Reconstruction of catches, fisheries, and carrying capacity of Galician (NW Spain) small-scale fisheries

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Abstract

This paper examines the carrying capacity of the nine ecogeographic areas of the Galician (NW Spain) continental platform during the 1998–2007 period by (i) reconstructing fisheries catches and (ii) quantifying the amount of available primary production required (PPR) required to sustain small-scale (inshore and coastal) fisheries catches. The results obtained indicate a decline of the appropriation of PPR in the majority of the areas analyzed, with a high range of variability among them. The three areas that showed an increase of PPR in the last decade are Ría of Vigo, Fisterra, and A Mariña-lucense. Furthermore, Galician small-scale fisheries utilize ~15.1% of total primary production in the Ría of Vigo, ~7.2% in the Ría de Arousa (without mussel farming production) and ~17.3% in the Ría of A Coruña-Ferrol; these values are below the 24–35% estimated by Pauly and Christensen (1995). These last results mainly reflect the range of variability in the estimates of total primary production, the decline of total catches in the areas explored, and the reduction of catches of trophic level (TL) $^{>3.25}$ species, which caused a decline in mean TL, mostly due to overexploitation of demersal species in recent years. Nevertheless, our PPR estimates should be considered conservative regarding that part of the discards and none of the illegal, unreported, and unregulated fishing (IUU) are not included in the analysis. Both factors can cause underestimation of the footprint of fisheries and bias the estimated mean TLs of catches.

Keywords: reconstruction of catches, carrying capacity, small-scale fisheries, Galicia (NW Spain)

1. Introduction

There is a consensus in the scientific community that overexploitation of most fisheries worldwide has had significant effects on coastal marine ecosystems (Hilborn et al., 2003), and the majority of assessed fish stocks still require rebuilding programs (Worm et al., 2009). Historical catch and biomass data indicate that a significant decline in marine abundance of high predators in the marine food web has occurred (Pauly et al., 1998; Myers and Worm, 2005), leading to a cascade effect of unknown and unpredictable consequences (Myers et al., 2007).

Under these circumstances, the concept of carrying capacity allows researchers to determine the limits of exploitation of marine ecosystems. The concept involves biological, ecological, economic, and social factors and provides relevant information regarding the capacity of ecosystems to continue providing goods and services (Costanza et al., 2007). The concept is traditionally associated with the sustainability of catches that can be supported by marine ecosystems and is associated with the trophic level (TL) of exploited species (Pauly and Christensen, 1995).

Many studies have dealt with carrying capacity (Costanza et al., 2007; Stromberg et al., 2009) and with potential catches of a determined area (Christensen and Pauly, 1993). Empirical applications of the primary production required (PPR) approach have been conducted in Brazil (Vasconcellos and Gasalla, 2001), the North Atlantic (Myers et al., 2001), the North East Pacific (Perry and Schweigert, 2008), and Sri Lanka (Haputhantri et al., 2008), among others.

1.1. Area of study

The Galician coast (NW Spain) extends for approximately 1,295 km and has a highly varied morphology, with rías and inlets, cliff areas with beaches or marshes, and areas exposed to storms with shaded areas (Penas, 1986). The continental Galician shelf, defined as the coastal zone to 200 m deep, is relatively narrow; its width varies between 20 and 35 km and its total surface area, from Ribadeo to the estuary of the Río Miño, is approximately 10,000 km^2. The richness of Galician rías, which consist of old tectonic valleys occupied by the sea as a result of the high sea level during the last glaciations, is due to upwelling phenomena (Fraga and Margalef, 1979).

[Figure 1]

The coasts of Galicia seasonally are influenced by wind-driven upwelling pulses that contribute to the high productivity of the rías. This upwelling process fertilizes the coastal and shelf areas with deep-water nutrients in discrete events that can occur between March and October. This seasonality of surface winds favours biological production processes (Bode and Varela, 1998).

From a biological point of view, the Galician rías are ecosystems with high primary production. Primary production can reach 250 g C/m^2/year in the Ría de Arousa (Varela et al., 1984), which is far higher than the average primary production observed in the Atlantic Ocean (100 g C/m^2/year) and is close to the estimated average for land ecosystems (Fraga and Margalef, 1979).

However, in spite of the biological (Freire and García-Allut, 2000) and socioeconomic (Varela-Lafuente et al., 2000; García-Negro et al., 2009) importance of the Galician small-scale fisheries seafood supply-demand sector and the high level of dependence on fishing activities in Europe (European Commission, 2000), the ecological and economic implications of fisheries have received little attention from the scientific community (López Veiga et al., 1993).

This paper presents a comparative analysis of small-scale fisheries (inshore and coastal) with the goal of assessing the carrying capacity of Galician marine ecosystems. The specific aims of the paper are to (a) reconstruct fisheries catches and (b) assess the carrying capacity of Galician rías using the primary production required (PPR) as a measure of sustainable exploitation of fishery resources between 1998 and 2007.

This reconstruction includes the catches (plus reported discards) of commercial fisheries, but it excludes the catch volume of recreational fisheries and the volume of illegal, unregulated and unreported (IUU) fishing activities. We divided the Galician coastline into the nine ecogeographic areas established by the Department of Fisheries and Maritime Affairs of the Autonomous Government of Galicia. The divisions are as follows: Area I-Ría de Vigo, Area II-Ría de Pontevedra, Area III-Ría de Arousa, Area IV-Ría de Muros, Area V-Fisterra, Area VI-Costa da Morte, Area VII-Ría A Coruña-Ferrol, Area VIII-Cedeira, and Area IX-A Mariña-lucense.

2. Materials and methods

2.1. Definition of inshore and coastal fisheries

The literature contains many definitions of artisanal or small-scale fishing (Chuenpagdee et al., 2006). It is often defined as a traditional activity of subsistence or one that uses passive gears (Orensanz et al., 2005). In this paper, small-scale fishing is defined "*as the group of vessels which catch species whose life cycle of maturity develops in the Galician continental shelf and not beyond 200 m deep*" (Villasante, 2009). In this definition, those vessels that operate in the continental shelf of Galicia are included, providing that they fulfil simultaneously the two following criteria:

(i) The maximum value of the average depth of caught species, which is considered to be the habitat of the species from its juvenile state to maturity excluding the larval phase, must not exceed 100 m (inshore fishing) or 200 m (coastal fishing), and

(ii) At least one of the following types of fishing gear is usually employed by these vessels in the continental shelf: driftnets, gillnet, long line, trawling, and shell-fishing nets.

As the fishing fleet based in Galicia operates not only at the coast but also in other fishing grounds such as Grand Sole, Africa, South American fishing grounds, and international waters, among others, it is necessary to identify the species that, having been landed in the most important ports (e.g., A Coruña, Burela, Celeiro, Marín, Ribeira, and Vigo), were caught by the inshore and coastal fleet.

2.2. Methodological routine to reconstruct the inshore and coastal fisheries catches in Galicia

Pauly (1998) pointed out the problems associated with the FAO's global fisheries statistics and presented the concepts and methodology that would need to be applied to reconstruct fishing statistics not well covered in the global FAO database of fisheries landings. This methodology then was applied to several fisheries from areas around the world to (re)estimate official fishing statistics because countries are misreporting fisheries catches (Zeller et al, 2006; Zeller and Pauly, 2007).

In Galicia, the only official statistical data regarding fishery product landings in all fish markets have been available at the Fishing Technological Platform *PescadeGalicia* (http://www.pescadegalicia.com), which is dependent on the Galician Regional Government. *PescadeGalicia* collects daily information about transactions for the ~200 species traded in the 64 fish markets governed by the Galician Administration. This information is extracted from sales receipts issued by species and market that are provided to the Platform by the owners of fresh fish and shellfish-selling markets. The collected data are used to prepare statistics relating to landings in weight (kilograms), sales turnover, and average, minimum, and peak prices for six-year periods beginning in 2001. For each six-year period available, landing data can be retrieved based on fish markets or traded species for the desired periodicity (weekly, monthly, or even daily).

Although the Galician Autonomous Government has invested a huge amount of effort to improve the reliability of its fishery statistics in the last decade, the database is often incomplete and does not provide detailed information (Molares and Freire, 2003). Moreover, unreported and misreported catches are still common, particularly for important commercial species (Rocha et al., 2004; Otero et al., 2005).

In our study, we emphasize the difference between catches and landings in Galicia. Galician fish markets receive landings from fishing areas far away from the local coast. However, we do not know the volume of species that were harvested only from the Galician coast by the inshore and coastal fishing fleet. To better understand the status of Galician rías, it is key to estimate accurately the extent and quantity of total extraction of marine fisheries (fishes, crustaceans, mollusks and other marine species) by these fleets.

