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Estimating the economic impact of the Prestige oil spill on the Death Coast (NW Spain) fisheries

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ABSTRACT

This paper presents an estimation of the economic effects of the Prestige oil spill in Galicia, focusing on the Death Coast fisheries and using fish landings as a market technique. Examining the evolution of landings in the Death Coast before and after the accident, the analysis reveals two opposing trends, with landings of some species increasing and those of other species diminishing.

However, it is necessary to stress that the results obtained from the use of landings as a main indicator are not enough to confirm the influence of the oil spill on stocks. Moreover, these results are quite predictable, since factors such as the species relationship with substratum, their sensitivity to the polluting oil, the way they prey on one another and the fishing effort, all affect these preliminary conclusions.

0. Introduction

The range of damage suffered after an oil spill is very wide. Such damage affects the productive areas related to the sea either directly or indirectly (for example, fish or tourism). In the same way, the marine environment in general experiences important changes. Thus, a wide range of goods suffers damages. Some of these goods are perfectly recognised by the market and others not to the same extent, but all of them have a use or existence value for the society in general. In the case of the *Prestige* accident, the economic repercussions of the alteration of the marine environment for those sectors most directly dependent on Galician fishing activities will not only affect fishing, shellfish collecting and aquaculture subsectors, but also others which directly depend on them, such as net makers, transport companies, shipyards, supply companies, wholesalers, etc., with knock-on effects on the remaining economic sectors.

With the objective of partially examining these impacts, the aim of this paper is to estimate the economic effect of the *Prestige* accident on the Death Coast fisheries, by using data on fresh fish landings as a market technique for evaluating the amount of resource that was not placed on the market due to the spill. For this reason, this research makes a valuable contribution to the study of this catastrophe by: (i) presenting, for the first time, a detailed analysis of the level of dependence on fishing in the Death Coast area, (ii) analysing trends in fresh fish landings at all auction markets of the Death Coast both in volume and value before (2001–2002) and after (2003–2005) the accident, presenting various case studies on the most important affected species and (iii) carrying out a lineal regression model by simulating a scenario for predicted landings in the absence of this oil spill.

1. The *Prestige* accident

On 13 November 2002, the *Prestige* oil tanker, loaded with 77,000 tonnes of oil, sent an SOS call at Cabo Fisterra (Galicia). The vessel initially moved towards the shore, later turned in a northerly direction, and finally moved south along a great part of the Galician coast, until it finally sank on 19 November at 130 nautical miles off shore, in a water depth of 3500 m.

The fuel spilt on the coast had a high level of toxicity and viscosity [1], with an enormous pollution capacity due to its benzene and toluene content, and with possible effects on the health of the population in the medium and long term [2]. Fuel impacted on areas bearing a very high ecological value, and mainly on areas protected and catalogued for their environmental and faunal interest. The Death Coast, the wetlands and marshes in Corrubedo and Baldaio, the mouth of the Anllóns River, and the Traba Lake are only some examples of the damaged areas, all of them among the richest ornithological areas of Europe. The Sisargas Islands and Cape Vilán, which are home to the last remaining colonies of guillemot (*Uria aalge*), green cormorant (*Phalacrocorax aristotelis*) and kittiwake gull (*Rissa tridactylae*),

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were also damaged. Furthermore, the affected coastline is also extremely rich in fish species, molluscs and marine crustaceans, all of them highly valued in the market for human consumption.

With regard to the impact on the marine ecosystem in the medium and long term, the oil spill acts in a variety of ways, ultimately preventing organisms from reaching their normal reproduction rates, either by affecting the reproductive capacity of adults, their egg-laying viability or larvae survival. The absence of eggs and larvae has an impact not only on the affected species but also leaves other species in the food chain without nourishment. Moreover, this anomalous situation, which causes losses in biodiversity and a serious biological and ecological impact, cannot be isolated from the economic impact, which will last for a long time [3]. The impact of this oil spill is more serious than that in other catastrophes, due to the extensive area of the affected coast. Part of this coast had already been affected by previous oil spills (*Polycommander* and *Erkowit* in 1970, *Urquiola* in 1976, *Andros Patria* in 1978, *Casón* in 1987 and *Aegean Sea* in 1992).

These successive catastrophes, some of them occurring in the same place, act as destabilising mechanisms in an already recovering ecosystem. As a consequence, the seriousness of this ecological catastrophe intensified the need to evaluate its effects in the most diverse scientific fields. At present, if compared to other ecological accidents that have happened in Galicia, this catastrophe has given rise to a prolific and varied literature. The response of the scientific community has been the development of a wide range of research studies [4,5]. These studies deal with the geological, hydrographical and seismic conditions of the area in which the sinking occurred [6–10], the chemical composition of the oil [11–13] and its toxitity [1], its treatment [14,15], the use of dispersants to alleviate oil effects [16,17] and the use of bioremediation techniques [18]. Likewise, different aspects have been examined: effects on the affected territories [19–21], matters related to shore cleaning actions [22,23], the coordination of volunteers [24], repercussions on the non-commercial value of the Galician coast [25], the promotion of sectors from the affected areas [26], the impact on the value of use of our shores [27] and issues related to the legal mechanisms for compensating admissible damage [28,29].

In the field of fishing activity, analyses have been carried out on biological characteristics [30–32], repercussions on marine birds [33,34], on fish and molluscs populations [35–41], as well as on features related to the impact on the fishing and shellfish-collecting sectors and tourism [42–44].

2. The *Death Coast* area

As a result of the disaster, the Fishing and Aquaculture Councillor of the Autonomous Galician Government established temporary bans on fishing and shellfish-collecting activities in different areas of the Galician coast. The bans affected 913.5 km for fishing and 788 km for shellfish collecting of a coastline of 1121 km, although bans on the Death Coast for certain species and fishing methods lasted even longer.

Regarding fresh fish landings, no import flows of fish products were identified from markets outside the Death Coast.[1] Therefore, the landing behaviour reflects a rather homogeneous reality marked by the following features: (i) no significant changes are identified in the fishing gear or in business strategies of the fishermen operating in the area and (ii) there are no signs of a concentration in the offer of fish products. Moreover, the Death Coast is characterised as an important tourist attraction, because of its landscape, natural environment and ethnographic peculiarities and also very especially due to the symbolism of Fisterra as the European Finisterrae or as the ending place of St. James Way (*Camino de Santiago*).

2.1. The level of dependence on fishing on the Death Coast

Before analysing landing patterns as a method of assessing the impact of the *Prestige* disaster, this area's level of dependence on fishing in terms of employment has to be examined.

The fishing industry comprises a range of activities that is much wider than those traditionally known as fishing and shellfish collecting, mussel farming and other aquaculture activities. Thus, it also covers industries such as wholesale and retail trading, and other fishing-related services and processing industries, that is, large fish-storage freezers, services provided by fish markets and fishermen's guilds, manufacturers' associations, the public administration and research activities carried out at marine institutes and universities.

The level of dependence on fishing will be mainly assessed on the basis of employment data in the area, despite the fact that existing statistics published by the Fishing and Aquaculture Councillor of the Autonomous Galician Government, the Marine Social Institute, the Galician Institute of Statistics, and the Ministry of Agriculture, Fisheries and Food, and the Ministry of Labour and Social Affairs, do not include complete data on employment in the fishing sector but only information on employees who have a direct involvement in the fishing activities.[2] However, in spite of this shortage, the statistics prepared by the Ministry of Labour and Social Affairs do represent an adequate source of information, since they include contributors to the Social Security System from all the coastal municipalities comprising the Death Coast area (Carnota, Camariñas, Corcubión, Fisterra, Laxe, Malpica, Muxía and Ponteceso) for the period 2001–2005 in the agriculture, building, manufacturing industry, fishing and service sectors. Likewise, the relevance of each sector in each municipality and in the whole area is compared in this paper, and a *Relative Specialisation Index*[3] is also elaborated, which should allow us to gain an insight into the degree of specialisation in each sector with reference both to the area and to the whole Autonomous Community of Galicia.[4]

According to data from the National Institute of Social Security, in the year 2005 the above municipalities had a high percentage of contributors in the tertiary (34%) and fishing (21%) sectors, which represented 55% of all industrial sectors (Tables 1–4). Despite this, cross-industrial relationships among the fishing sector, the secondary and tertiary industrial sectors should also be reinterpreted, since fishing activities both provide and demand goods and services to and from each of these sectors, given the role played by fishing as a key driver for other economic sectors [45]. This would increase the importance of fishing activities in the Death Coast economy [21].

[1] This was revealed by a direct survey made among local fishermen's guilds, which let us discard the role of these variables in the potential changes in the offer of fish products.

[2] Fishermen on board of Galician joint ventures and under other schemes both in EU and non-EU countries are not included in national, regional and European statistics. Therefore, the data below are to be understood as a *minimum-data approach* in the understanding of the size of the Galician fishing sector.

[3] *Specialisation index* $= (E_{ij}/E_j)/(E_i/E)$, where E_{ij} is the number of employees in the industry i of the municipality j, E_j the total number of employees in municipality j, E_j the number of employees in the industry i in the whole area of Fisterra and E the total number of employees in the area.

[4] For methodological purposes we only selected those activities with 10 or more employees, the relative specialisation in each industry and activity area being expressed through the definition of rates above 1, which is a sign of a highly specialised industry.

