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The macroinfauna of the Galician sandy beaches (NW Spain) affected by the *Prestige* oil-spill

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Abstract

Eighteen sandy beaches were sampled along the 1659 km of the Galician coast (NW Spain) six months after the *Prestige* oil-spill to study the impact of the fuel and the clean-up activities on the macroinfauna community. A transect was extended at each beach, from above the drift line to below the swash line at five sampled levels; at each level six 0.05 m^2 replicates were taken to a depth of 30 cm and sieved through a 1 mm mesh, and the organisms collected and preserved. Results were compared with previous data obtained using the same procedures.

The macroinfauna was numerically dominated by the amphipod *Pontocrates arenarius*, the isopod genus *Eurydice*, the polychaete *Scolelepis squamata*, and the amphipod *Talitrus saltator*. As a result of the *Prestige* oil-spill and the clean-up activities, beach populations were reduced, with *Eurydice* and *S. squamata* as the most affected taxa.

Keywords: Oil-spill; Fuel; *Prestige*; Beach; Macroinfauna; Galicia

1. Introduction

The *Prestige*, a tanker with a cargo of 70,000 tons of fuel-oil ran into trouble in heavy seas on November 13, 2002. It broke in half and sank in international waters six days after, about 42°12′N, 12°02′W and 42°10′N, 12°03′W, 133 nm off Spain's western Cape Finisterre. It created one of the largest spills ever, about twice the size of the *Exxon Valdez* spill off the Alaska in 1989, and is already the worst shipping disaster off Spain since the tanker *Aegean Sea* ran aground near La Coruña in 1992. Up to October 2003, 63,717 tons of heavy fuel oil and sediments were removed from the coast of Galicia (NW Spain) (data from AZTI, 2004).

Affected beaches were exposed, open to severe wave action and subject to considerable swells. These beaches were cleaned during the winter and spring of 2002–2003, removing the fuel and the underlying sand, mainly with the aid of shovels. In May 2003, six months after the oil-spill, most of the Galician beaches (98.3%) were cleaned (Xunta de Galicia, 2003a), and clean-up activities were limited to removing tar balls that occasionally arrived to the beaches.

The aim was to study the possible effects on many beaches, visiting each one, and sampling sufficiently to give a reliable picture of the macroinfauna present and to identify the short-term effects, six months after the *Prestige* oil-spill. Results were compared with previous data, mainly from 1995 and 1996, obtained using the same procedures. There is a considerable amount of information related with the effects of petroleum hydrocarbon contamination on benthic soft-bottom fauna following the wreck of oil tankers (e.g., Sanders et al.,

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1980; Dauvin, 1982, 2000; Elmgren et al., 1983; Majeed, 1987; Kingston et al., 1995; Mora et al., 1996; Guidetti et al., 2000), but much less attention has been paid to the macroinfauna of oiled sandy beaches.

The few descriptive studies on the macroinfauna of the Galician sandy beaches (Viéitez and López Cotelo, 1982; Viéitez and Baz, 1988; Mazé et al., 1990; Pérez Edrosa and Junoy, 1991; Junoy and Viéitez, 1992) show that the faunal composition of these beaches is similar to those exposed beaches of the northeast Atlantic (e.g., Salvat, 1967; Eleftheriou and McIntyre, 1976; Withers, 1977; Dexter, 1988, 1990; Degraer et al., 1999).

2. Material and methods

The 18 beaches studied, situated along the 1659 km of the Galician coast, were: América, La Lanzada, Corrubedo, Xuño, Louro, Carnota, Rostro, Area Longa, Traba, Seiruga, Baldaio, Barrañán, Doniños, Frouxeira, San Román, Esteiro, Llas, and Altar (Fig. 1).

These beaches were sampled once during the spring low tides of May 2003. In the middle of the beach, a transect was extended from above the drift line to below the swash line. Beach division was based on Salvat's zonation scheme (Salvat, 1964, 1967), and five sampled stations marked to levels: (1) 2 m above the drift line; (2) drift line, tidal level >3 m; (3) retention, tidal level 3–2 m; (4) resurgence, tidal level 2–1 m; and (5) saturation, tidal level 1–0 m. At each station six 0.05 m^2 replicates (1 m apart) were taken with plastic cylinders to a depth of 30 cm and sieved through a 1 mm mesh. The residue was preserved in 7% formalin; the macroinfauna was later sorted from the sediments, identified, and counted. A sample of sediment for grain size analysis

