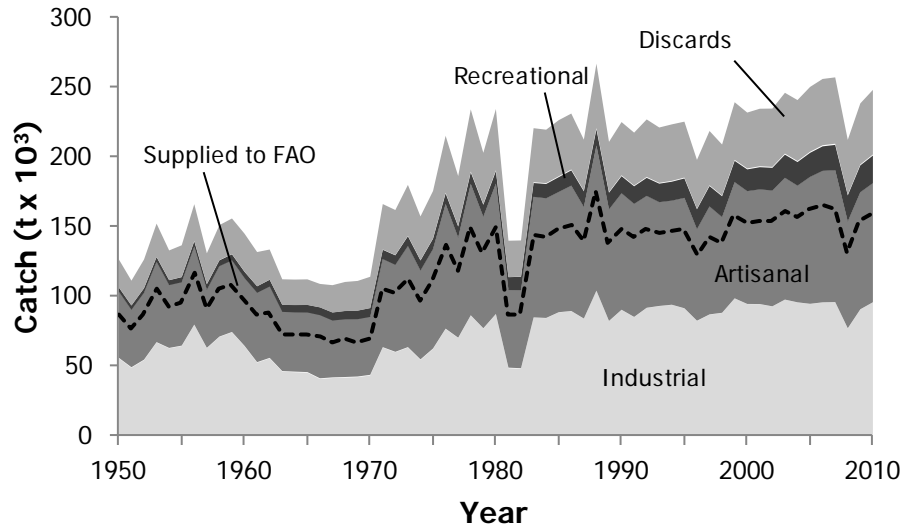
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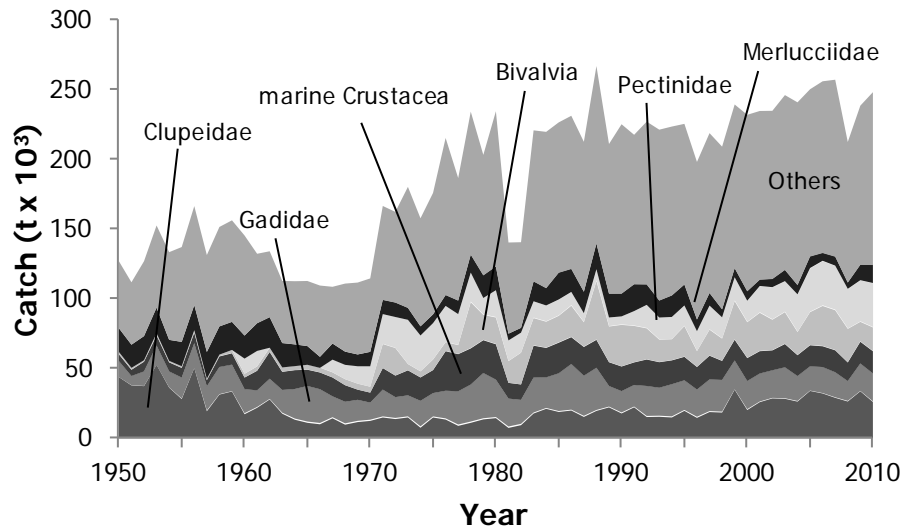
**Figure 1.** Map of France Atlantic and its Exclusive Economic Zone (EEZ).



**Figure 2.** ICES catch vs FAO aquaculture and landings for blue mussels, Pacific cupped and European flat oysters, 1950-2010.