Table 1
Importance of the economic sectors in the coastal municipalities of the Death Coast, 2001 (number of contributors)

Municipality	Agriculture	Fishing	Manufacturing	Building	Services	Total
Camariñas	42	407	146	139	360	1094
%/Municip.	*3.84*	*37.2*	*13.35*	*12.71*	*32.91*	
Carnota	152	259	402	116	278	1207
%/Municip.	*12.59*	*21.46*	*33.31*	*9.61*	*23.03*	
Corcubión	6	23	18	31	176	254
%/Municip.	*2.36*	*9.06*	*7.09*	*12.2*	*69.29*	
Fisterra	61	303	56	70	273	763
%/Municip.	*7.99*	*39.71*	*7.34*	*9.17*	*35.78*	
Laxe	65	114	52	129	205	565
%/Municip.	*11.5*	*20.18*	*9.20*	*22.83*	*36.28*	
Malpica	182	346	385	203	483	1599
%/Municip.	*11.38*	*21.64*	*24.08*	*12.70*	*30.21*	
Muxía	285	220	130	128	249	1013
%/Municip.	*28.13*	*21.72*	*12.83*	*12.64*	*24.58*	
Ponteceso	290	140	293	324	463	1510
%/Municip.	*19.21*	*9.27*	*19.40*	*21.46*	*30.66*	
Total	1083	1812	1482	1140	2487	8004

Table 2
Relative Specialisation Index by sectors with respect to Galicia, 2001

Area	Municipality	Agriculture	Fishing	Manufacturing	Building	Services
Muros	Carnota	7.0	2.5	3.5	2.7	0.7
	Muros	4.2	2.1	2.5	4.0	1.8
	Camariñas	0.2	12.1	1.5	0.6	0.8
Terra de Soneira	Vimianzo	2.5	0.0	3.0	2.1	1.3
	Zas	2.9	0.1	1.3	1.3	0.9
	Cee	1.3	1.3	4.6	3.1	1.1
Fisterra	Corcubión	0.7	0.2	0.4	0.2	0.1
	Dumbría	3.0	0.0	2.7	1.2	0.1
	Fisterra	1.6	4.3	0.6	0.7	0.2
	Muxía	3.5	3.1	2.6	1.3	0.2
	Carballo	2.5	3.2	2.6	2.2	1.3
	Cabana	1.0	0.7	0.3	0.2	0.1
	Coristanco	1.5	0.0	0.3	0.3	0.2
Malpica	Laracha, A	1.6	0.7	0.5	0.7	0.3
	Laxe	0.3	4.6	0.0	0.1	0.1
	Malpica	0.7	10.0	0.4	0.2	0.1
	Ponteceso	1.2	5.9	0.3	0.3	0.1

Table 3
Importance of the economic sectors in the coastal municipalities of the Death Coast, 2005 (number of contributors)

Municipality	Agriculture	Fishing	Manufacturing	Building	Services	Total
Camariñas	43	431	250	187	477	1388
%/Municip.	*3.12*	*31*	*18.12*	*13.40*	*34.30*	
Carnota	146	307	267	158	285	1163
%/Municip.	*12.55*	*26.4*	*22.96*	*13.59*	*24.51*	
Corcubión	6	17	22	35	214	294
%/Municip.	*2.04*	*5.78*	*7.48*	*11.97*	*72.79*	
Fisterra	50	299	21	92	382	844
%/Municip.	*5.92*	*35.43*	*2.49*	*10.90*	*45.26*	
Laxe	72	125	72	136	273	678
%/Municip.	*10.62*	*18.44*	*10.62*	*20.06*	*40.27*	
Malpica	184	270	340	232	560	1586
%/Municip.	*11.60*	*17.02*	*21.44*	*14.63*	*35.31*	
Muxía	292	218	123	163	325	1121
%/Municip.	*26.05*	*19.45*	*10.97*	*14.54*	*28.99*	
Ponteceso	284	158	271	384	516	1613
%/Municip.	*17.61*	*9.80*	*16.85*	*23.81*	*31.99*	
Total	1077	1825	1366	1387	3032	8687

Table 4
Relative Specialisation Index by sectors with respect to Galicia, 2005

Area	Municipality	Agriculture	Fishing	Manufacturing	Building	Services
Muros	Carnota	7.0	17.9	3.8	3.1	0.4
	Muros	4.2	15.3	2.5	4.6	1.1
	Camariñas	0.6	36.9	1.7	1.1	0.4
Terra de Soneira	Vimianzo	6.3	0.3	3.2	4.1	0.6
	Zas	7.3	0.0	1.4	2.6	0.4
	Cee	2.4	5.0	2.7	3.6	0.9
Fisterra	Corcubión	0.1	0.9	0.2	0.3	0.1
	Dumbría	4.6	0.0	1.5	1.4	0.1
	Fisterra	1.0	15.8	0.4	0.8	0.2
	Muxía	6.0	11.5	1.5	1.5	0.1
	Carballo	4.1	3.7	3.6	4.1	0.8
	Cabana	1.6	0.9	0.5	0.5	0.0
	Coristanco	2.3	0.0	0.4	0.6	0.1
Malpica	Laracha, A	2.5	1.0	0.7	1.2	0.2
	Laxe	0.4	6.2	0.1	0.2	0.0
	Malpica	1.2	13.4	0.5	0.4	0.1
	Ponteceso	1.9	7.8	0.4	0.6	0.1

Source of Tables 4–7: Security Social System.

These evolutionary patterns are the answer to, at least, three explanatory factors when facing the catastrophe: (i) the fishing sector is operating as a key activity for these coastal communities by alleviating the demographic crisis that has arisen in recent decades; (ii) this evolution is particularly relevant in those communities that depend on fishing subsectors as a vital factor for their socioeconomic development or (iii) where sea-related activities become, in some of them, the main activity [21].

3. Material studied

The economic evaluation of the *Prestige* impacts faces a series of methodological difficulties such as: irregularities in data series that indicate the economic activity prior to the accident, problems when measuring the impact on non-market resources and the length of the impact effects in terms of time and space. In the economic analysis of environmental damage, different valuation methodologies have been thoroughly reviewed in the literature [46–48], showing the diversity of the types of damage that have to be taken into account. They include the effects on fish prices or the loss of benefits derived from passive uses of marine ecosystems (Exxon Valdez, Alaska, 1989).

Since the Galician Government does not have consistent and uniform statistics series on the behaviour of commercial and non-commercial stocks, the use of a direct observation and analysis method on the species affected would not be plausible. Therefore, in order to make this assessment, the evolution of the market resources is analysed by means of landing studies, following a methodology that is similar to the one used in other studies after oil spills such as the *Amoco Cadiz* [3], *SS Glacier Bay* [49], *Exxon Valdez* [50], *Aegean Sea* [51], *Sea Empress* [52] and the *Prestige* [43,44].

3.1. Official statistics

Since 2004, the Fishing Technological Platform *PescadeGalicia*[5] has provided the single official statistical database on fish landings in all Galician fish markets. *PescadeGalicia* collects daily

[5] See 〈http://www.pescadegalicia.com〉. Until 1986, the *Anuarios de Pesca Marítima* issued by the Spanish Ministry for Agriculture, Fishing and Food Ministry collected landing data organised by species and landing port. At present, the Spanish authority *Puertos del Estado*, an institution dependent on the Ministry of Public Works, provides global landing data corresponding to the 27 port authorities dependent on

information about transactions of the 183 species traded at the 64 auction markets or authorised centres for these auctions governed by the Galician Administration.[6] The collected data are used to prepare statistics on landings in weight (kilos) and value (euros), sales turnover as well as average, minimum and peak prices for 6-year periods first beginning in 1998.[7]

The high level of development of the statistics prepared by *PescadeGalicia* is to be emphasised, being comparable to those of any other existing statistical systems on fish landings. Besides, it perfectly serves its stated purposes, by providing detailed information on the activities performed in the Galician fish markets. Nevertheless, its usefulness decreases when used as an information source to study the economic impact of the *Prestige* disaster. For the purposes of this paper, a longer time series would have been desirable, so as to prevent the linking of the spill to some behavioural patterns that are really driven by contextual factors associated with species population dynamics and socio-economic factors affecting fishing activities. Apart from the problems associated with the length of the time series, it is also important to point out that *PescadeGalicia* does not provide information about fish origin or the area where fish is captured.[8]

3.2. Unofficial statistics

While analysing the official statistics, a complementary exercise was carried out in order to refine the information that could be assumed to be anomalous or to contain data errors. In the course of this research, discrepancies were detected in the volume of landings in the historical series corresponding to the Death Coast auction markets published by *PescadeGalicia*, which did not seem to correspond either to biological cycles of landings or to productive cycles of the auction markets considered [53].

Furthermore, this was followed by direct observation of the auction markets where anomalous behaviour in greater landings was recorded, in particular in Camariñas and Malpica.[9] Comparing the official landing data from *PescadeGalicia* with the original source, a reconstruction of the statistical series of landings for the whole Death Coast was developed, as reflected in Figs. 1 and 2. Therefore, this reconstructed historical data for the period 1998–2005 both in volume and value are used for the analysis of fresh fish landings on the Death Coast.

4. Results

4.1. Volume of fresh fish landings on the Death Coast (in kilos)

The coastline of the Death Coast has 11 fishing ports and 12 fish auction markets.[10] Some of them, like the port of Malpica, are among the most important ports in Galicia, where coastal and inshore fishings are the main fishing activities. After investigating the evolution of fresh fish landings, a remarkable reduction in the overall landings on the Death Coast is observed, from 10,125 tonnes in 1998 to only 7951 in 2005 (Table 5). This represents a decrease of 17.1%, which resulted in a reduction in the relative importance in the overall Galician fishing landings, from 5.6% to 4.9%.