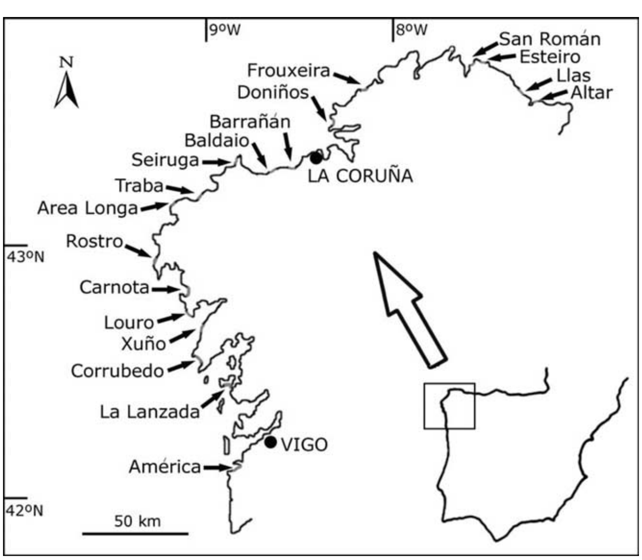

Fig. 1. Map showing location of sampled beaches.

and organic matter content was collected at each station. Particle size analysis was performed by dry sieving (Buchanan, 1984). Organic matter content of the fraction of the sediment <0.5 mm was estimated as weight loss of dried samples after combustion (450 °C, 24 h). For comparison we used previous macroinfaunal data obtained using exactly the same procedures followed in 1995 and 1996 (de la Huz, 1999), and 2002 for Altar beach.

All beaches studied were affected to some degree by the fuel; evaluation of their state was made on the basis of the data recorded every day by the "Comisionado para las actuaciones derivadas de la catástrofe del buque Prestige" (Spanish Ministery of Environment-Ministerio de Medio Ambiente) from November 18, 2002 to May 19, 2003 (180 days) (Table 1). These data were used to compute Bray-Curtis similarity coefficients for all beaches pairs after the spill. Hierarchical agglomerative clustering of the matrix of Bray-Curtis similarity coefficients were used to quantify associations between beaches according to their pollution grade.

Specimens collected before the oil-spill were ashed, and some taxonomic discrepancies with the list of species collected in May, 2003, were impossible to solve. For example, a species of the genus *Eurydice*, *E. nailory* described in 1997 (Jones and Pierpoint, 1997) was obviously present only in the 2003 samples. To avoid problems with the correct determination of some species, analyses were conducted for data aggregated to a mixed taxonomic level (Smith and Simpson, 1995; Guidetti et al., 2000). The validity of this approach is supported by studies suggesting that effects of pollution are detectable at taxonomic levels higher than species (Warwick, 1988a,b; Smith and Simpson, 1993; Gómez Gesteira et al., 2003).

For the purposes of this paper, a Before–After impact data was analysed by aggregating the total abundance for all five levels at each beach and at both sampling occasions, based on an orthogonal ANOVA design with sites (beaches), impact (grade of pollution), and time (before spill vs. after spill) considered as fixed factors. Analysis of the macrofauna according to the tidal elevation will be described in a subsequent paper. Species number, diversity (H', $\log_2$ based, Shannon and Weawer, 1964), evenness (Pielou, 1969), and dominance were calculated for every beach before and after the spill. Species constancy (Dajoz, 1971) was referred to the 36 data (18 beaches, two periods); species present in more than half the samples were termed "common"; those present only in three or less occasions were considered "rare". ANOVA's were conducted for total abundance and abundance of common taxa using $\log(x + 1)$ because raw data compromised normality assumptions of ANOVA; species number, diversity, and evenness data were not transformed. The Bray-Curtis similarity index was calculated to compare the two sampling periods within each beach.

Table 1
Beach pollution state along 180 days (from 18/11/2002 to 19/05/2003)

Beach	First date of fuel arrival	Pollution grade: number of days						
		T	P5	P4	P3	P2	P1	L
América	05/02/2003	0	0	0	0	1	53	47
La Lanzada	13/12/2002	0	0	0	1	8	93	53
Corrubedo	29/11/2002	0	32	0	19	92	17	9
Xuño	21/11/2002	3	45	3	31	84	7	4
Louro	20/11/2002	5	0	4	40	61	49	19
Carnota	21/11/2002	1	49	0	32	72	11	12
Rostro	18/11/2002	23	59	1	7	79	11	0
Area Longa	20/11/2002	11	115	0	11	32	9	0
Traba	18/11/2002	15	66	0	36	63	0	0
Seiruga	18/11/2002	5	5	0	53	60	38	19
Baldaio	18/11/2002	3	92	0	19	36	30	0
Barrañán	18/11/2002	7	119	8	18	19	9	0
Doniños	22/12/2002	4	35	0	38	98	1	0
Frouxeira	01/12/2002	0	63	0	16	59	10	19
San Román	13/12/2002	0	0	0	2	22	95	36
Esteiro	13/12/2002	0	0	0	0	5	100	50
Llas	13/12/2002	0	0	0	0	10	36	109
Altar	13/12/2002	0	0	0	0	8	86	61

Data from the "Comisionado para las actuaciones derivadas de la catástrofe del buque Prestige" (Spanish Ministerio de Medio Ambiente). T: beach totally affected; P5: beach with affection in deep layers; P4: beach with abundant tar balls; P3: beach with disperse tar balls; P2: beach with some signs of fuel; P1: beach apparently clean; L: state of the beach similar to before the spill.