The reconstruction of catches is necessary not only because of the above-mentioned underestimation of catch data (Rocha et al., 2004), but also because it is essential to (i) distinguish total landings by differentiating the geographic origin of the species from catches made only from the Galician continental shelf, (ii) identify the discrepancies between official landings published by *PescadeGalicia* and primary statistical sources from auction markets (See Figure S1 of the Supplementary material), (iii) include discards from International Council for the Exploration of the Sea (ICES) yearly reports (For detailed information about the procedure followed and the species included in this study, see Tables S1 and S2 of the Supplementary Material).

Our analysis followed the standard routine established by Pauly (1998), Zeller et al. (2006), Freire and Pauly (2010) and Rossing et al. (2010) for the reconstruction of catches of Galician small-scale fisheries. We do not claim that the reconstructions of the results presented here provide true catches. Rather, these catches certainly represent an improvement over the present situation and thus can be considered to be closer to likely true catch levels than those previously available (Zeller and Pauly, 2007).

2.3. Estimating the carrying capacity of Galician marine ecosystems

In this study, we report for the first time the estimation of the PPR for inshore and coastal catches for the entire coast of Galicia. The PPR is calculated from information based on the TL values of caught species (Table S2), the energy-transfer (TE) between each of the TLs, and the primary production of the areas of study (Table S3) (Pauly and Christensen, 1995). The PPR required to maintain catches for a marine ecosystem is based on a conversion factor of ~0.09 g of carbon equal to 1 g of weight of catches and on the average TE per TL, which here is 0.10 or 10% (Pauly and Christensen, 1995):

$$PPR = (Catches/9) \times 10^{(TL-1)} \qquad \text{(Eq. 1)}$$

where $\alpha = TE^{(-1)}$, and TE is the average of the energy transfer between consecutive TLs. The usual method to quantify carrying capacity of marine ecosystems follows the methodology established by Pauly and Christensen (1995). The authors estimated that worldwide fisheries need approximately 8% of the primary production of the oceans to sustain fisheries catches. This value is around 24–35% for continental shelves and coastal ecosystems due to industrial fisheries that operate on species with high TLs. The data used here to calculate the PPR for Galician catches of small-scale fisheries come from the original Chlorophyll *a* (Chl *a* mg/m^{-2}) data (daily, monthly, and yearly) from measures of ^{14}C (Tilstone et al., 1999) collated by the *RADIALES program* of the Spanish Institute of Oceanography (Instituto

Español de Oceanografía) (Varela et al., 2006). Chl *a* data were used to estimate the biomass of microalgae (phytoplankton) and Chl *a* concentration was measured using spectrofluorimetry at 40 m depth and ultimately converted and integrated to values of average primary production in $gC/m^2/year^{-1}$ (Bode, pers. comm.) (For different estimates of primary production for the Galician coast, see Table S3). This information was then used to estimate the PPR to sustain Galician inshore and coastal fisheries catches in the ecogeographic areas of Ría de Vigo, Ría de Arousa, and Ría A Coruña-Ferrol.

3. Results

3.1. Reconstructed catches from Galician small-scale fisheries

3.1.1 Results by zones

Following the methodology described, Table 1 presents the results of the statistical reconstruction of the catches of the inshore fleet in order of importance by volume (kg) for each of the Galician ecogeographic zone. From 1998 to 2007, the inshore fleet decreased its catches from 56.4 to 55.3 thousand tonnes, with an average catch for the entire period of 51.5 thousand tonnes. The period of greatest decrease occurred between 1998 and 2002 (24%), and an increase has occurred since then. The results obtained here differ from the ~14–19 thousand tonnes recently reported by Arnáiz (2010) for inshore fisheries for 2001–2007. This is because Arnáiz (2010) included the gillnet fishing fleet in his analysis, but he excluded the trawlers, longlines, and purse seiner vessels. Furthermore, Arnáiz (2010) did not include discards, interpolations and extrapolations of catches when official data contained gaps.

[Table 1]

Of the nine ecogeographic areas, Ría de Vigo, A Coruña-Ferrol, and Ría de Arousa had the greatest total production of inshore fisheries, with 22.5%, 20.9%, and 19%, respectively. Only three areas showed an increase in catches throughout the period (A Mariña-lucense

126%, Ría de Muros 86.2% and Costa da Morte 12.5%), whereas the remaining areas exhibited a decline in catches (Ría de Pontevedra 47%, Fisterra 39.4%, Cedeira 27.3%, Ría de A Coruña-Ferrol 23.6%, Ría de Arousa 4.7% and Ría de Vigo 1.05%). Finally, when comparing catches of the inshore fleet with total landings in *PescadeGalicia*, the former represent about ~29.8–39.6% of the total volume of fresh fish sold in Galician auction markets.

Table 2 presents the results for the reconstruction of catches of Galician coastal fisheries. According to our results, the total volume of catches decreased from 106.0 to 99.1 thousand tonnes during the 1998–2007 period. Ría de Arousa, Ría de A Coruña-Ferrol, Ría de Vigo, A Mariña-Lucense and Ría de Muros are the most important areas in terms of catch volume, and Ría de Arousa, Ría de Vigo and Ría de Muros show an increased trend of catches in these years. The remaining areas exhibited a decreasing trajectory of the catch volume (Ría de Pontevedra 53.3%, Cedeira 36.8%, Ría de A Coruña-Ferrol 31.2%, Fisterra 28.2% and Costa da Morte 12.2%).

[Table 2]

3.1.2 Results by group of species

The reconstruction of the Galician inshore catches indicated a great diversity of the species harvested in each area. For example, the number of species with $^{<3.25}$TL caught in Ría de Vigo are mainly pelagic ones (i.e., European sardine, *Sardina pilchardus*; Atlantic mackerel, *Scomber scomber*; and Horse mackerel, *Trachurus trachurus*; cephalopods such as Horned octopus, *Eledone cirrhosa;* Common octopus, *Octopus vulgaris*; European squid *Logilo vulgaris*, and mollusks (Common edible cockle, *Cerastoderma edule*). The catch volume of these species has increased between 1998-2007 (19.4%).

Ría de Pontevedra was characterized by a high concentration of species $^{>3.25}$TL (i.e., European sardine) and $^{>3.25}$TL (95% of total catches) at the beginning of the period. However, by 2007 this concentration had slightly fallen to 90% due to a decrease in the catches of mollusks (Barnacle, *Pollicipes pollicipes*) and Japanese carpet shell.

In Ría de Arousa, pelagic species (Atlantic horse mackerel, European pilchard, and Atlantic mackerel) and mollusks such as the Banded carpet shell (*Venerupis rhomboideus*), Grooved carpet shell (*Ruditapes decussatus*), and Japanese carpet shell (*Ruditapes philippinarum*) represent over 85% of total volume caught. This indicates a high productive specialization on these types of fisheries. The other productive activity is the cultivation of mussels (*Mytilus galloprovincialis*), making the Ría de Arousa one of the most productive area in the world (Rodríguez Rodríguez, 2009).

[Figure 2]

In A Coruña-Ferrol, pelagic species (i.e., European sardine and Horse mackerel) account for 50% of the total volume of catches in 2007. However, Costa da Morte and Fisterra are dominated mainly by $^{>3.25}$TL catches (Atlantic mackerel and Horse mackerel represent 25% of total catches in Costa da Morte) and cephalopods (Common octopus accounts for 67% in Fisterra). In the remaining areas, Cedeira and Muros, the European sardine is the dominant species, representing almost 80% of all catches in each area (Figure 2).

3.2.The primary production required to sustain Galician small-scale fisheries

For the ecogeographic areas for which measures of primary production were available, it was possible to estimate the percentage of the PPR as compared to the net primary production (NPP), thereby evaluating the carrying capacity in a more precise way (Vasconcellos and Gasalla, 2001). The percentage of PPR from inshore fishing in the Ría de Vigo was ~15.1%; this value increased in 2007 and settled at ~18.1%, which is lower than the 24–35% estimated by Pauly and Christensen (1995). Nevertheless, this result shows that fishing exploitation uses a high proportion of the carrying capacity of this marine ecosystem. In fact, Guerra et al. (2009) also asserted that overexploitation of marine resources exists at several levels. In our study, the increase of PPR in Ría de Vigo occurred because (i) the primary production exhibited high variability in recent years, with minimum and maximum values oscillating between 290-340 gC m^2 $year^{-1}$ (TS3); (ii) the total catches decreased from 12.3 thousand tonnes in 1998 to 12.1 thousand tonnes in 2007; and (iii) a decrease of catches of $^{>3.25}$TL species occurred (Table S4).

[Figure 3]

The results obtained for Ría de Arousa indicate a reduction of the PPR in relation to the PP from ~12.10% in 1998 to 7.23% in 2007; these values are lower than the 24–35% estimated by Pauly and Christensen (1995). These results likely were due to (i) the variability of the total primary production; (ii) the decline in the volume of total catches in the 1998–2007 period; and (iii) the reduction of catches of $^{>3.25}$TL species (Common octopus and Pouting) (Table S5).