Regarding fish landings, Malpica stands out with 52% of the total volume in the period 1998–2005, followed by Camariñas (28.4%) and Laxe (6.8%). In Malpica, landings decreased by around 49.8% with regard to 1998 values (from 60% to 38.9%), while in Camariñas, they increased by 67.5% (from 20.2% in 1998 to 43.1% in 2005). On the other hand, Laxe, Fisterra and Muxía are characterised by the wide variety of landed species, including fish, molluscs, crustaceans and others (Table 6).

Likewise, a complementary analysis of the magnitude of the main species makes possible the identification of a high concentration in a reduced variety of them. The importance of landings at the ports of Camariñas and Malpica means that a high percentage of the overall fish landings for the period consisted of only 10 species, and the sum of the first six species (Horse mackerel, European sardine, Atlantic horse mackerel, Common octopus, Rock sea urchin and Conger eel) has a considerable relative significance (83.8%) in total landings (Table 7).

However, it should be stressed that this situation changed after the *Prestige* disaster, by a decrease in the weight of these species, which reduced from 97.2% of total landings in 2001 to 84.5% in 2005.

This new scenario for the main six species is characterised by a substitution process with other species (Table 8) that are not necessarily identified with the typical products of the area, and that can be attributable to various factors: (i) fluctuations in the biological behaviour of the natural cycle of species (i.e., the European sardine) due to changes in environmental conditions, (ii) exclusively economic causes: landings, which in previous years concentrated on only six species, were replaced by varied species, covering in weight the demand for a fairly vital fishery and finally (iii) to the exploitation of new species.

4.2. Value of fresh fish landings on the Death Coast (in euros)

Since the statistical database of *PescadeGalicia.com* offers information on the value (euros) of landings compared with data in kilos only for a relatively short period of time (2001–2005), only this time series was used. With regard to the possible effect of price fluctuations on the landings' monetary value, the Galician fresh fish market is characterised by a relative stability of prices, suffering slight changes over time [50,54].

After the oil spill, the value of fresh fish landings on the Death Coast hardly suffered any changes, which made it possible to observe a non-lineal evolution, taking as a basis the whole year 2002, where a constant fall in the value of landings of about 14 millions euros is detected, except for the year 2002 (Table 9). This trend contrasts reasonably with the fall experienced in the year 2003 as a consequence of the ban on fishing and shellfish-collecting activities. In the same way as with landing volumes, a high concentration in terms of value is identified, since Malpica (35.1%) and Camariñas (22.1%) recorded over 55% of the sales in the area.

Nonetheless, landings in Galicia increased from 354.8 million euros to 412.5 million in the same period, representing an increase of 16.2%. Anyhow, a feature that is important to stress is the loss of relative weight of the group of landings on the Death

(*footnote continued*)
the State Administration that are considered to be of general interest. Five Galician ports are included (A Coruña, Ferrol, Vilagarcía de Arousa, Marín and Vigo).

[6] Spanish Royal Decree 2064/2004, BOE, 261, 29 October 2004 and Galician Order of 4 August 2004 DOG, 155, 11 August 2004.

[7] Currently, these data cover the period between 2001 and 2007.

[8] Since fish imports are not equal at all Galician markets, the problem might be solved by selecting markets reporting only few exports or no exports at all. Even in the event of a significant relevance of the imported species, limiting the analysis to those species that are certainly caught off the Galician coast appears to be a feasible alternative.

[9] This was important because these two auction markets are critical in the evolution of fresh fish landings on the Death Coast.

[10] The fishing ports are in Caión, Camariñas, Camelle, Corcubión, Corme, Fisterra, Laxe, Lira (Carnota), Malpica, Muxía and O Pindo; the fish auction markets, sorted according to their relative relevance in the total amount of landings in the area, are in Malpica, Camariñas, Laxe, Fisterra, Corme, Lira (Carnota), Muxía, Corcubión, Río Anllóns, O Pindo, Baldaio and Camelle.

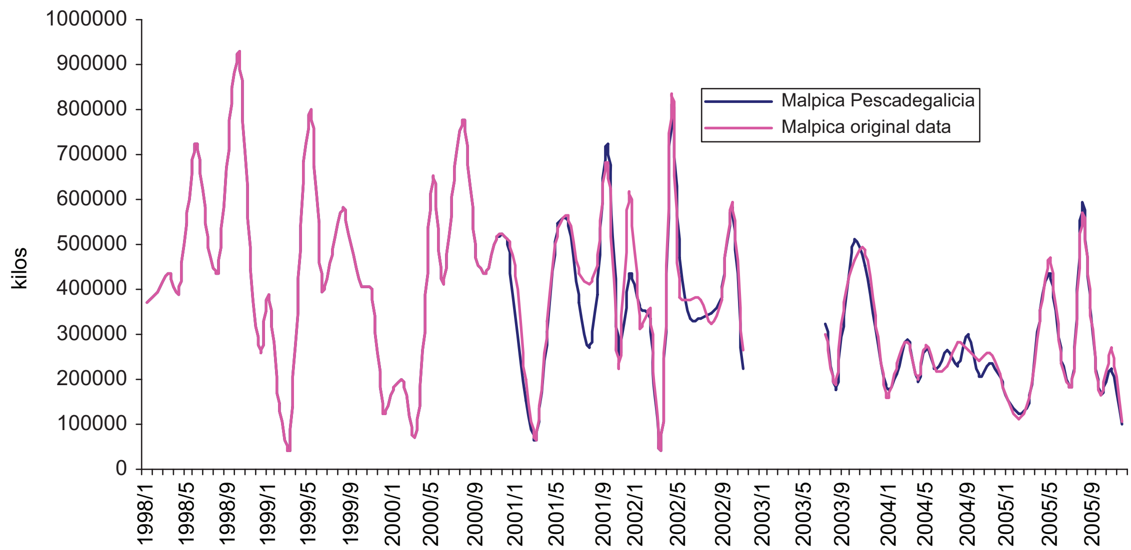

Fig. 1. Monthly fresh fish landings in the Malpica auction market. Source: data from Pescadegalicia.com and the Malpica auction market.

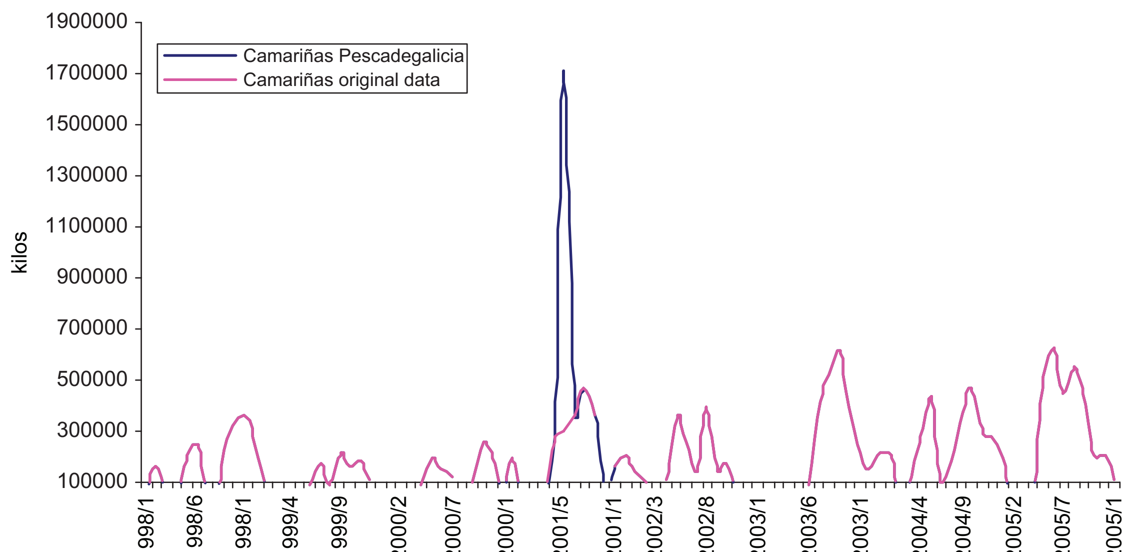

Fig. 2. Monthly fresh fish landings in the Camariñas auction market. Source: data from Pescadegalicia.com and the Camariñas auction market.