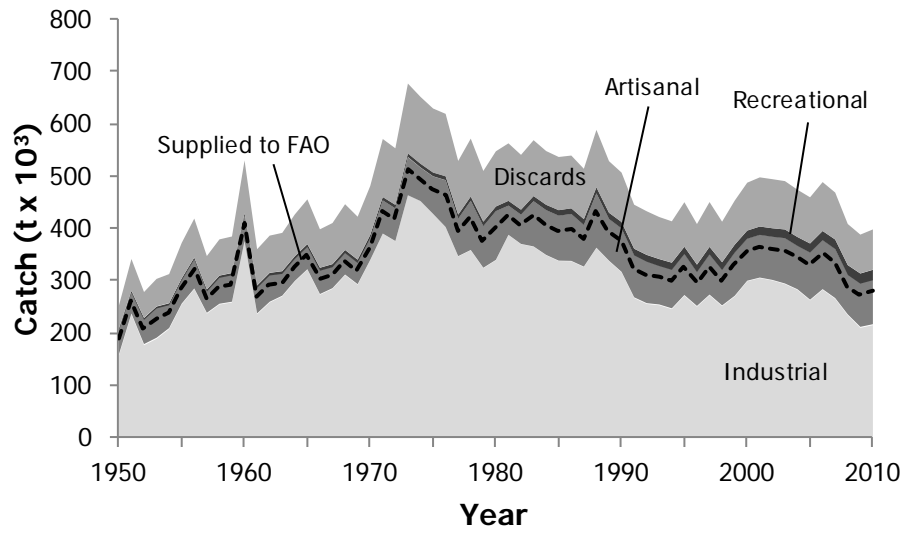


**Figure 3a.** Total reconstructed catch of the French Atlantic Coasts (EEZ only), 1950-2010.



**Figure 3b.** Total reconstructed catch by major taxa (EEZ only), 1950-2010, 'Others' includes 51 other taxa.





**Figure 4.** Total reconstructed catch of the French Atlantic (EEZ and beyond in FAO area 27), 1950-2010.

**Appendix Table A1.** French Atlantic coasts catch within the EEZ as reported to FAO, compared to total reconstructed catches by sector, discards being shown separately, 1950-2010.

Year	FAO landings	Total reconstructed catch	Artisanal	Industrial	Recreational	Discards
1950	87,000	127,000	48,100	55,500	2,980	19,900
1951	76,000	111,000	41,800	48,800	3,130	17,700
1952	86,400	127,000	48,600	54,200	3,260	20,500
1953	105,400	152,000	58,200	66,900	3,410	23,600
1954	92,800	133,000	45,700	62,700	3,540	21,100
1955	94,600	137,000	46,000	64,300	3,690	22,600
1956	116,800	166,000	56,500	79,500	3,850	26,200
1957	90,400	131,000	42,200	62,700	4,010	22,000
1958	104,700	151,000	51,100	70,900	4,170	24,900
1959	107,700	156,000	51,900	74,200	4,340	25,300
1960	97,000	145,000	49,200	64,200	4,510	27,100
1961	86,000	132,000	50,400	52,400	4,680	24,400
1962	88,400	134,000	51,800	55,500	4,860	21,500
1963	72,600	112,000	43,100	46,000	5,110	18,200
1964	72,500	112,000	43,200	45,600	5,300	18,200
1965	71,800	112,000	43,400	45,300	5,490	18,300
1966	71,400	109,000	46,000	40,800	5,660	16,700
1967	66,900	108,000	41,500	41,500	5,850	19,500
1968	69,800	111,000	42,100	41,700	6,030	20,700
1969	67,300	111,000	41,800	42,100	6,210	21,200
1970	68,800	114,000	42,200	43,300	6,400	22,400
1971	105,800	166,000	63,800	63,200	6,610	32,400
1972	101,900	162,000	63,000	59,900	6,810	32,100
1973	112,000	180,000	73,100	63,300	7,010	36,300
1974	97,400	157,000	64,400	54,400	7,210	31,200
1975	110,300	175,000	72,000	62,300	7,390	33,700
1976	136,600	215,000	90,000	76,600	7,560	40,500
1977	118,300	186,000	72,400	70,000	7,900	35,600
1978	149,400	233,000	94,800	86,200	8,230	44,200
1979	130,600	203,000	80,600	76,800	8,570	36,600
1980	149,900	234,000	94,100	87,100	8,900	43,600
1981	86,200	140,000	56,300	48,500	9,240	25,900
1982	86,100	140,000	56,700	48,100	9,570	25,800
1983	143,400	220,000	87,100	84,700	9,900	38,500
1984	142,800	219,000	86,400	84,300	10,240	38,100
1985	147,400	226,000	86,900	88,400	10,570	39,900
1986	151,000	231,000	90,500	89,300	10,910	39,800
1987	139,000	212,000	80,600	83,800	11,240	36,200
1988	175,900	266,000	104,700	104,000	11,570	45,900
1989	137,700	210,000	80,600	82,100	11,910	35,700
1990	148,400	224,000	84,100	90,200	12,240	37,900
1991	141,800	217,000	81,700	85,000	12,580	37,600
1992	148,000	226,000	80,800	91,600	12,910	41,000
1993	145,500	221,000	75,000	92,900	13,250	39,400
1994	146,700	223,000	75,200	93,800	13,580	40,200
1995	147,600	225,000	79,800	91,300	13,910	39,800
1996	129,200	198,000	66,200	82,300	14,250	34,800
1997	142,300	218,000	78,000	86,800	14,580	38,700
1998	137,400	208,000	69,200	88,000	14,920	36,300
1999	158,600	239,000	83,900	98,400	15,250	41,000
2000	153,000	231,000	81,500	94,400	15,590	39,800
2001	154,200	234,000	82,800	94,300	15,920	40,900
2002	153,400	234,000	83,700	92,600	16,250	41,500
2003	161,600	245,000	87,900	97,500	16,590	43,300
2004	157,200	240,000	84,300	95,500	16,920	43,400
2005	161,800	249,000	91,600	94,500	17,260	46,200
2006	165,500	255,000	94,900	95,500	17,590	47,200
2007	163,000	256,000	95,200	95,700	18,150	47,300
2008	131,100	212,000	77,200	76,800	18,690	39,100
2009	153,700	238,000	84,500	90,500	19,240	43,500
2010	160,100	247,000	86,000	95,600	19,780	46,000