A comparative analysis can also be made by including total PPR and annual average landings from mussel farming rafts in the area (Figure 3). Figure 3 shows the expected PPR when uncertainties and species trophic level estimates are taken into account. Using the more conservative estimates of the PP, the results obtained indicate a decline of the PPR from ~66.2% in 1998 to ~51.2% of the total primary production in 2007. However, the resulting PPR values are particularly high when compared to the estimates made by Pauly and Christensen (1995), Vasconcellos and Gasalla (2001), or Sánchez et al. (2005) for this type of marine ecosystem. This finding strengthens empirically what Pérez-Camacho et al. (1995), Penas (2000), Álvarez-Salgado et al. (2009) and Rodríguez Rodríguez (2009) predicted: that is, that mussel farming production requires high appropriation of PPR to sustain its activity.

Around 68.8% of 3,338 mussel farming rafts are concentrated in Ría de Arousa, which suggests that they have a high energetic requirement from phytoplankton and that mussel rafts have negative impacts on the ecosystem by generating a high volume of dissolved organic matter at the bottom of the ría (Perez-Camacho et al., 1995). Both our results and those obtained by Varela et al. (1984), who estimated that mussel farming in the Ría de Arousa required ~60% of the available phytoplankton, confirm the extremely high consumption of total primary production by these mollusks. Thus, cultivation of mussels is notably contributing to reaching the carrying capacity of the examined area. In addition, mussel farming has not only altered the composition of the zooplankton of the bay, thereby modifying the natural flow of energy between the lower and upper levels of the ecosystem, but it also has created a special microenvironment that causes changes in the abundance and composition of the benthic communities (Guerra et al., 2009).

Finally, the analysis of the appropriation of PPR to sustain catches in Ría de A Coruña-Ferrol revealed a decline in catches in the area during the period 1998–2007; catches decreased from an average of 15.3 thousand tonnes in 1998–2002 to 11.7 thousand tonnes in 2003–2007. Estimates obtained for the ecogeographic area of A Coruña-Ferrol showed a reduction in PPR during 1998–2007, with values of 23.5% in 1998 and 17.3% of the total primary production in 2007.

This reduction does not necessarily indicate lesser fishing effort in the area. In fact, the lower appropriation of the total primary production was likely due to (i) the increase of the total primary production, (ii) the lower volume of total catches, (iii) the decline in catches of the main commercial species (Atlantic mackerel, common octopus, European sardine, and Atlantic horse mackerel), and in particular of the $^{>3.25}$TL species (i.e, European conger) due to overfishing, leading to a reduction in the TL of catches, or (iv) because an increase of fishing effort in the area may be masked by the increase of total primary production. That is, the increase in the total primary production may be masking a suboptimal effort, where the vessels would exert greater pressure on fishery resources (Table S6).

4. Discussion

Although Varela et al. (1984) were the first to attempt to describe the Ría de Vigo from a holistic and ecosystem approach in the 1980s; this paper represents the first study of comparable characteristics comprising all of the Galician rías. Although fishing activities conducted within the continental shelf are known, we have no systematic, rigorous and complete information about such basic variables as catches (not landings), fishing effort, size and sex distributions of species harvested in the Galician coasts. This study is an attempt to solve, at least partially, some of these problems.

The results presented here indicate a decline in the appropriation of the PPR in the majority of the areas analyzed, with a high range of variability among them. Our PPR estimates should be considered conservative considering that all discards and IUU fishing activities were not included in the calculations and that part of the catches may remain unreported in official statistics. Results also indicate a level of fisheries impact in the Galician coast comparable to the most intensively exploited temperate shelf ecosystems of the world (Pauly and Christensen, 1995).

Table 3 shows the results of calculating the PPR for the catch of Galician inshore and coastal fisheries. The Southern areas (Ría de Vigo, Ría de Arousa, and Ría de Pontevedra) of the Galician coast showed a decrease (17.4%) in the appropriation of the PPR of the small-scale fleet, whereas in the central areas (Ría de Muros, Fisterra, and Costa da Morte) and North of the Galician coast increases of 4.5% and 17.5% were observed, respectively. However, the results for the coastal fleet differ considerably. All areas showed a decline in appropriation of PPR, which was around 20% in the north, 43% in the centre, and 28.8% in the south.

[Table 3]

Comparing these results with those from other areas with similar upwelling phenomena such as the Brazilian coast, both areas are characterized by the high volume of catches of pelagic species (Rocha et al., 1998; Freire and Pauly 2010). Another common feature is that both areas show a diversity of species (cephalopods, demersals and pelagics) caught. However, different intensities in the appropriation of primary production seem to have occurred along the Brazilian and Galician coast. Catches in the southern and southwestern areas of the Brazilian coast required 27% and 52.7% of the primary production, respectively, in the 1990s (Vasconcellos and Gasalla, 2001).

In addition, changes were observed in the mean TL of catches of the inshore and coastal fleet in almost all Galician areas after excluding the $^{<3.25}$TL species, which implies that not complying with the effects of "*bottom-up*" leads to an increase in primary production (Caddy et al., 1998; Pauly et al., 1998; Essington et al., 2006; Mutsert et al., 2008). The decline of the $^{>3.25}$TL did not occur with the same intensity in all areas. Rates of decline for inshore and coastal fishing were as follows: Ría de Vigo (−0.2388 and −0.1432 per decade), Ría de Arousa (−0.0419 and −0.2222 per decade), Ría de Muros (−0.0986 and −0.0733 per decade), Costa da Morte (−0.0943 and −0.0335 per decade), Ría de A Coruña-Ferrol (−0.0975 and −0.4007 per decade), Cedeira (−0.1084 and −0.0375 per decade), and A Mariña-lucense (−0.0331 and −0.0417 per decade). Thus, for example, the area of A Mariña-lucense, which is part of the ICES VIIIc area, has a ratio of decline that is greater than the estimated worldwide decline (−0.100 per decade) (Pauly et al., 1998), due to declining catches of anglerfish, European hake, megrim (ICES, 2008), and common octopus (Arnáiz, 2007). The Ría de Pontevedra shows an unclear trend in the inshore fishing fleet and a decreasing (−0.0545 per decade) one in the coastal fleet. Conversely, the ecogeographic area of Fisterra is the only one that exhibits an increasing growth rate of the mean trophic level of catches

(+0.0411 per decade) both in the inshore and the coastal fleets (Villasante, 2009). These results show that *fishing down marine food webs* phenomena becomes apparent after regional data are disaggregated into smaller entities, as presented here for nine ecogeographic zones of the Galician coast. The decline of trophic levels compromises the well-being of human beings, now and in future generations (Sumaila and Walters, 2005), and puts at risk the benefits of marine ecosystems, such as providers of goods and services (Costanza et al., 2007), the food supply, and employment in coastal communities (Chuenpagdee et al., 2006).

Given the complete absence of official statistical information about other indicators of relative abundance (such as biomass, recruitment, or exploitation rates) gathered by survey data or other stock assessments that would complement the methodology used here (Rocha et al., 2004; Worm et al., 2009), we used TL data and the variable of reconstructed catches to estimate the primary production required for Galician small-scale fisheries.

In this paper, we minimize the problems of taxonomic and spatial resolution of the catches (Caddy et al., 1998), and the cited commercial catches are by no means sporadic because they represent a high volume of total landings in Galicia (Mutsert et al., 2008). In any case, according to consultations with fishermen and local experts from auction markets, this study reveals that in most of the areas, the effort or number of fishing trips stays constant over time. In particular, the Ría de Vigo, for example, showed an increase of 53.6% in the number of boat trips of the inshore and coastal fleet, which led to an increase of only 25% of catches in the 2001–2007 period (García-Negro et al., 2009). Overfishing, changes in some of the vital parameters (e.g., decreasing minimum size at first maturity), and the general decline of biodiversity loss were observed in the Ría de Vigo (Guerra et al., 2009) but also in the majority of the Galician rías.

In conclusion, in recent years the biodiversity loss has been important almost everywhere on the Galician coast (Villasante, 2009). For example, the Ría de Vigo is witnessing the decline of the relative abundance of pelagic species (i.e., Sprat and European sardine), and some crustaceans (i.e., the Small European locust lobster, among others). Although fishing causes negative impacts on marine ecosystems in Galicia, the current situation of Galician rías have multiple sources, such as overfishing, pollution, the introduction of invasive species, increasing coastal development, the use of explosives in fishing, the illegal, unregulated and unreported catches, and the alteration of biogeochemical conditions of the ecosystems. In addition, sea-related activities compete with each other (i.e., capture fisheries, shellfishing, aquaculture, canned-industry, maritime transport, recreational fishing, etc.), resulting in synergism among factors that leads to the deterioration of biological diversity. Therefore, there is an urgent need to understand and reverse the cumulative effects at temporal and spatial scale of anthropogenic impacts on marine biodiversity (González-Garcés et al., 2009).