Table 5
Fresh fish landings in the fish markets of the Death Coast in the 1998–2005 period (kilos)

Auction markets	1998	1999	2000	2001	2002	2003	2004	2005	1998–2005
Malpica	6,173,078	4,844,401	5,233,961	4,425,314	4,233,196	2,115,871	2,816,762	3,093,940	32,936,523
Camariñas	2,049,720	1,217,772	1,388,095	2,643,275	1,944,233	2,328,969	3,008,131	3,433,838	18,014,033
Laxe	745,881	708,244	712,782	791,394	415,228	255,149	312,915	374,454	4,316,047
Fisterra	469,671	510,695	394,515	422,907	441,556	226,401	372,884	433,616	3,272,245
Corme	219,077	119,852	245,728	270,963	274,742	205,333	282,292	147,535	1,765,522
Lira	222,430	128,220	112,625	168,763	170,303	140,195	201,992	138,290	1,282,818
Muxía	186,377	163,583	133,939	131,200	119,292	46,169	93,391	84,140	958,091
Corcubión	40,328	36,537	23,490	5976	22,922	2671	80,507	75,981	288,412
Río Allóns	4380	0	25,635	13,919	30,106	47,930	74,523	166,126	362,619
O Pindo	4017	15,150	17,150	800	0	0	0	0	37,117
Baldaio	2574	0	6514	8425	6185	0	0	3090	26,788
Camelle	8306	0	0	0	0	0	0	0	8306
Death Coast (a)	*10,125,837*	*7,744,454*	*8,294,434*	*8,882,936*	*7,657,763*	*5,368,687*	*7,243,398*	*7,951,010*	*63,268,519*
Galicia	178,083,638	156,282,422	145,294,416	142,877,677	128,035,835	124,665,700	151,246,800	161,843,359	1,188,329,847
(a)/Galicia (%)	5.68	4.92	5.71	6.22	5.98	4.31	4.79	4.91	5.32

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 6
Diversity of fresh fish landings in the auction markets of the Death Coast in the 1998–2005 period (kilos)

	Malpica	Camariñas	Laxe	Fisterra	Corme	Lira	Muxía	Corcubión	Río Allóns	O Pindo	Baldaio	Camelle
Auction markets/total 1998–2005 (%)	52.06	28.47	6.82	5.17	2.79	2.03	1.51	0.46	0.57	0.06	0.04	0.01
Auction markets/total 2002 (%)	55.28	25.39	5.42	5.77	3.59	2.22	1.56	0.30	0.39	0.00	0.08	0.00
Auction markets/total 2005 (%)	38.91	43.19	4.71	5.45	1.86	1.74	1.06	0.96	2.09	0.00	0.04	0.00
	Species	Species	Species	Species	Species	Species	Species	Species	Species	Species	Species	Species
	A. horse mackerel European sardine A. mackerel Common octopus Bogue Conger eel	European sardine A. horse mackerel A. mackerel	European sardine A. horse mackerel A. mackerel Thornback tray Common octopus European hake Pouting Conger eel Pollack Angler	Common octopus European hake Conger eel Thornback tray Pouting A. horse mackerel A. mackerel Common cuttlefish Back-bellied angler Ballan wrasse Pod razor shell	Rock sea urchin Blue whiting A. horse mackerel Goose barnacle A. mackerel Common octopus	Common octopus Rock sea urchin	Rock sea urchin Common octopus Conger eel Blue whiting Greater forkbeard Pollack Goose barnacle Whit sea bream Thornback tray Pouting A. horse mackerel Ballan wrasse European hake	Cockle Common octopus Banded Carpet Shell	Cockle	Rock sea urchin	Cockle Grooved Carpet Shell	Goose Barnacles
1998–2005 Main species	28,373,210.00	17,258,444.00	3,703,767.00	2,558,414.00	1,569,934.00	1,115,190.00	835,788.00	265,245.00	445,547.00	33,100.00	27,095.00	8,306.00
1998–2005 Total	32,936,523.00	18,014,033.00	4,316,048.00	3,272,245.00	1,765,521.00	1,283,073.00	958,874.00	288,413.00	450,385.00	37,117.00	30,140.00	8,306.00
%/Total 1998–2005	86.20	88.72	85.81	78.19	88.92	86.92	87.16	91.97	98.93	89.18	89.90	100.00
2005 Main species	2,550,779.00	3,094,523.00	304,402.00	326,691.00	146,976.00	123,023.00	76,263.00	69,655.00	166,065.00	0.00	2773.00	0.00
2005 Total	3,093,940.00	3,433,838.00	374,454.00	433,616.00	147,535.00	138,290.00	84,141.00	75,981.00	166,126.00	0.00	3090.00	0.00
%/Total 2005	82.43	89.80	81.29	75.34	99.62	88.96	90.64	91.67	99.96	–	89.74	–

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 7
Fresh fish landings evolution of the 10 main species of the Death Coast in the1998–2005 period (kilos)

Species	1998	1999	2000	2001	2002	2003	2004	2005	1998–2005
Horse mackerel	4,096,471	3,472,057	4,173,214	3,277,647	1,988,786	1,099,688	1,504,008	1,169,227	20,781,098
European sardine	1,389,769	1,017,643	1,047,482	2,998,606	2,966,967	2,724,393	3,183,084	4,036,722	19,364,666
A. mackerel	1,622,664	910,155	858,802	903,558	803,977	389,311	225,916	395,380	6,109,763
Common octopus	777,333	531,831	414,715	526,194	465,344	264,340	547,631	414,879	3,942,267
Rock sea urchin	190,902	101,177	77,384	212,746	215,674	182,917	346,834	313,066	1,640,700
Conger eel	206,233	229,775	162,928	179,050	185,934	83,465	72,346	75,264	1,194,995
Bogue	122,324	136,623	120,499	179,428	152,830	69,951	119,969	83,536	985,160
Thornback ray	110,489	121,531	114,373	122,479	58,570	47,513	100,060	74,925	749,940
Pouting	106,373	105,776	120,959	129,779	74,011	44,394	53,936	60,394	695,622
Goose barnacle	84,613	77,011	76,981	105,245	72,854	36,122	97,831	96,857	647,514
10 Species (a)	*8,707,171*	*6,703,579*	*7,167,337*	*8,634,732*	*6,984,947*	*4,942,094*	*6,251,615*	*6,720,250*	*56,111,725*
Death Coast	10,125,837	7,744,454	8,294,434	8,882,936	7,657,763	5,368,687	7,243,398	7,951,010	63,268,519
(a)/Death Coast	85.99	86.56	86.41	97.21	91.21	92.05	86.31	84.52	88.69
Galicia	178,083,638	156,282,422	145,294,416	142,877,677	128,035,835	124,665,700	151,246,800	161,843,359	1,188,329,847

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 8
Substitution process—fresh fish landing evolution with the exclusion of the six main species of the Death Coast (kilos)

Species	2001	2002	2003	2004	2005	2001–2005
Common edible cockle	24,336	81,033	99,513	195,584	258,710	659,176
European hake	132,510	79,570	69,158	139,133	191,521	611,892
Marine fish varied	137,890	23,158	8,709	57,777	69,862	297,396
Pollack	71,514	38,659	39,489	67,736	53,747	271,145
Japanese carpet shell	25,957	36,176	39,795	71,662	26,564	200,154
Ballan wrasse	43,160	36,935	23,921	43,930	41,203	189,149
Black-bellied angler	9954	6450	20,744	53,718	37,123	127,989
White sea bream	34,329	32,015	13,143	17,653	25,394	122,534
European sea bass	26,502	17,267	9746	25,185	32,531	111,231
Blue whiting	52,539	44,517	6105	6886	6357	116,404
A. John Dory	37,768	20,144	13,511	17,773	13,876	103,072
Angler	12,692	9145	6317	14,891	42,498	85,543
Red gurnard	23,461	10,821	6049	22,484	22,060	84,875
Spider Crab	22,979	6465	5660	14,981	24,985	75,070
Red sea bram	2,479	47,882	1704	7847	14,095	74,007
Broadtail squid	20,412	18,649	6029	9686	17,071	71,847
Striped red mullet	16,155	12,325	8251	16,046	17,537	70,314
17 species (a)	*694,637*	*521,211*	*377,844*	*782,972*	*895,134*	*3,271,798*
Total	958,049	675,804	459,365	943,288	1,032,949	4,069,455
(a)/Total (%)	72.51	77.12	82.25	83.00	86.66	80.40

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 9
Fresh fish landings in the fish markets of the Death Coast in the 2001–2005 period (euros)

Auction markets	2001	2002	2003	2004	2005	2001–2005
Malpica	5,825,103.00	4,856,252.76	2,276,389.00	4,581,157.75	4,869,483.36	22,408,385.87
Camariñas	2,316,423.79	2,312,561.00	2,306,957.00	3,508,901.00	2,868,133.00	13,312,975.79
Fisterra	1,485,549.75	1,716,340.11	886,218.64	1,511,892.60	1,831,529.17	7,431,530.27
Laxe	2,155,174.72	1,194,798.51	740,250.81	1,288,855.91	1,195,311.73	6,574,391.68
Corme	917,891.78	632,406.43	536,504.54	1,046,378.00	755,699.63	3,888,880.38
Lira	737,769.06	864,650.48	635,155.90	888,835.44	718,016.07	3,844,426.95
Muxía	770,760.20	738,988.09	283,089.12	593,525.31	533,419.18	2,919,781.90
Río Anllóns	49,965.48	67,352.57	152,907.40	421,420.75	509,695.00	1,201,341.20
Corcubión	50,534.01	129,838.00	11,175.40	410,959.18	441,290.81	1,043,797.40
Caión	251,614.65	266,762.44	112,682.64	271,693.78	184,289.04	1,087,042.55
Baldaio	53,178.81	32,012.17	0	20,778.36	18,905.50	124,874.84
Death Coast (a)	*14,613,965*	*12,811,963*	*7,941,330*	*14,544,398*	*13,925,772*	*63,837,428*
Galicia	354,890,787	329,148,357	334,918,518	389,551,301	412,558,601	1,821,067,564
(a)/Galicia (%)	4.12	3.89	2.37	3.73	3.38	3.51

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Coast in Galicia, going from 4.1% in year 2001 to 3.3% in year 2005 (Table 10).

In carrying out the analysis to examine the evolution of landings in terms of value per species, the composition of landings included a total of 115 species, with a high concentration level, since 18 of them represent around 88.5% of the Death Coast landings.

This concentration level is still higher if the first four species are taken into account, representing over 64.4% of the total value: the Common octopus (19.9%), the European sardine (17.4%), the Goose barnacle (15.6%) and the Atlantic horse mackerel (11.4%). Among this selected group of 18 species, there are others that have an outstanding relevance such as the European hake (5.6%), the Common edible cockle (3.6%), the Rock sea urchin (3.6%), the Atlantic mackerel (3.1%) or the Japanese carpet shell (2.8%, Table 11). There is a third group of species that even without reaching as high values as the former ones, has a relative relevance, since it reached figures between 100 thousand and 750 thousand euros in the same period.[11] Finally, there are over 70 species having less significance in the total value of landings, with figures lower than 100 thousand euros.