**Appendix Table A2.** French Atlantic coasts catch outside the EEZ reported to FAO, compared to total reconstructed industrial catch and discards, 1950-2010.

Year	Reported data	Total reconstructed catch	Industrial	Discard
1950	102,000	125,000	102,000	23,800
1951	187,000	230,000	187,000	43,000
1952	123,000	152,000	123,000	28,900
1953	122,000	151,000	122,000	28,900
1954	145,000	180,000	145,000	34,400
1955	191,000	236,000	191,000	45,200
1956	205,000	253,000	205,000	48,500
1957	175,000	216,000	175,000	41,800
1958	184,000	228,000	184,000	44,300
1959	184,000	229,000	184,000	44,500
1960	311,000	386,000	311,000	74,300
1961	184,000	228,000	184,000	44,800
1962	203,000	253,000	203,000	49,700
1963	224,000	279,000	224,000	55,000
1964	253,000	315,000	253,000	61,800
1965	276,000	343,000	276,000	67,600
1966	233,000	289,000	233,000	56,800
1967	243,000	302,000	243,000	59,100
1968	269,000	336,000	269,000	66,900
1969	250,000	311,000	250,000	61,000
1970	296,000	367,000	296,000	71,600
1971	327,000	406,000	327,000	79,100
1972	316,000	392,000	316,000	76,500
1973	400,000	498,000	400,000	98,000
1974	398,000	495,000	398,000	97,300
1975	365,000	455,000	365,000	89,400
1976	326,000	405,000	326,000	79,400
1977	276,000	344,000	276,000	67,400
1978	272,000	339,000	272,000	67,000
1979	247,000	308,000	247,000	60,800
1980	252,000	314,000	252,000	62,400
1981	339,000	423,000	339,000	84,500
1982	322,000	401,000	322,000	79,400
1983	280,000	349,000	280,000	68,900
1984	264,000	330,000	264,000	65,200
1985	249,000	311,000	249,000	62,200
1986	248,000	309,000	248,000	61,500
1987	242,000	303,000	242,000	60,300
1988	259,000	323,000	259,000	64,500
1989	255,000	319,000	255,000	63,400
1990	226,000	283,000	226,000	56,900
1991	182,000	229,000	182,000	46,700
1992	164,000	207,000	164,000	42,600
1993	160,000	201,000	160,000	41,100
1994	152,000	191,000	152,000	39,000
1995	180,000	226,000	180,000	45,500
1996	168,000	211,000	168,000	42,900
1997	185,000	233,000	185,000	47,200
1998	163,000	205,000	163,000	41,200
1999	171,000	215,000	171,000	43,300
2000	205,000	257,000	205,000	52,000
2001	211,000	264,000	211,000	53,400
2002	208,000	261,000	208,000	52,600
2003	196,000	246,000	196,000	49,400
2004	187,000	234,000	187,000	47,200
2005	168,000	210,000	168,000	42,300
2006	187,000	234,000	187,000	46,600
2007	170,000	213,000	170,000	42,800
2008	157,000	197,000	157,000	39,600
2009	120,000	151,000	120,000	30,900
2010	120,000	151,000	120,000	31,200