Different methods of management at the sectoral and jurisdictional level and the existence of multiple actors in decision making have only delayed the recovery of marine ecosystems of the Galician coast (Guerra et al., 2009). Against the multiplicity of rules, the adoption of a integrated mechanism that simplifies the decision-making process and covers all economic sectors (fisheries, aquaculture, tourism, recreational activities, and maritime transport, among others) operating in the coastal areas becomes necessary (Villasante, 2009). Among the actions of management needed is the creation of marine protected areas, the reduction of the fishing effort, and modification of how the fish auction mechanisms operate to sell the fish. However, a plan of this nature must necessarily overcome local conflicts or interests and be able to reconcile the different sectors and urgent needs of the coastal areas to ensure local fishery resources for future generations.

Acknowledgments

This work was partially developed during the first author's research visit to the UBC Fisheries Centre (Canada). Sebastián Villasante is grateful for the information and methodology framework provided by Dr. Dirk Zeller and María L. (Deng) Palomares (UBC). The authors would also like to thank Xosé Antón Álvarez-Salgado, Antonio Bode, Xosé Iglesias, Manuel Varela (IEO), and Yolanda Pazos (INTECMAR) for the valuable biological information they provided for the understanding of the functioning of Galician rías. Nélida Pérez and Valentín Trujillo (IEO) also provided data on by-catch and discards of the Spanish fleet in European fishing grounds. The authors would also like to thank Carlos Arnáiz Arreondo, Susana Rodríguez Carballo, and Xoán Pérez from the *Unidade Técnica de Baixura* of the Department of Fisheries and Maritime Affairs of the Autonomous Government of Galicia, as well as experts of the ports of A Coruña, Burela, Celeiro, Marín, Ribeira, and Vigo, and the auction markets consulted for this study. Sebastián Villasante acknowledges the financial support of the *Latin American and Caribbean Environmental Economics Program* (LACEEP), the *Canadian International Development Research Center* (IDRC) and the *Swedish International Development Cooperation Agency* (SIDA), and the Karl-Göran Mäler scholarship from *Beijer Institute of Ecological Economics* (Sweden). Rashid Sumaila would also like to thank the financial support of the *Pew Charitable Trusts*, Philadelphia, for their funding of the *Sea Around Us* Project, and the *Lenfest Ocean Program*.

Supplementary material

Supplementary material associated with this article (Tables S1, S2, S3, S4, S5, S6 and Figure S1) can be found in this section.

References

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Figures

Fig. 1. Ecogeographic zones of the Galician coast.

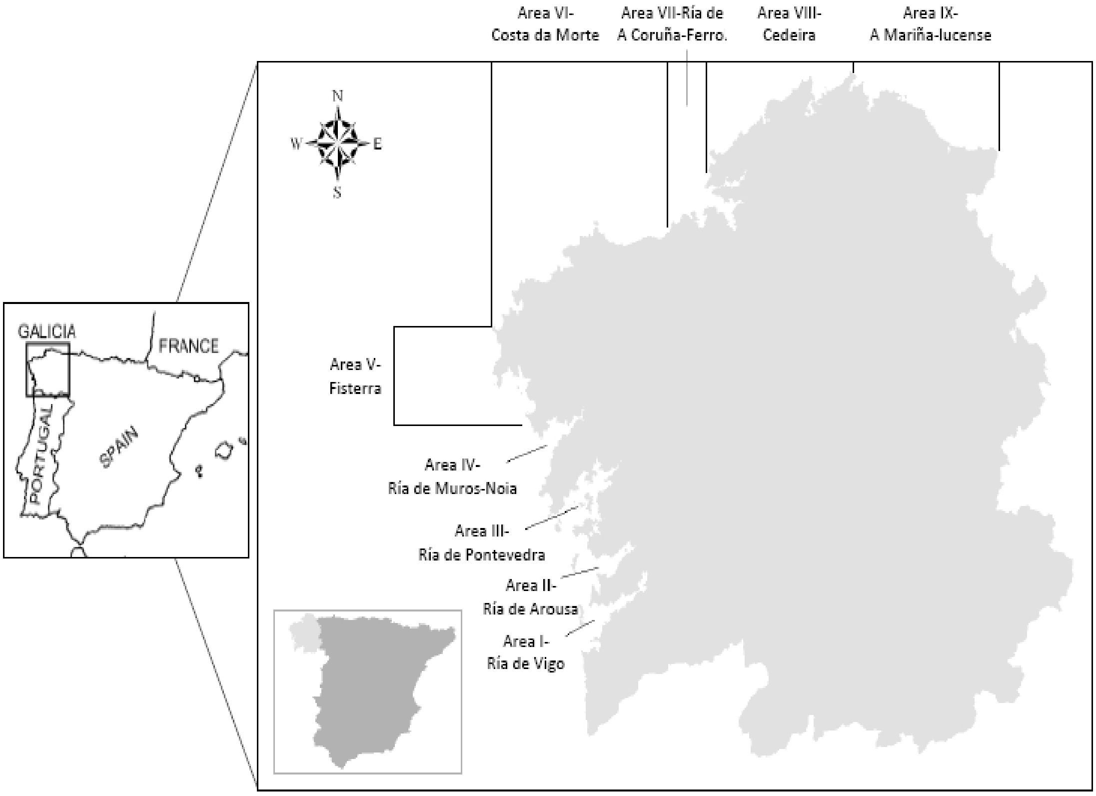


Fig. 2. Reconstructed catches of Galician inshore and coastal fisheries fleet by group of species ($^{<3.25TL}$ species (□), $^{>3.25TL}$species (■), cephalopods (▧), crustaceans (□), molluscs (⧅), algae and invertebrates) (in thousand tonnes) in **a)** Ría de Vigo, **b)** Ría de Pontevedra, **c)** Ría de Arousa, **d)** Ría de Muros, **e)** Fisterra, **f)** Costa da Morte, **g)** Ría de A Coruña-Ferrol, **h)** Cedeira, **i)** A Mariña lucence. Source: own compilation from primary data of auction markets, PescadeGalicia, ICES, and consultations with local experts.