4.3. Fresh fish landings on the Death Coast before and after the *Prestige* accident

In the absence of a more adequate methodology that adapts to the bioeconomic dynamics of fishing resources, the evolution of annual mean values of landings before (2001–2002) and after (2003–2005) the accident is examined, assuming fewer landings in the post-*Prestige* period to be an indicator of a degree of damage.

After exploring the volume of fresh fish landings of the 11 main commercial species, it is necessary to emphasise the following points. First, the amount of landings has decreased by 17.1% on the Death Coast after the *Prestige* disaster (Table 12). Second, no homogeneous patterns in landings behaviour have been identified. In fact, two opposed behaviours have been found: landings of some species increased while others diminished. Decreasing species represent, as a whole, around 55.4% of the total landings in the area, whereas reductions in Atlantic horse mackerel (−60.5%), Conger eel (−57.7%), Turbot (−57.7%), Horse mackerel (−52.2%), Pouting (−48%) and Atlantic John Dory (−48%) are particularly remarkable in such a short period of time.

On the other hand, increases in landings of other species such as the Black-bellied angler (353.4%), the Common edible cockle (250.3%), the Angler (94.4%), the Japanese carpet shell (48.1%) and the Greater forkbeard (31.2%) are also considerable. However, such increases could be associated with circumstances not necessarily linked to the oil spill effects. These circumstances are the development of new extraction plans (the Rock sea urchin), the regeneration of shellfish grounds prior to the disaster (the Common edible cockle), the existence of landings from fishing grounds different from those on the Death Coast (the Angler and the European hake), landings of species that had not been harvested before (the Greater forkbeard and the Japanese carpet shell) and even an increase in landings related to the fishing of adult specimens not affected by the spill. Other major elements to be stressed are both the fishing effort pressure and the declaration of some amount of fish that was not previously declared. This latter measure is important to give legitimacy or strength to future claims for damage caused by the *Prestige* accident.

Moreover, by comparing the mean values of the period 2001–2002 with those of 2003–2005, the global trend on the Death Coast evolved in a negative way, with a fall in landing value of 11.4% (Table 13). The main species that have decreased are the Atlantic mackerel (−77.8%), the Conger eel (−70.1%), the Atlantic horse mackerel (−50.4%), the Turbot (−43.1%), the Atlantic John Dory (−39%), the Thornback ray (−21%), the European sardine (−14.9%), the Pollack (−7.5%) and the Common octopus (−0.8%), representing 57.2% of the total value of landings.

Nevertheless, not all these species evolved in such a negative way. Thus, among those that present an increasing trend we find the Common edible cockle (273.2%), the Japanese carpet shell (36.9%), the Rock sea urchin (23.1%), the European sea bass (18.5%), the Grooved carpet shell (15.1%), the Goose barnacle (11%) and the European hake (6.8%), accounting for 30% of the total value of landings.

4.4. Assessing various case studies

With regard to the assessment of the resource condition from the evolution of landings coming from the Death Coast, heterogeneous tendencies have been identified over time, since habitats, biological cycles, habits, feeding and migratory behaviours are different. Therefore, the exposure and the possible effects of the spillage for each species can be remarkably diverse. The research done distinguishes four different groups in the evolution of landings.

Group 1: those species whose annual mean analyses for the pre- and post-*Prestige* periods show a reduction in kilos as well as in monetary value: the Atlantic horse mackerel, the Atlantic mackerel, the Common octopus, the Conger eel, the Bogue, the Thornback ray, the Pouting, the Ballan wrasse, the Turbot, the Pollack and the Atlantic John Dory.

Group 2: those species whose annual mean analyses for the pre- and post-*Prestige* periods show a decrease in kilos though an increase in value: the European sardine.

Group 3: those species whose annual mean analyses for the pre- and post-*Prestige* periods show an increase in kilos but a decrease in value: the Pod razor shell, the Grooved carpet shell and the Goose barnacle.

Group 4: those species whose annual mean analyses for the pre- and post-*Prestige* periods show an increase in kilos as well as in monetary value: the Rock sea urchin, the European sea bass, the Striped red mullet, the European hake, the Velvet swimming crab, the Angler, the Black-bellied angler, the Common edible cockle, the Japanese carpet shell, the Red sea bream and the Spider crab.

After considering its importance in volume or value in landings and also the habitats where it grows, we show only one species per group from each of the four identified groups. In this way the behaviour of the species belonging to the different habitats and/or levels of the food chain can be assessed. Therefore, we selected for evaluation the Atlantic horse mackerel from group 1, the European sardine from group 2, the Rock sea urchin from group 3 and the Goose barnacle from group 4.

4.4.1. Group 1: the Atlantic horse mackerel (*Trachurus trachurus*)

It is a pelagic species normally living in areas with sandy bottoms, 100–200 m deep. It reproduces in the summer and feeds on fish, crustaceans and cephalopods, reaching its sexual maturity between the second and third year of life [55,56]. It is the most important species in volume, with 36.1% of total landings on the Death Coast in the period 1998–2005. Except for year 2003, it reached the worst results in the year 2005 (Fig. 3). After the oil

[11] It is a varied group of fish like the Striped red mullet, Pouting, Angler and Ballan wrasse, and crustaceans such as the Velvet swimming crab.

Table 10
Diversity of fresh fish landings in the auction markets of the Death Coast in the 1998–2005 period (euros)

	Malpica	Camariñas	Laxe	Fisterra	Corme	Lira	Muxía	Corcubión	Río Allóns	O Pindo	Baldaio	Camelle
Auction markets/total 1998–2005 (%)	52.06	28.47	6.82	5.17	2.79	2.03	1.51	0.46	0.57	0.06	0.04	0.01
Auction markets/total 2002 (%)	55.28	25.39	5.42	5.77	3.59	2.22	1.56	0.30	0.39	0.00	0.08	0.00
Auction markets/total 2005 (%)	38.91	43.19	4.71	5.45	1.86	1.74	1.06	0.96	2.09	0.00	0.04	0.00
	Species	Species	Species	Species	Species	Species	Species	Species	Species	Species	Species	Species
	A. horse mackerel	European sardine	European sardine	Common octopus	Rock sea urchin	Common octopus	Rock sea urchin	Cockle	Common edible cockle	Rock sea urchin	Common edible cockle	Goose barnacle
	European sardine	A. horse mackerel	A. horse mackerel	European hake	Blue whiting	R. sea urchin	Common octopus	Common octopus			Grooved carpet shell	
	A. mackerel	A. mackerel	A. mackerel	Conger eel	A. horse mackerel		Conger eel	Grooved carpet shell				
	Common octopus		Thornback ray	Thornback ray	Goose barnacle		Blue whiting					
	Bogue		Common octopus	Pouting	A. mackerel		Greater forkbeard					
	Conger eel		European hake	A. horse mackerel	Common octopus		Pollack					
			Ballan wrasse	A. mackerel			Goose barnacle					
			Pouting	C. cuttlefish			White sea bream					
			Conger eel	Black-bellied angler			Thornback ray					
			Pollack	Ballan wrasse			Pouting					
			Angler	Pod razor shell			A. horse mackerel					
				Pollack			Ballan wrasse					
							Pod razor shell					
							European hake					
1998–2005 Main Species	28,373,210.00	17,258,444.00	3,703,767.00	2,558,414.00	1,569,934.00	1,115,190.00	835,788.00	265,245.00	445,547.00	33,100.00	27,095.00	8,306.00
1998–2005 Total	32,936,523.00	18,014,033.00	4,316,048.00	3,272,245.00	1,765,521.00	1,283,073.00	958,874.00	288,413.00	450,385.00	37,117.00	30,140.00	8,306.00
%/total 1998–2005	86.20	88.72	85.81	78.19	88.92	86.92	87.16	91.97	98.93	89.18	89.90	100.00
2005 Main Species	2,550,779.00	3,094,523.00	304,402.00	326,691.00	146,976.00	123,023.00	76,263.00	69,655.00	166,065.00	0.00	2,773.00	0.00
2005 total	3,093,940.00	3,433,838.00	374,454.00	433,616.00	147,535.00	138,290.00	84,141.00	75,981.00	166,126.00	0.00	3,090.00	0.00
%/total 2005	82.43	89.80	81.29	75.34	99.62	88.96	90.64	91.67	99.96	–	89.74	–

Source: Data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 11
Fresh fish landings in the fish markets of the 18 main species of the Death Coast in the 1998–2005 period (euros)