**Appendix Table A3. Total reconstructed catch within the EEZ by major taxa 1950-2010.**

Year	Clupeidae	Gadidae	Marine Crustacea	Bivalvia	Pectinidae	Merlucciidae	Others <sup>a</sup>
1950	43,400	11,900	4,890	1,460	0	17,000	47,900
1951	37,600	6,900	4,510	1,470	0	16,500	44,600
1952	37,000	10,700	7,040	1,000	0	17,200	53,500
1953	52,200	14,500	7,290	1,070	0	18,300	58,800
1954	36,000	11,800	6,540	1,050	0	14,900	62,700
1955	27,900	15,400	7,030	1,230	0	17,300	67,800
1956	49,900	18,500	7,480	1,240	0	18,000	70,800
1957	19,200	17,700	4,420	1,350	0	19,000	69,300
1958	31,000	20,000	7,680	1,130	0	20,100	71,100
1959	33,200	19,500	8,250	2,150	0	20,000	72,600
1960	17,100	17,700	8,430	2,670	11,100	16,400	71,600
1961	21,700	12,200	14,270	3,030	11,200	19,700	49,700
1962	27,600	14,900	19,480	2,810	0	21,800	47,200
1963	17,500	16,700	13,210	3,280	0	17,300	44,400
1964	13,200	21,700	13,720	2,970	0	15,500	45,200
1965	11,100	26,100	11,850	3,590	0	13,300	46,500
1966	10,000	24,800	12,170	3,430	0	7,900	50,900
1967	14,200	15,300	13,760	3,630	9,300	11,500	40,600
1968	9,700	15,800	12,090	4,340	10,500	9,400	48,600
1969	11,600	15,400	7,460	4,320	12,800	8,400	51,400
1970	12,400	12,600	7,310	4,290	15,000	10,200	52,500
1971	14,800	19,600	15,710	17,250	21,200	10,200	67,200
1972	13,700	15,300	15,710	19,880	22,000	10,300	64,900
1973	14,900	15,400	18,250	4,420	31,700	8,600	86,500
1974	7,600	18,700	17,060	4,350	25,800	6,500	77,300
1975	14,800	17,100	16,780	7,500	26,000	6,300	86,900
1976	13,400	20,300	28,860	6,310	25,700	7,800	112,400
1977	8,900	24,300	27,120	6,290	22,000	9,700	87,600
1978	11,100	27,100	26,380	33,140	20,500	12,900	102,300
1979	13,500	33,200	23,930	17,980	11,600	16,200	86,200
1980	14,400	27,400	25,820	19,040	19,000	17,000	111,000
1981	7,400	20,400	11,500	15,670	14,900	4,800	65,200
1982	9,400	17,600	11,270	22,930	14,300	3,400	61,200
1983	17,600	25,600	23,290	19,610	11,600	14,300	108,100
1984	21,000	22,500	21,470	18,690	11,200	12,400	111,800
1985	18,700	27,700	22,330	19,100	11,300	19,200	107,500
1986	19,700	33,500	19,540	22,410	9,300	16,500	109,600
1987	15,200	29,400	20,970	17,580	6,100	15,300	107,300
1988	19,500	31,000	20,340	42,200	7,600	18,500	127,000
1989	22,000	15,100	17,350	25,650	6,200	17,000	107,100
1990	17,700	15,700	17,980	29,970	5,700	16,300	121,100
1991	22,000	15,900	16,450	26,240	10,300	19,200	106,900
1992	15,200	22,000	19,330	22,330	16,500	14,600	116,400
1993	15,300	20,500	18,650	16,140	15,600	12,200	122,200
1994	14,800	23,600	17,380	15,080	15,700	15,400	120,800
1995	19,500	21,800	17,120	22,000	14,400	15,000	114,900
1996	14,600	19,900	16,490	11,310	14,200	8,300	112,700
1997	18,700	23,200	17,300	18,570	16,900	9,000	114,400
1998	18,300	23,200	13,880	15,940	15,000	5,700	116,300
1999	34,500	21,300	15,100	27,630	16,400	6,600	117,100
2000	20,100	20,600	16,740	25,730	15,000	6,800	126,200
2001	25,700	20,600	16,290	27,470	18,700	4,600	120,700
2002	28,300	20,300	14,500	21,920	22,800	5,900	120,300
2003	28,100	22,700	16,940	22,770	21,700	8,100	125,100
2004	26,100	18,300	15,200	16,520	26,700	6,700	130,700
2005	33,600	17,900	15,320	23,670	31,000	8,400	119,600
2006	31,800	19,100	15,160	28,860	31,700	5,700	122,800
2007	28,800	18,400	16,000	28,730	31,300	6,600	126,500
2008	26,100	14,600	13,570	24,130	28,300	4,600	100,600
2009	33,400	20,200	15,830	14,080	29,300	11,100	113,800
2010	25,800	20,500	16,200	16,940	31,400	13,000	123,600

<sup>a</sup> This group includes 51 taxa.