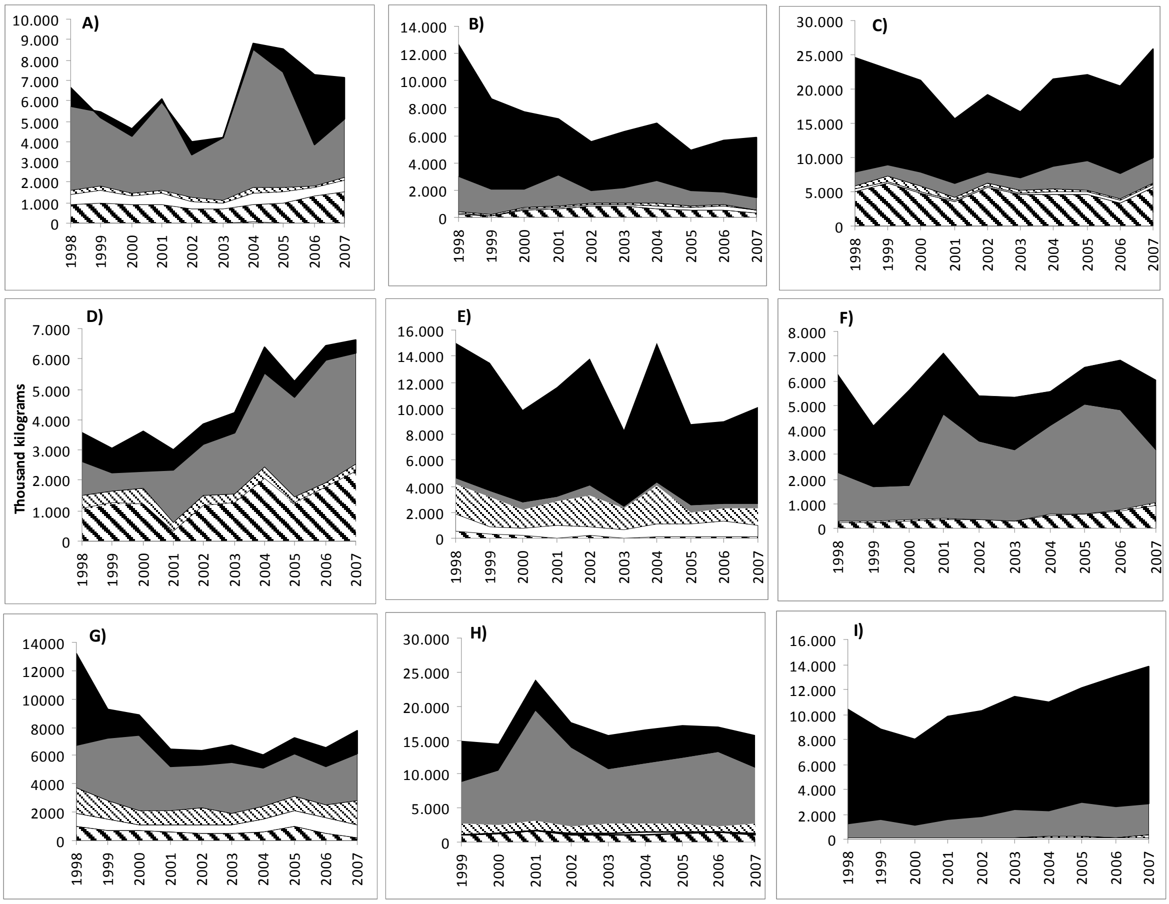
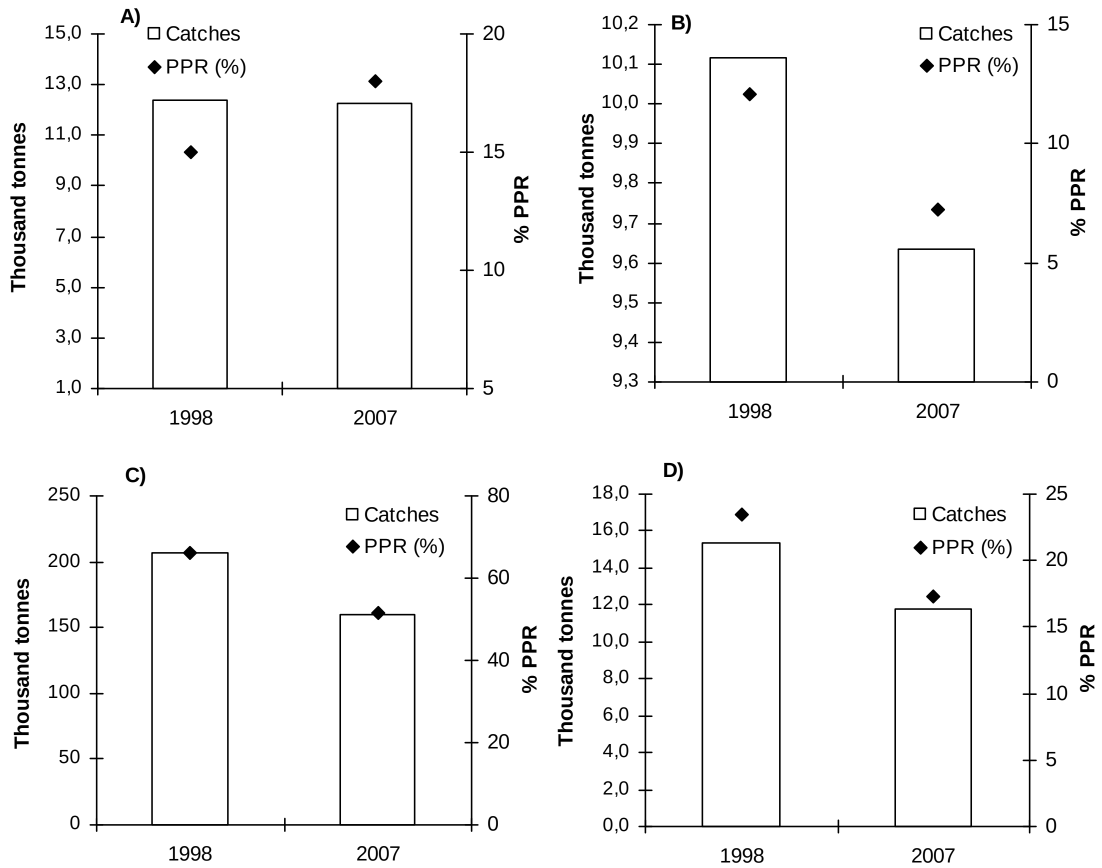


Fig. 3. Fisheries catches (thousand tonnes) and PPR estimates for the **a)** Ría de Vigo, **b)** Ría de Arousa (without mussel farming production), **c)** Ría de Arousa (with mussel farming production), and **d)** Ría de A Coruña-Ferrol. PPR is expressed as percentage of total primary production. Source: own compilation from PescadeGalicia, Varela et al. (1984), Prego (1993), and Bode and Varela (1998).



Tables

Table 1. Reconstructed catches of the Galician inshore fisheries (in tonnes). [§]Catches plus discards. Source: own compilation from primary data of auction markets, PescadeGalicia, ICES, and consultations with local experts.* Landings (not catches) data from PescadeGalicia.

Ecogeographic area	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ría de Vigo	12,384	10,614	8,939	12,074	7,298	8,443	17,368	15,916	11,167	12,253
Ría de A Coruña-Ferrol	15,377	12,278	13,323	8,464	8,987	10,401	8,717	9,828	8,990	11,736
Ría de Arousa	10,117	11,602	10,609	7,849	9,419	8,955	10,842	10,832	8,602	9,634
Costa da Morte	4,310	3,106	4,517	6,085	4,463	4,880	5,217	5,993	5,926	5,620
Ría de Muros	3,563	3,065	3,597	3,009	3,867	4,212	6,402	5,239	6,426	6,636
Ría de Pontevedra	5,372	4,173	3,886	4,923	3,736	3,933	4,985	3,405	3,198	2,844
A Mariña-lucense	2,230	2,435	2,127	2,694	2,687	3,857	3,743	4,202	3,873	4,519
Cedeira	2,150	1,482	1,457	2,397	1,758	1,571	1,654	1,730	1,701	1,565
Fisterra	949	865	614	734	893	556	978	511	514	574
Inshore fleet[§]	**56,452**	**49,620**	**49,069**	**48,228**	**43,109**	**46,808**	**59,905**	**57,658**	**50,398**	**55,381**
Total Galicia*	178,084	156,282	145,294	142,878	128,035	124,666	151,247	161,843	169,326	172,249
Inshore/Galicia (%)	***31.7***	***31.8***	***33.8***	***33.8***	***33.7***	***37.5***	***39.6***	***35.6***	***29.8***	***32.2***

Table 2. Reconstructed catches of the Galician coastal fisheries (in tonnes). [§]Catches plus discards. Source: own compilation from primary data of auction markets, PescadeGalicia, ICES, and consultations with local experts. * Landings (not catches) data from PescadeGalicia.

Ecogeographic area	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ría de Arousa	24,685	22,988	21,347	15,702	19,102	16,601	21,516	22,018	20,511	25,907
Ría de A Coruña-Ferrol	19,590	15,872	15,956	11,352	11,495	12,068	10,972	12,896	11,473	13,469
Ría de Vigo	13,454	11,577	10,060	13,185	8,149	9,988	19,242	18,499	15,389	15,229
A Mariña-lucense	10,427	8,756	8,063	9,854	10,322	11,444	10,932	12,113	12,981	13,897
Ría de Muros	10,660	8,551	7,289	8,257	7,596	6,910	10,740	10,076	12,377	12,882
Costa da Morte	10,380	7,754	9,815	10,432	7,385	6,497	7,195	7,825	8,589	9,108
Ría de Pontevedra	12,648	8,655	7,779	7,247	5,556	6,217	6,898	4,904	5,633	5,902
Cedeira	3,140	2,269	2,122	3,206	2,574	2,147	2,420	2,359	2,516	1,982
Fisterra	1,039	979	721	846	975	594	1.073	633	634	745
Coastal fleet	**106,023,5**	**87,401,2**	**83,150,5**	**80,081,1**	**73,154,0**	**72,465,2**	**90,988,8**	**91,323,6**	**90,101,7**	**99,119,2**
Total Galicia	178,084	156,282	145,294	142,878	128,035	124,666	151,247	161,843	169,326	172,249
Coastal/Galicia (%)	***59.54***	***55.93***	***57.23***	***56.05***	***57.14***	***58.13***	***60.16***	***56.43***	***53.21***	***57.54***

Table 3. Trophic level, mean catch and PPR estimate for all ecogeographic areas of Galician (NW Spain) shelf. Source: own compilation from PescadeGalicia and reconstruction of catches following the steps described in TS1.* Mussel farmed production (not catches).