Species	2001	2002	2003	2004	2005	2001–2005
Common octopus	2,038,129	2,489,464	1,613,413	2,862,331	2,258,650	11,261,987
European sardine	1,954,871	2,372,523	1,722,069	2,043,939	1,758,095	9,851,497
Goose barnacle	1,922,585	1,384,499	1,012,135	2,291,972	2,203,015	8,814,206
Horse mackerel	2,196,626	1,510,335	430,283	1,139,621	1,183,763	6,460,628
European hake	731,430	495,349	369,490	702,714	893,984	3,192,967
Common edible cockle	109,351	204,202	320,230	509,744	925,475	2,069,002
Sea urchin	337,269	384,430	293,255	540,919	499,258	2,055,131
A. mackerel	891,802	457,641	138,085	104,966	204,572	1,797,066
Japanese carpet shell	189,699	345,590	332,624	568,364	198,427	1,634,704
Pollack	397,161	247,583	203,605	381,840	309,021	1,539,210
European sea bass	279,501	195,460	134,202	332,183	378,475	1,319,821
Grooved carpet shell	264,745	190,674	257,302	356,453	173,122	1,242,296
Pod razor shell	194,917	216,849	187,838	211,982	279,743	1,091,329
A. John Dory	310,321	209,382	133,979	182,043	159,058	994,783
Conger eel	278,713	317,474	95,392	83,106	88,278	862,963
Thornback ray	252,360	115,964	85,379	196,909	153,718	804,330
Turbot	253,444	154,305	89,755	160,471	97,755	755,730
Spider crab	224,149	71,010	50,804	143,397	260,828	750,188
18 species (a)	*12,827,073*	*11,362,734*	*7,469,840*	*12,812,954*	*12,025,237*	*56,497,838*
Death Coast	14,613,695	12,811,963	7,941,330	14,544,398	13,925,772	63,837,158
(a)/Death Coast (%)	87.77	88.69	94.06	88.10	86.35	88.50

Source: Data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 12
Landings trend in the main species of the Death Coast after the Prestige oil spill (kilos)

Species	Average 2001–2002	Average 2003–2005	Difference	Difference (%)	Species	Average 2001–2002	Average 2003–2005	Difference	Difference (%)
A. mackerel	853,768	336,869	−516,899	−60.54	Black-bellied angler	8202	37,195	28,993	353.49
Conger eel	182,492	77,025	−105,467	−57.79	Common edible cockle	52,685	184,602	131,917	250.39
Turbot	13,259	5606	−7,653	−57.72	Angler	10,919	21,235	10,316	94.48
Horse mackerel	2,633,217	1,257,641	−1,375,576	−52.24	Japanese carpet shell	31,067	46,007	14,940	48.09
Pouting	101,895	52,908	−48,987	−48.08	Greater forkbeard	9171	12,040	2869	31.28
A. John Dory	28,956	15,053	−13,903	−48.01	Rock sea urchin	214,210	280,939	66,729	31.15
Bogue	166,129	91,152	−74,977	−45.13	European hake	106,040	133,271	27,231	25.68
Thornback ray	90,525	74,166	−16,359	−18.07	Common cuttlefish	7709	9500	1791	23.23
Common octopus	495,769	408,950	−86,819	−17.51	European sardine	2,982,787	3,314,733	331,946	11.13
Goose barnacle	89,050	76,937	−12,113	−13.60	Spider crab	14,722	15,209	487	3.31
Ballan wrasse	40,048	36,351	−3697	−9.23	European sea bass	21,885	22,487	602	2.75

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 13
Landing trends in the main species of the Death Coast after the Prestige oil spill (euros)

Species	Average 2001–2002	Average 2003–2005	Difference	Difference (%)	Species	Average 2001–2002	Average 2003–2005	Difference	Difference (%)
A. mackerel	674,721.50	149,207.67	−525,514	−77.89	Common edible cockle	156,776.00	585,149.67	428,373.67	273.24
Conger eel	298,093.50	88,925.33	−209,168	−70.17	Japanese carpet shell	267,644.50	366,471.67	98,827.17	36.92
A. horse mackerel	1,853,480.50	917,889.00	−935,592	−50.48	Rock sea urchin	360,849.50	444,477.33	83,627.83	23.18
Turbot	203,874.50	115,993.67	−87,881	−43.11	European sea bass	237,480.50	281,620.00	44,139.50	18.59
A. john dory	259,851.50	158,360.00	−101,492	−39.06	Grooved carpet shell	227,709.50	262,292.33	34,582.83	15.19
Thornback ray	184,162.00	145,335.33	−38,827	−21.08	Goose barnacle	1,653,542.00	1,835,707.33	182,165.33	11.02
European sardine	2,163,697.00	1,841,367.67	−322,329	−14.90	Pod razor shell	205,883.00	226,521.00	20,638.00	10.02
Pollack	322,372.00	298,155.33	−24,217	−7.51	European hake	613,389.50	655,396.00	42,006.50	6.85
Common octopus	2,263,796.50	2,244,798.00	−18,999	−0.84	Spider crab	147,579.50	151,676.33	4097	2.78

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

spill, this species reached it maximum landing volume in the year 2004 with a value of 1511 thousand kilos. From here on a considerable diminution is observed until it fell to 1100 thousand kilos.

Taking into account its relative weight in the landing groups (volume) in Galicia during the period 2001–2005, it decreased from 13% in 1998 to 5.2% in 2005; likewise, its value changed in a similar way (Table 14).

The minimum value is recorded in 2003 with 4.6%, later increasing to 1139 thousand euros in 2005. The mean price per kilo suffers a fall during the overall period close to 33.5%, though it reached it maximum value (2.5 €/kg) in 2003.

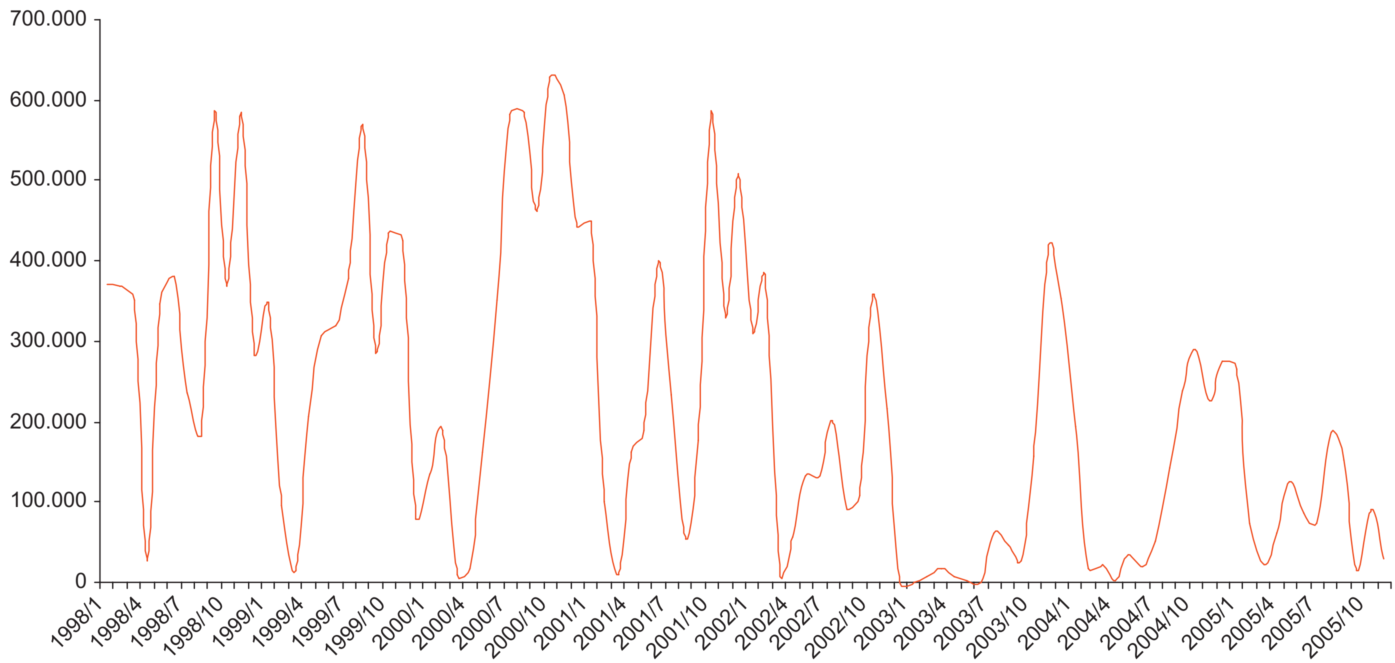

Fig. 3. Monthly fresh fish landings of Atlantic horse mackerel (*Trachurus trachurus*) in the Death Coast (kilos). Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 14
Volume, value, percentage of landings and price/kg of A. horse mackerel (*Trachurus trachurus*) in the Death Coast and Galicia

	2001	2002	2003	2004	2005	2001–2005
Volume (kg)	3,277,650	1,988,788	1,099,688	1,503,688	1,167,476	9,037,290
%/Galicia	*13.01*	*10.83*	*6.22*	*6.27*	*5.24*	
Value (euros)	2,196,626	1,510,335	430,283	1,139,621	1,183,763	6,460,628
%/Galicia	*12.96*	*12.03*	*4.60*	*6.57*	*9.54*	
Price (€/kg)	1.49	1.32	2.56	1.32	0.99	0.71

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

4.4.2. *Group 2: the European sardine (Sardina pilchardus)*

The European sardine is a species that inhabits the coastline, being one of the most traditional fisheries and of the greatest commercial interest in Galicia. It develops at the 100-m isobath of depth though rarely beyond the continental platform [57], in spite of the fact that this species is also harvested in Portuguese waters and in the Cantabric Sea [58]. With 36% of the overall landings on the Death Coast in the 1998–2005 period, this species shows a continuous landing growth during these years (Fig. 4).

Landings for the European sardine are concentrated in a much-reduced number of auction markets (Camariñas—49% and Malpica—44% of the total landings). Nevertheless, regarding its volume with respect to the Galician landings, there is a decreasing trend, dropping from 22.2% in the year 2001 to 18.1% in the year 2005, while following a similar trend in value, that is to say, a drop of its relative significance occurred from 21.2% in the year 2001 to 14.8% in the year 2005 (Table 15).

Its price per kilo gradually fell, since the mean price per landed kilo during the whole period reduced from 0.65 €/kg in the year 2001 up to 0.45 €/kg in the year 2005.