**Appendix Table A4.** Total reconstructed catch outside the EEZ by major taxa, 1950-2010.

Year	Gadidae	Clupeidae	Merlucciidae	Marine Crustacea	Lotidae	Others <sup>a</sup>
1950	32,900	51,500	5,970	2,210	110	32,700
1951	34,200	126,200	8,120	3,340	130	58,100
1952	50,900	54,900	7,810	3,240	140	34,700
1953	34,800	64,300	7,970	3,610	140	40,500
1954	60,100	60,100	8,430	4,130	1,680	45,100
1955	106,700	55,900	10,500	4,880	1,480	56,300
1956	122,300	53,700	10,560	5,340	1,980	59,200
1957	106,000	34,000	12,660	4,690	2,100	56,900
1958	104,900	37,600	16,530	5,780	2,490	60,800
1959	97,200	38,400	18,710	6,630	2,920	65,100
1960	220,100	42,600	18,390	8,950	3,300	92,300
1961	86,000	35,200	21,310	9,530	4,990	71,500
1962	102,300	36,000	24,690	13,470	6,230	70,000
1963	115,000	40,300	22,640	11,010	8,570	81,700
1964	137,000	40,400	21,730	12,510	10,160	92,900
1965	162,600	31,800	19,560	12,110	14,780	102,600
1966	136,000	33,200	15,330	12,780	7,050	85,000
1967	150,900	28,800	20,190	14,640	7,950	79,800
1968	144,500	27,800	19,180	14,180	9,780	120,600
1969	146,700	30,100	18,260	12,100	8,670	95,500
1970	199,400	26,200	21,240	11,710	7,960	100,800
1971	214,100	26,600	19,790	20,130	9,090	115,900
1972	198,900	31,000	17,800	19,350	14,080	111,000
1973	209,200	33,100	23,070	24,380	27,910	180,600
1974	219,500	27,900	22,140	25,180	23,470	177,100
1975	196,700	25,600	22,360	27,090	15,590	167,500
1976	197,700	18,400	17,790	17,630	26,500	127,200
1977	181,400	7,800	11,620	16,220	24,710	101,900
1978	173,600	7,700	12,160	16,600	19,870	109,100
1979	161,400	8,700	13,040	16,830	16,680	91,200
1980	150,400	11,300	14,150	16,240	19,100	103,200
1981	179,500	18,500	23,400	27,480	17,580	157,000
1982	177,300	18,700	17,930	26,280	19,050	141,900
1983	161,600	13,600	12,760	16,960	20,850	123,500
1984	152,100	16,900	13,470	15,210	22,590	109,300
1985	139,700	12,500	14,520	14,300	29,140	101,300
1986	151,400	9,100	10,560	12,500	26,080	99,900
1987	145,800	8,200	9,500	14,250	25,150	99,700
1988	145,200	18,400	10,970	13,080	22,280	113,200
1989	135,800	25,300	13,560	12,360	18,750	113,100
1990	110,200	19,400	10,440	13,160	14,720	114,900
1991	75,700	18,000	5,950	11,600	12,740	104,800
1992	66,200	13,200	6,330	12,030	11,170	97,800
1993	73,900	5,800	5,060	12,580	9,580	94,400
1994	72,200	5,400	4,190	13,090	8,370	87,800
1995	68,300	30,800	4,980	13,630	8,700	99,300
1996	75,200	12,500	4,920	11,970	9,240	97,200
1997	82,900	22,500	4,310	11,990	9,550	101,300
1998	68,700	22,400	3,440	10,730	10,300	89,100
1999	69,100	26,600	5,110	10,980	9,130	93,800
2000	80,500	24,600	8,060	12,310	8,600	122,600
2001	86,300	30,600	7,910	13,610	6,580	119,100
2002	83,700	28,400	9,590	13,330	5,770	119,900
2003	74,900	35,900	7,470	11,870	6,090	109,400
2004	66,200	36,000	8,450	10,610	6,030	106,900
2005	50,000	41,800	9,070	9,930	5,310	94,200
2006	73,200	43,000	9,080	10,450	5,320	92,900
2007	66,800	25,300	9,920	10,180	5,580	94,800
2008	64,500	24,700	9,310	9,160	5,130	84,000
2009	39,100	12,400	9,830	8,970	4,750	75,500
2010	35,600	9,400	10,330	8,730	4,770	82,000

<sup>a</sup> This group includes 50 taxa.