			1998-2002 (average)			2003-2007 (average)		
Ecogeographic area	**Area (km^2)**	**Type of fishing and aquaculture activity**	**TL**	**Catches (tonnes)**	**PPR ($x10^{12}$ gC)**	**TL**	**Catches (tonnes)**	**PPR ($x10^{12}$ gC)**
Ría de Vigo	502.0	Inshore	3.92	10,261.82	252,687.68	3.68	13,029.40	484.802,00
		Coastal	4.03	11,285.55	15,924.98	3.89	15,669.41	28.106,44
		Mussel farming	2.00	14,070.32*	23,450.56	2.00	11,536.58	19.227,63
Ría de Pontevedra	362.0	Inshore	3.61	4,424.66	1,899,419.86	3.61	3,673.14	1,245,752.22
		Coastal	3.80	8,377,02	245,111.43	3.80	5,910,55	103,156.66
		Mussel farming	2.00	10,050.37*	16,750.40	2.00	8,240.82	13,734.02
Ría de Arousa	452.0	Inshore	3.39	9,919.16	52,588.99	3.18	9.701.000	48,110.30
		Coastal	3.55	20,764.25	354,975.20	3.35	21,310.22	279,207.65
		Mussel farming	2.00	182,076.99*	303,461.48	2.00	149,288.59	248,814.77
Ria de Muros	375.0	Inshore	3.19	3,420.69	151,711.46	3.09	5,783.82	141,393.24
		Coastal	3.70	8,470.55	36,092.05	3.63	10,597. 77	17,288.38
		Mussel farming	2,00	18,927.47*	31,546.59	2.00	15,519.79	25,865.74
Fisterra	376.0	Inshore	4.04	811,025	167,592.56	4.09	626,600	178,839.31
		Coastal	4.06	912,000	90,066.40	4.10	735,800	4,417,017.40
Costa da Morte	481.0	Inshore	3.87	4,495.29	943,983.85	3.84	5,372.04	996,667.30
		Coastal	3.75	9,153.44	158,426.43	3,73	7,842.10	33,102.91
Ría de A Coruña	532.0	Inshore	4.04	11,685.17	671,323.05	3.95	9,934.99	525,323.68
		Coastal	3.73	14,853.55	555,997.91	3.33	12,175.93	326,897.05
		Mussel farming	2.00	12,060.85*	20,100.48	2.00	9,888.98	16,480.83
Cedeira	452.0	Inshore	3.95	1,848.55	276,517.77	3.92	1,644.88	176,769.95
		Coastal	3.84	2,662.10	31,021.26	3.78	2,286.10	31,920.82
A Mariña-lucense	457.0	Inshore	4.07	2,434.33	2,138,610.01	4.03	4,038.01	2,901,313.90
		Coastal	3.77	14,853.14	190,151.04	3.73	12,175.66	191,555.01

Table S1. Sources of data and scientific literature used to reconstruct statistical fisheries catches of the Galician small-scale fisheries

Steps for the reconstruction of catches	Data	Year(s)	Official	Not official§	Source(s)
1. Theoretical framework, methodological routine for the statistical reconstruction of catches	All official statistics as well as reports and publications of the agencies with jurisdiction in this matter	1990s-2000s	✓		Zeller et al. (2003), Bhathal (2005), Zeller and Pauly (2007), Booth et al., (2008)
2. Identification of the sectors, official statistics landings, existing time series	Total landings of species by ecogeographic areas	1998-2007	✓		PescadeGalicia
	Total catches of inshore and coastal fleet from the Galician continental shelf	1998-2007		✓	Auction markets and ports of A Coruña, Burela, Celeiro, Marín, Riberia and Vigo
3. Identification and characteristics of inshore and coastal fisheries	Small-scale fisheries	1990s-2000s	✓		CIS (1991), Freire et al. (2002), Guerra (2002), Molares (2002), Méndez and Vilas (2003), Alba (2006), Pereiro and García del Hoyo (2007), Villasante et al. (2007), García-Negro et al. (2009), González-Garcés et al (2009)
4. Information of commercial marine fishes, crustaceans and mollusk species	Description and main characteristics of commercial species (habitat, size, depth, longevity)	1980s-2000s	✓		Rodriguez Solórzano et al. (1983), CIS (1991); López Veiga et al. (1993), Rodriguez Villanueva et al. (1994, 1994a), Fariña et al. (1997), Lahuerta Mariño and Vázquez Álvarez (2000), Froese and Pauly (2008)
5. Detailed information main fisheries	Algae		✓		Valeriano Moldes (2007)
	Atlantic scallop		✓		Arnáiz (2005), Otero et al. (2005), Cerviño-Otero et al. (2006), Rocha et al. (2006), Pereira and García del Hoyo (2007)
	Barnacle		✓		López Veiga et al. (1993), Molares and Freire (2003)
	Common sole		✓		ICES reports
	European hake		✓		López Veiga et al. (1993), ICES reports
	European sardine		✓		López Veiga et al. (1993), Bode et al. (2009)
	Golden cuttlefish		✓		López Veiga et al. (1993), Arnáiz (2007), Rocha et al (2006) Cerviño-Otero et al. (2006)
	Groved carpet shell		✓		López Veiga et al. (1993),
	King scallop		✓		Sánchez Mata et al. (2007)
	Norway lobster		✓		López Veiga et al. (1993), ICES reports
	Octopus		✓		López Veiga et al. (1993), Rocha et al. (1994), Arnáiz (2005)
	Pod razor shell		✓		Darriba and Miranda (2006)
	Pullet carpet shell		✓		Gómez-León et al. (2007)
	Sea urchin		✓		López Veiga et al. (1993), Fernández Pulpeiro et al. (2006)
	Spinous spider crab		✓		López Veiga et al. (1993), González-Gurriarán et al. (1998)
6. Exclusion of species caught out of the continental platform	Given that a significant number of species landed in Galician ports come from fishing grounds from all over the world, not all these have been included in the analysis. As they are caught beyond the limits of the continental platform, we exclude some species which do not fulfill the criteria highlighted in section 2.1 of the main text of the paper. Thus, 25 species were excluded because they occur mainly on the continental shelf.	1990s-2000s		✓	This study
7. Selection of species of artisanal fishing at the main ports in terms of catches volume (A Coruña, Burela, Celeiro, Marín, Ribeira and Vigo)	As the Galician fleet based in Galicia does not only fish at the coast but also in other fishing grounds, it is necessary to identify the species which, having been landed in the main ports such as A Coruña, Burela, Celeiro, Marín, Ribeira and Vigo, were caught by the inshore and coastal fleet. In	1990s-2000s		✓	This study

	order to do it, we sent a direct survey to each of these ports from April–October 2008, with the list of species which are only caught at the coast and assuming that they come from coastal and inshore fishing.				
8. Collecting discards data	Discards of Anglerfish, Common Sole, Megrim, and Norway lobster	1998-2006	✓		ICES (several years)
	Discards of Northern Hake stock	1998-2002	✓		Pérez et al. (2005)
	Discards of Southern Hake stock	1994, 1997, 1999, 2000, and 2003-2007	✓		Santos et al. (2008)
9. Interpolation and extrapolation of values in the absence of data for years, areas, or species	From steps 1-6.	1990-2007		✓	This study
10. Collecting other relevant data	Chlorophyll (Chl-*a*), and phytoplankton				See Appendix A, Bode and Varela (1994), Figueiras et al. (2002), Cermeño et al. (2006)
	Climate change	1990-2007	✓	✓	Álvarez-Salgado et al. (2009), Bode et al. (2009), Freire et al. (2009), Otero et al. (2009), Varela et al., (2009)
	Mussel farming production				OPMEGA (2001, 2002, 2003, 2004, 2005 and 2006), Bermejo et al. (2006), Rodríguez Rodríguez (2009)
11. Consultations with local experts to fill data gaps and validated them		1998-2007	✓	✓	Consellería do Mar, and ports of A Coruña, Burela, Celeiro, Marín, and Vigo.
12. Final estimation of the time series of catches for Galician inshore and coastal fisheries		1998-2007	✓	✓	This study
13. From point 1-12, we developed a database containing estimates of primary productivity required to sustain Galician small-scale fisheries catches		1998-2007	✓		This study

Source: Source: own compilation from primary data of auction markets, PescadeGalicia, ICES, and consultations with local experts.[§] This category includes personal consultations with local experts, unpublished data and own data and information from researchers and local institutions.

Table S2. Common and scientific names, mean depth and trophic level (TL) of caught species by the small-scale (inshore and coastal) fisheries in Galicia. [1]Trophic level values based on a standard error ± 0.24 (CI=95%). [2] Trophic level estimated from a number of food items using a randomized resampling routine.[§]It also includes the species *Crassosotrea gigas*. [†] Family name. [*]It includes the species *Aspitrigla obscura* and *Trigla lyra/lucerna*. Source: own compilation from primary data of auction markets, PescadeGalicia, ICES, Algaebase, Cephbase, Fishbase, PescadeGalicia, Rodríguez Solórzano et al. (1983), Lahuerta Mouriño and Vázquez Álvarez (2000), and Rodríguez Villanueva et al. (1994, 1994a), and consultations with local experts.[§] Local name.