4.4.3. *Group 3: the Goose barnacle (Pollicipes pollicipes)*

The Goose barnacle is a crustacean found in the rocky substrate of sea cliffs. It feeds by filtrating suspension particles. It is a resource of outstanding commercial importance located only in a limited part of the Galician coast [59]. The gathering of this species is provided for in the specific exploitation plans approved by the Galician Government (Xunta de Galicia), being harvested either on foot in the intertidal zone or from vessels when sea conditions allow.

It ranks tenth with 647 thousand kilos, with 1.1% of the total landing volume in the period 1998–2005. In these years, a 15.1% increase in landings was observed, reaching its maximum in the year 2001 with 105 thousand kilos and its minimum in the year 2003 with scarcely 36.1 thousand kilos (Fig. 5). Furthermore, there is a concentration of landings at the auction markets of Malpica (with 39.9% of the overall volume and 258.3 thousand kilos) and Corme (30.1% and 194 thousand kilos).

Finally, a decrease in the period 2001–2005 from 23.7% to 19% should be highlighted with respect to the relative landing weight of Goose barnacle in Galicia. The highest value was attained in the year 2004 with 23.9% and the minimum in the year 2003 with 11.9% (Table 16).

However, this loss in the relative weight is to some extent compensated by a 22% increase in the mean price per kilo (28 €/kg) as a consequence of the shortage of fish products after the ban on fishing and shellfish-collecting activities.

4.4.4. *Group 4: the Rock sea urchin (Paracentrotus lividus)*

The Rock sea urchin is an echinoderm, well widespread along the Galician fishing grounds. It inhabits rocky shores exposed or moderately exposed to strong swell and located in the strip

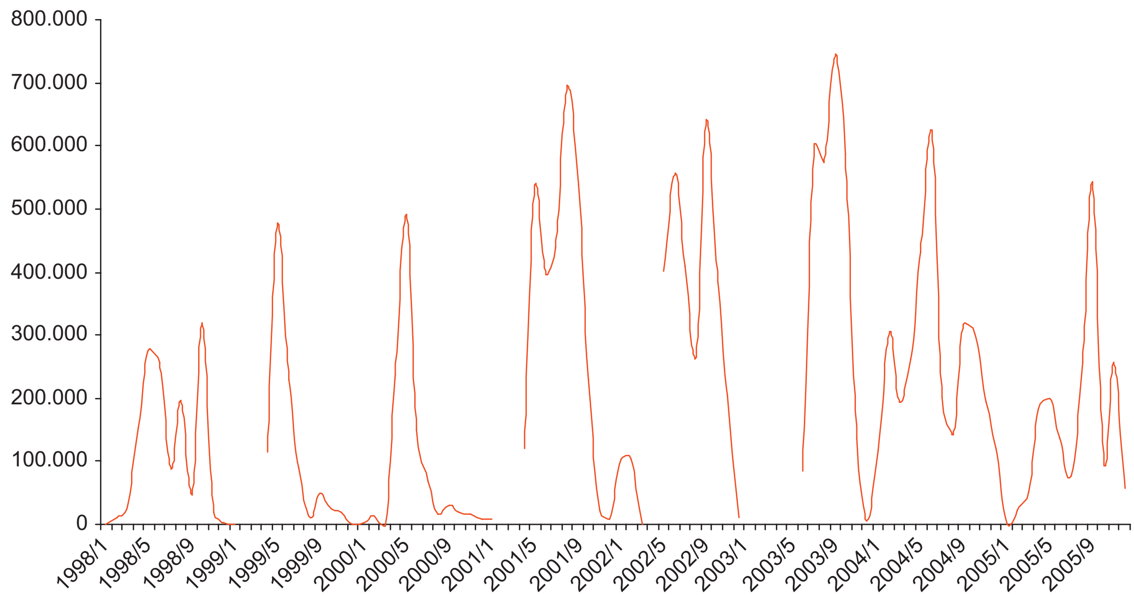

Fig. 4. Monthly fresh fish landings of European sardine (*Sardina pilchardus*) in the Death Coast (kilos). Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 15
Volume, value, percentage of landings and price/kg. of European sardine (*Sardina pilchardus*) in the Death Coast and Galicia

	2001	2002	2003	2004	2005	2001–2005
Volume (kg)	2,998,606	2,966,968	2,724,393	3,183,083	4,036,723	15,909,773
%/Galicia	*22.26*	*25.90*	*20.80*	*16.37*	*18.77*	
Value (euros)	1,954,871	2,372,523	1,722,069	2,043,939	1,822,009	9,915,411
%/Galicia	*21.27*	*26.84*	*20.59*	*16.96*	*14.85*	
Price (€/kg)	0.65	0.80	0.63	0.64	0.45	0.62

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

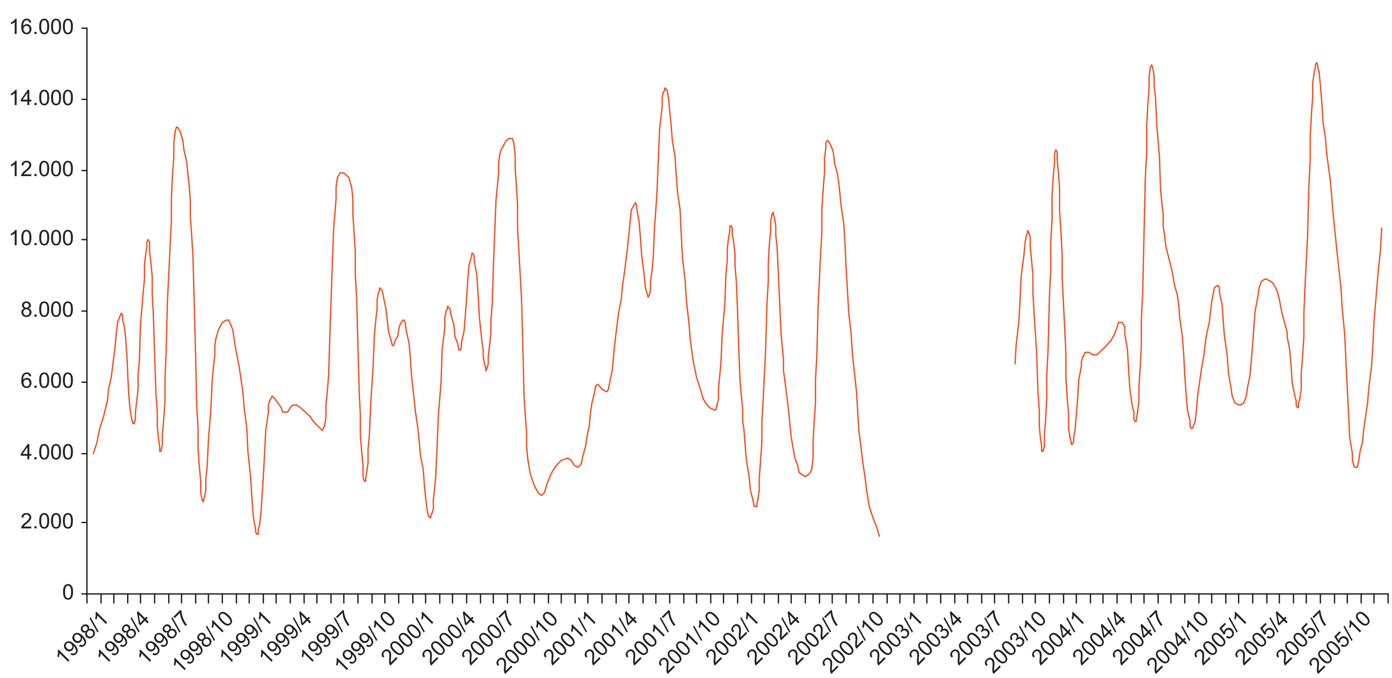

Fig. 5. Monthly fresh fish landings of Goose barnacle (*Pollicipes pollicipes*) in the Death Coast (kilos). Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 16
Volume, value, percentage of landings and price/kg of Goose barnacle (*Pollicipes pollicipes*) in the Death Coast and Galicia

	2001	2002	2003	2004	2005	2001–2005
Volume (kg)	105,245	72,854	36,121	97,526	96,860	408,606
%/Galicia	*23.79*	*21.04*	*11.97*	*23.97*	*19.03*	
Value (euros)	1,922,582	1,384,495	1,012,130	2,291,967	2,203,012	8,814,186
%/Galicia	*21.77*	*17.59*	*11.18*	*17.99*	*15.14*	
Price (€/kg)	18.26	19.00	28.02	23.50	22.28	21.57