Species inhabit between 0-50 m depth (N=94)					
Common name	**Scientific name**	**TL[1]**	**Common name**	**Scientific name**	**TL[1]**
Allis shad	*Alosa alosa*	3.62	Knobbed triton	*Charonia rubicunda*	2.00
Atlantic saury	*Scomberesox saurus*	3.64	Lamellated haliotis	*Haliotis tuberculata*	2.00
Argazo bravo	*Saccorhiza polyschides*	2.00	Leerfish	*Lichia amia*	4.50
Ballan wrasse	*Labrus bergylta*	3.07	Leitura de mar[§]	*Chlorophyceae*	2.00
Banded carpet shell	*Venerupis rhomboideus*	2.10	Limpet	*Patella vulgate* [†]	2.00
Barbel	*Barbus barbus*	3.10	Lugworm	*Arenicola marina*	2.00
Barnacle	*Pollicipes pollicipes*	2.50	Mature dosinia	*Dosinia exoleta*	2.00
Blue-leg swimming crab	*Liocarcinus depurator*	2.60	Meagre	*Argyrosomus regius*	3.70
Blue-spotted sea bream	*Pagrus coeruleostictus*	3.81	Mediterranean moray	*Muraena helena*	4.18
Bolos[§]	*Ammodytidae*[†]	4.15	Mediterranean slimehead	*Hoplostethus mediterraneus*	2.00
Brill	*Scophthalmus rhombus*	3.79	Midsize squid	*Alloteuthis media*	2.00
Camarote prawn	*Penaeus kerathurus* [c]	2.00	Miñoca de tubo[§]	*Diopatra neapolitana*	2.00
Comber	*Serranus cabrilla*	3.35	Morruncho[§]	*Ostrea plicata*	2.00
Common cuttlefish	*Sepia officinalis*	3.60	Muxo[§]	*Mugilidae*[†]	3.01
Common edible cockle	*Cerastoderma edule*	2.10	Norway lobster	*Nephrops norvegicus*	2.60
Common European bittersweet	*Glycymeris glycymeris*	2.00	Piarda[§]	*Atherinidae*[†]	3.24
Common octopus	*Octopus vulgaris*	4.10	Pink cuttlefish	*Sepia orbignyana*	3.60
Common otter shell	*Lutraria lutraria*	2.00	Pullet carpet shell	*Venerupis pullastra*	2.10
Common prawn	*Palaemon serratus*	2.70	Queen scallop	*Chlamys opercularis*	2.00
Common sea bream	*Pagrus pagrus*	3.65	Razor shell	*Ensis arcuatus*	2.40
Common sole	*Solea vulgaris*	3.13	Rock sea urchin	*Paracentrotus lividus*	2.00
Common spiny lobster	*Palinurus elephas*	2.60	Rockpool prawn	*Palaemon elegans*	2.60
Common two-banded sea bream	*Diplodus vulgaris*	3.24	Salema	*Sarpa salpa*	2.10
Cuckoo wrasse	*Labrus bimaculatus*	3.91	Sand sole	*Pegusa lascaris*	3.19
Deep-sea red crab	*Chaceon affinis*	2.60	Scarlet shrimp	*Plesiopenaeus edwardsianus*	2.30
Deep-water rose shrimp	*Parapenaeus longirostris*	2.70	Sea anemona	*Anemonia sulcata*	2.00
Dragonet	*Callionymus lyra*	3.27	Sea lamprey	*Petromyzon marinus*	4.37
Dwarf bobtail	*Sepiola rondeleti*	3.20	Sea thong	*Himanthalia elongata*	2.00
Edible crab	*Cancer pagurus*	2.60	Sea trout	*Salmo trutta trutta*	3.16
Edible periwinkle	*Littorina littorea*	2.00	Shore rockling	*Gaidropsarus mediterraneus*	3.50
European flat oyster	*Ostrea edulis*[§]	2.00	Smooth-hound	*Mustelus mustelus*	2.30
European lobster	*Homarus gammarus*	2.60	Spinous spider crab	*Maja squinado*	2.30
European seabass	*Dicentrarchus labrax*	3.79	Spotted seabass	*Dicentrarchus punctatus*	3.94
European sprat	*Sprattus sprattus*	3.00	Stackhouse	*Codium tomentosum*	2.00
European squid	*Loligo vulgaris*	3.20	Sturgeon	*Acipenser sturio*	3.53
Flounder	*Platichthys flesus*	3.26	Surf clam	*Spisula solida*	2.00
Gilthead sea bream	*Sparus aurata*	3.26	Sword razor shell	*Ensis siliqua*	2.00
Golden carpet shell	*Venerupis aurea*	2.10	Tope shark	*Galeorhinus galeus*	4.30
Great Atlantic scallop	*Pecten maximus*	2.00	Topknot	*Zeugopterus punctatus*	3.99
Green crab	*Carcinus maenas*	2.60	Truncate donax	*Donax trunculus*	3.20
Grey wrasse	*Symphodus gryseuss*	3.27	Twaite shad	*Alosa fallax*	3.59

Grooved carpet shell	*Ruditapes decussates*	2.00	Variegated scallop	*Chlamys varia*	2.10
Grooved razor clam	*Solen marginatus*	2.00	Velvet swimming crab	*Necora puber*	2.60
Horned octopus	*Eledone cirrhosa*	4.10	Wakame	*Undaria pinnatifida*	2.00
Irish moss	*Chondrus crispus*	2.00	Warty venus	*Venus verrucosa*	2.00
Japanese carpet shell	*Ruditapes philippinarum*	2.00	Wedge sole	*Dicologlossa cuneata*	3.32
Kelp	*Laminariaceae sp.*†	2.00	White seabream	*Diplodus sargus*	3.04
Species inhabit between 0-100 m. depth (N=28)			**Species inhabit between 0-200 m. depth (N=31)**		
Angler	*Lophius piscatorius*	4.49	Atlantic cod	*Gadus morhua*	4.01
Axillary seabream	*Pagellus acarne*	3.48	Atlantic horse mackerel	*Trachurus trachurus*	3.64
Black scorpionfish	*Scorpaena porcus*	3.50	Atlantic mackerel	*Scomber scombrus*	3.65
Black-bellied angler	*Lophius budegassa*	4.49	Blackspot sea bream	*Brama brama*	4.08
Broadtil squid	*Illex coindetii*	3.20	Blue shark	*Prionace glauca*	4.24
Common dentex	*Dentex dentex*	4.50	Bogue	*Boops boops*	3.00
Common pandora	*Pagellus thrinnus*	3.40	Bullet tuna	*Auxis rochei*	4.27
Dab	*Limanda limanda*	3.29	Dogtooth tuna	*Orcynopsis unicolor*	4.50
European conger	*Conger conger*	4.29	European anchovy	*Engraulis encrasicolus*	3.11
European locust lobster	*Scyllarus arctus*	2.50	European eel	*Anguilla anguilla*	3.53
European sardine	*Sardina pilchardus*	2.61	European hake	*Merluccius merluccius*	4.48
Forkbeard	*Phycis phycis*	4.11	Greater forkbeard	*Phycis blennoides*	3.73
Garfish	*Belone belone*	4.21	Haddock	*Melanogrammus aeglefinus*	4.09
John dory	*Zeus faber*	4.50	Large-eye hartail	*Trichiurus lepturus*	4.45
Lesser flying squid	*Todaropsis eblanae*	3.20	Ling	*Molva Molva*	4.25
Red scorpionfish	*Scorpaena scrofa*	3.50	Little tunny	*Euthynnus alletteratus*	4.44
Rainbow	*Coris julis*	3.20	Megrim	*Lepidorhombus* spp†	3.69
Pollack	*Pollachius pollachius*	4.15	Painted comber	*Serranus scriba*	3.82
Pouting	*Trisopterus luscus*	3.73	Piked dogfish	*Squalus acanthias*	3.89
Red gurnard	*Triglidae**†	3.42	Poor cod	*Trisopterus minutus*	3.83
Red mullet	*Mullus barbatus*	3.42	Portbeagle	*Lamna nasus*	4.50
Short-finned squid	*Illex illecebrosus*	3.20	Rock fish-blue mouth	*Helicolenus dactylopterus*	3.81
Shri drum	*Umbrina cirrosa*	3.46	Red sea bream	*Pagellus bogaraveo*	3.66
Striped red mullet	*Mullus surmuletus*	3.42	Saithe	*Pollachius virens*	3.75
Tickback sole	*Microchirus variegates*	3.28	Scalloped hammerhead	*Sphyrna* spp†	4.20
Turbot	*Psetta maxima*	3.96	Shortfin mako	*Isurus oxyrinchus*	4.50
Whiting	*Merlangius merlangius*	4.29	Skates	*Raja* spp†	3.98
Wrinkled swim crab	*Liocarcinus corrugatus*	3.20	Small-spotted catshark	*Scyliorhinus canicula*	3.69
			Spotted chub mackerel	*Scomber australasicus*	3.65
			Thresher shark	*Alopias vulpinus*	4.21
			Wreckfish	*Polyprion americanus*	3.83

Table S3. Main estimates of primary production in Galician marine ecosystems Note: Biomass factor = 50 gC: g Cla (in all the biomass estimates). [1]Annual averages based on in-situ measurements with C-14 (1984-1992 period). [2]Average of net production estimates based on surface temperatures (AVHRR satellite), during 1982-1999 (March-October being the only outcropping period). [3]Annual average of net production estimates based on surface temperatures (AVHRR satellite) during 1998-2004 and of chlorophyll-a estimates (SeaWifs satellite). [4]Annual average based on in-situ measurements with C-14 (year 1993).[5]Annual average based on in-situ measurements with C-14 (various years). [6]Annual average based on in-situ measurements with C-14 (year 1989). [7]Annual average based on in-situ measurements with C-14 (various years). [8] Annual average estimated based on carbon balances (year 1986).