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

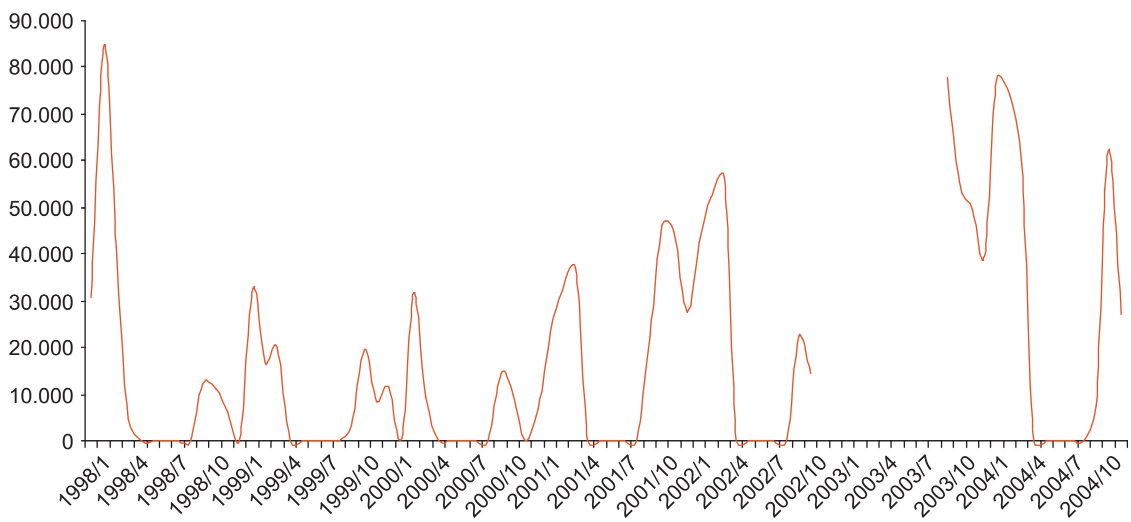

Fig. 6. Monthly fresh fish landings of Rock sea urchin (*Paracentrotus lividus*) in the Death Coast (kilos). Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

Table 17
Volume, value, percentage of landings and price/kg of Rock sea urchin (*Paracentrotus lividus*) in the Death Coast and Galicia

	2001	2002	2003	2004	2005	2001–2005
Volume (kg)	212,746	215,674	182,917	346,835	313,066	1,271,238
%/Galicia	*36.91*	*35.03*	*60.82*	*46.71*	*40.93*	
Value (euros)	337,266	384,428	293,254	540,917	499,256	2,055,121
%/Galicia	*38.83*	*39.07*	*59.19*	*43.55*	*39.92*	
Price (€/kg)	1.58	1.78	1.60	1.55	1.59	1.61

Source: data from Pescadegalicia.com and the Malpica and Camariñas auction markets.

between the inferior levels of the mesolittoral and 30 m deep approximately.

This echinoderm accounts for 2.8% of the total volume, ranking fifth among total landings. Between 1998 and 2005, landings of Rock sea urchin increased by 122 thousand kilos, rising from its lowest sale point in 1999 with 101.7 thousand kilos to its peak in 2004 with more than 346.8 thousand kilos ((Fig. 6). To a great extent, this could be due to the approval of new exploitation plans, in accordance with inquiries carried out among workers and shellfish gatherers in the area and the affected fishermen guilds. Rock sea urchin landings are concentrated in a reduced number of auction markets. Corme with 40.2% (667.7 thousand kilos between 1998 and 2005), Lira with 23.3% (383.1 thousand kilos) and Camariñas 19.4% (318.7 thousand kilos) represent 83% of the total volume.

Sale values rose but to a minor extent. With a slight increase of 2.8% observed in the 2001–2005 period, the final value in 2005 of 540.9 thousand euros is noteworthy, this figure being much higher than values of preceding years (Table 17).

Finally, the price per landed kilo at auction markets kept constant throughout the overall period with just a 1.5 €/kg fluctuation, reaching its maximum value of 1.78 €/kg in the year 2002.

4.5. Simulating fresh fish landings on the Death Coast: a lineal regression model

Once our analysis was developed on the pattern of landings before and after the accident, an enhanced effort aimed at examining the effects of the disaster was developed, starting from the record of actual landings and modelling a possible scenario for predictable landings in the absence of the oil spill. This prediction was attained through a lineal regression model that allows for the comparison of anomalies present in landings in the pre- and post-*Prestige* periods.

Although accurately quantifying the economic effects on affected stocks is difficult, since these effects could last for some

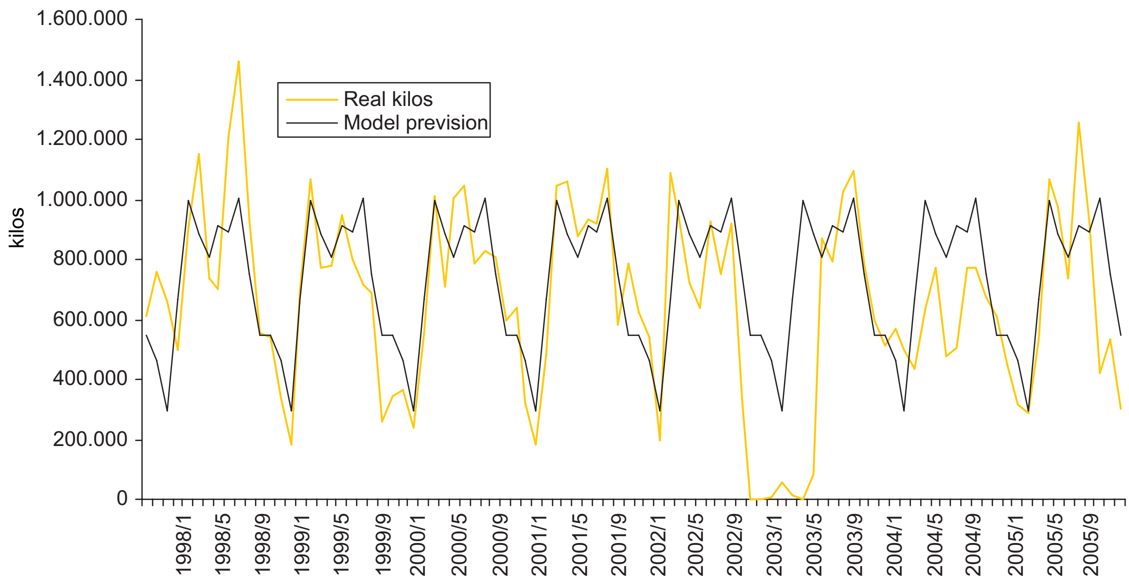

Fig. 7. Lineal regression model of fresh fish landings in the Death Coast fisheries. Source: own elaboration.

time, the truth is that this difficulty does not invalidate the possibility of contrasting landings cycles on the Death Coast. In this way, the evolution of monthly cycles of landings for the years 1998–2002 and 2003–2005 was modelled, in order to observe if the disaster had caused changes in landing cycles.

It should be pointed out that the Death Coast is characterised by the cycle of natural migration and harvesting of the European sardine, as well as by a dynamic cycle of landings marked by a high concentration between the months of May and October. That is to say, following the categorisation stated by Caddy and Gulland [60] regarding the classification of the possible behaviour of populations, the fishing activity in the area shows a strong cyclic seasonality, the highest productivity peaks taking place during and after summer.

Once these characteristics were known and having the monthly landing values, a linear regression model was used to predict the hypothetical tendency of landings in a *normal* scenario, that is, without the oil spill. In this way, Fig. 7 shows the existence of a 6-month cycle that practically recurs with the same characteristics in all the years prior to the catastrophe, except for year 1998 when the highest landing value was recorded as 1459 million kilos in the month of October.

Likewise, a breach in this cycle of landings was identified after the disaster. This means that except for year 2003, when the ban on fishing and shellfish collecting was approved, the years 2004 and 2005 show clear indicators of an anomalous change in landings. In addition, the prediction established by this model makes it possible to investigate if the actual behaviour of landings has a correlation with what the model foresees. In this case, it will be noticed that if the accident had not occurred, the seasonal features of landing cycles would not have suffered major alterations.

5. Conclusions and limitations of the current study

Regarding fresh fish landings, this exploratory and preliminary analysis reveals that no import flows were identified from markets outside the Death Coast. Before the *Prestige* oil spill, a high concentration of landings in only 10 species was observed. The sum of them had a considerable relative importance in the total amount of landings (88.5%). However, this situation changed considerably after the *Prestige* disaster, when a drop-off in the weight of the species on the Death Coast occurred: from 97.2% in the year 2001 to 84.5% in the year 2005.

On the other hand, this paper has mainly focused on the pattern of landings for the periods 2001–2002 and 2003–2005. Reviewing developments in the two periods, it is clear that the amount of landings decreased by 17.1% after the accident. However, no homogeneous patterns in landing behaviours have been identified. Some species clearly diminished while others increased. This second pattern might be mainly the response to the harvesting of mature individuals present at the moment of the accident, to the exploitation of new species or to a possible increase in the fishing effort. In any case, we observed a disruption in the cycle of landings after the oil spill, after modelling a scenario in the absence of the accident. This indicates an unusual evolution of landings, given that if the spillage had not occurred, the seasonal features would not have suffered major changes.

Nevertheless, it is necessary to point out a series of limitations when interpreting these conclusions. First, it should be emphasised that by using landings as a main indicator, these results are not still enough to confirm the influence of the oil spill on the affected populations. Second, these results are quite predictable, since the way that species were affected depends on a great variety of biological factors such as their relationship to substratum, their sensitivity to the pollutant, the way they prey on other species, species' longevity, their seasonality, etc. Third, other factors like the ban on fishing and shellfish collecting could affect these conclusions by showing an apparent recovery of the resource on the short term. Fourth, it should be considered that landings only reflect the state of adult fish but they do not explain the situation of juveniles, more sensitive to the spill. Finally, another essential issue to be assessed is the fishing effort of the vessels operating in the area because it is necessary to know that this parameter remains constant over time, since an increase in the fishing effort could produce an increase associated with catches that do not necessarily correspond to the recovery of stocks.

It must be stressed, therefore, that this paper is just a starting point for more extensive analyses in the medium and long term on the environmental effects of the disaster on the Death Coast fisheries. Any feasible extensions of this research might include (i) the incorporation of biomass data corresponding to the main commercial species for a much longer data series, (ii) a detailed analysis of the price of all commercial species and (iii) the development of empirical analyses by assessing the long-term effects, including the fishing effort parameter.

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