Area	Primary production ($x10^{12}$ gC/ m^2 y^{-1})	Source
Galicia (continental shelf)[1]	315,0	Bode et al. (1996), Tenore et al. (1995), OSPAR (2000)
Cantabrian Sea (continental shelf)[1]	329,6	Bode et al. (1996), OSPAR (2000)
Galicia (continental shelf in front of Rías Baixas)[2]	334,12*-334,63**	Álvarez-Salgado et al. (2002)*, Varela et al. (2006)**
Galicia (ocean in front of Rías Baixas)[3]	210,1	Varela et al. (2006)
Ría de Coruña[4]	608,0	Bode and Varela (1998)
Ría de Ares[4]	166,0	Bode and Varela (1998)
Ría de Ferrol[4]	201,0	Bode and Varela (1998)
Ría de Arousa[5]	250,0	Varela et al. (1984)
Ría de Arousa[6]	537,0	Álvarez-Salgado et al. (1996)
Ría de Vigo[7]	260,0	Fraga (1976)
Ría de Vigo[8]	288,0	Prego (1993)

Table S4. Trophic level, average catches and PPR of main commercial species harvested by the Galician inshore and coastal fishing fleet in the ecogeographic area of Ría de Vigo. Source: own compilation from primary data of auction markets, PescadeGalicia, ICES, and consultations with local experts. * Inshore and coastal fisheries.

			1998-2002 (average)		2003-2007 (average)	
Common name	**Scientific name**	**TL**	**Catches (t)**	**PPR ($gC/10^{12}$/year)**	**Catches (t)**	**PPR ($gC/10^{12}$/year)**
European sardine	*Sardina pilchardus*	2.61	3,430.98	64,160.40	5,335.40	99,773.67
Atlantic mackerel	*Scomber scombrus*	3.65	506.03	37,672.82	1,608.70	119,763.42
Atlantic horse mackerel	*Trachurus trachurus*	3.64	312.69	22,749.09	620.66	45,155.18
Horned octopus	*Eledone cirrhosa*	4.10	253.89	16,846.12	462.08	30,659.67
Common octopus	*Octopus vulgaris*	4.10	293.87	61,662.07	327.27	68,669.42
Common edible cockle	*Cerastoderma edule*	2.10	179.16	375.93	210.42	441.52
European squid	*Logilo vulgaris*	3.20	177.34	4,684.42	176.63	4,665.80
Pouting	*Trisopterus luscus*	3.73	173.36	15,516.75	173.29	15,510.96
Rock sea urchin	*Paracentrotus lividus*	2.00	193.37	643.07	152.39	506.53
Grooved carpet shell	*Ruditapes decussatus*	2.00	256.53	80.75	85.77	92.52
Blackspot sea bream	*Brama brama*	4.08	78.17	17,985.68	209.35	48,165.72
Norway lobster	*Nephrops norvegicus*	2.60	105.19	697.42	117.34	778.53
Banded carpet shell	*Venerupis rhomboides*	2.10	72.90	153.00	125.90	264.17
Barnacle	*Pollicipes pollicipes*	2.50	78.45	1,308.09	80.75	1,345.99
White seabream	*Diplodus sargus*	3.04	7.51	217.53	64.60	1,871.03
Main 15 species			**6,119.45**	**244,753.15**	**9,685.93**	**437,664.12**
Ría de Vigo*			**11,285.55**		**15,669.41**	

Table S5. Trophic level, average catches and PPR of main commercial species harvested by the Galician inshore and coastal fishing fleet in the Ría de Arousa. Source: own compilation from primary data of auction markets, PescadeGalicia, ICES, and consultations with local experts. * Inshore and coastal fisheries. # Local name. † Family name.

			1998-2002 (average)		2003-2007 (average)	
Common name	**Scientific name**	**TL**	**Catches (t)**	**PPR ($gC/10^{12}/year$)**	**Catches (t)**	**PPR ($gC/10^{12}/year$)**
Atlantic horse mackerel	*Trachurus trachurus*	3.64	8,180.22	595,132.95	6,662.67	484,727.22
European pilchard	*Sardina pilchardus*	2.61	1,748.85	11,874.15	3,241.54	22,009.04
Atlantic mackerel	*Scomber scombrus*	3.65	1,941.15	1,941.15	2,583.12	192,306.55
Common edible cockle	*Cerastoderma edule*	2.10	1,457.55	3,058.26	1,625.87	3,411.42
Mature dosinia	*Dosinia exoleta*	2.00	1,198.28	1,997.15	877.68	1,462.81
Pullet carpet shell	*Venerupis pullastra*	2.10	950.45	1,994.26	517.89	1,086.65
Common octopus	*Octopus vulgaris*	4.10	743.80	156,065.84	549.82	115,365.77
Japanese carpet shell	*Ruditapes philippinarum*	2.00	533.14	888.57	638.29	1,063.82
Spotted chub mackerel	*Scomber australasicus*	3.65	135.64	10,098.43	871.60	64,888.59
Grooved carpet shell	*Ruditapes decussatus*	2.00	383.14	638.57	285.26	475.44
European conger	*Conger conger*	4.29	268.32	87,199.18	325.14	105,663.70
Banded carpet shell	*Venerupis rhomboides*	2.00	314.87	660.67	270.86	568,34
Pouting	*Trisopterus luscus*	3.73	333.58	29,857.22	227.38	20,352.42
Bolos#	*Ammodytidae*†	2.00	297.00	69,921.50	144.03	33,909.38
Lesser flying squid	*Todaropsis eblanae*	3.20	299.00	7,898.06	137.376	3,628.78
Main 15 species			**18,785.05**	**979,225.96**	**18,958.59**	**1,050.91**
Ría de Arousa*			**20,764,81**		**21,310.61**	

Table S6. Trophic level, average catches and PPR of main commercial species harvested by the Galician inshore and coastal fishing fleet in the Ría de A Coruña-Ferrol. Source: own compilation from primary data of auction markets, PescadeGalicia, ICES, and consultations with local experts. * Inshore and coastal fisheries. # Local name. † Family name.

			1998-2002 (average)		1998-2002 (Average)	
Common name	**Scientific name**	**TL**	**Catches (t)**	**PPR ($gC/10^{12}$/year)**	**Catches (t)**	**PPR ($gC/10^{12}$/year)**
European sardine	*Sardina pilchardus*	2.61	3,514.47	65,721.69	2,878.22	53,823.60
Atlantic horse mackerel	*Trachurus trachurus*	3.64	1,518.15	113,022.31	973.43	70,819.99
Norway lobster	*Nephrops norvegicus*	2.60	603.38	4,003.54	843.34	5,595.71
Lesser flying squid	*Todaropsis eblanae*	3.20	704.17	18,600.64	701.65	18,534.08
European hake	*Merluccius merluccius*	4.48	362.54	182,476.25	379.23	190,879.41
Atlantic mackerel	*Scomber scombrus*	3.65	478.70	35,638.58	259.90	19,349.06
Common octopus	*Octopus vulgaris*	4.10	427.37	89,672.25	312.26	65,519.34
Japanese carpet shell	*Ruditapes decussatus*	2.00	473.41	993.33	215.10	451.33
European conger	*Conger conger*	4.29	352.12	114,431.89	206.17	67,000.04
Comber	*Serranus cabrilla*	3.35	165.05	6,158.67	242.58	9,051.45
Black-bellied angler	*Lophius budegassa*	4.49	141.64	72,955.39	154.08	79,363.86
Horned octopus	*Eledone cirrhosa*	4.10	145.12	30,450.76	140.58	29,497.84
Rock fish-blue mouth	*Helicolenus dactylopterus*	3.81	146.87	15,805.21	74.34	7,999.81
European squid	*Logilo vulgaris*	3.20	139.99	3,697.86	45.28	1,196.16
Small spotted catshark	*Scyliorhinus canicula*	3.69	102.49	8,366.43	23.25	1,898.22
Main 15 species			**9,275.54**	**761,994.80**	**7,449.47**	**620,979.90**
Ría A Coruña-Ferrol*			**14,853.10**		**12,175.62**	

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