Relationships between benthic assemblages at the different beaches were investigated using non-metric multidimensional scaling (MDS) in order to produce the best graphical depictions of faunal similarities between sites. For these analyses, the data matrix, consisting of total abundances of species at each site, was square root transformed and then converted to a symmetric matrix of biotic similarity between pairs of sites using the Bray-Curtis similarity index. The similarity matrix was agglomerately clustured using average linkage. The above analyses were performed by the PRIMER software package (Clarke and Warwick, 1994).

3. Results

Characteristics of the beaches are given in Table 2. The median diameter of the sand grains varies between 200 and 1570 μm. The grain size on these beaches depends largely on the degree of exposure to wave action,

Table 2
Summary table describing the locations and the principal characteristics of the beaches studied

Beach	Sampling dates		Location		W	L	Md	Wentworth grades	OM
	Before	After							
América	26/09/1996	13/05/2003	42°08′N	8°49′W	104	2300	240–370	Fine-medium	1.2–2.5
La Lanzada	07/09/1995	13/05/2003	42°28′N	8°51′W	127	2400	200–1570	Fine-very coarse	1.3–2.2
Corrubedo	09/09/1995	14/05/2003	42°32′N	9°01′W	139	2900	210–460	Fine-medium	0.8–2.1
Xuño	29/09/1996	14/05/2003	41°01′N	9°01′W	108	2700	460–1380	Medium-very coarse	0.3–1.2
Louro	12/09/1995	14/05/2003	42°43′N	9°03′W	114	1470	380–560	Medium-coarse	0.3–1.1
Carnota	10/09/1995	14/05/2003	42°41′N	9°07′W	133	7000	210–410	Fine-medium	1.0–1.8
Rostro	11/09/1995	14/05/2003	42°90′N	9°12′W	125	2070	380–490	Medium	0.4–1.3
Area Longa	01/09/1996	15/05/2003	43°10′N	9°11′W	185	310	450–770	Medium-coarse	0.7–1.7
Traba	28/09/1995	15/05/2003	43°11′N	9°09′W	98	2630	350–810	Medium-coarse	0.3–1.1
Seiruga	31/08/1996	15/05/2003	43°18′N	8°52′W	91	530	340–540	Medium-coarse	1.7–2.6
Baldaio	27/09/1995	16/05/2003	43°41′N	8°41′W	163	3650	370–1290	Medium-very coarse	0.8–1.4
Barrañán	30/09/1996	16/05/2003	43°18′N	8°32′W	140	1200	430–550	Medium-coarse	0.8–1.4
Doniños	27/09/1996	16/05/2003	43°28′N	8°18′W	154	1700	480–620	Medium-coarse	0.6–1.2
Frouxeira	26/09/1995	16/05/2003	43°35′N	8°10′W	215	3000	350–1070	Medium-very coarse	0.4–1.2
San Román	25/09/1995	17/05/2003	43°44′N	7°39′W	153	910	330–390	Medium	1.0–1.6
Esteiro	29/08/1996	17/05/2003	43°43′N	7°34′W	184	1160	360–430	Medium	0.9–1.7
Llas	28/08/1996	18/05/2003	43°35′N	7°16′W	68	760	300–370	Medium	0.5–1.4
Altar	22/01/2002	18/05/2003	43°34′N	7°14′W	220	950	260–350	Medium	0.8–1.5

W: wide in meters; L: large in meters; Md: range of median particle diameters (μm); OM: range of organic matter content (%).

and in general, the median diameter on the more exposed sites was over 500 μm, and lower than this in more sheltered areas. Usually, the finest grades were found on the lower parts of the beaches, with the area between about mid tidal level and low water springs comparatively uniform. The organic matter content of the sediments was relatively low throughout the beaches and ranged from 0.3% to 2.6%; usually higher contents were found at the lower level of every beach (ANOVA, F-ratio = 4.99, $p = 0.0014$).

Fig. 2 shows the results of the analyses of the pollution data recorded by the Spanish Ministry of Environment. There are six beaches relatively unimpacted by the oil, and considered as lightly polluted: América, La Lanzada, San Román, Esteiro, Llas, and Altar. The other group is formed by the remaining 12 beaches, cataloged as heavily polluted: Corrubedo, Xuño, Louro, Carnota, Rostro, Area Longa, Traba, Seiruga, Baldaio, Barrañán, Doniños and Frouxeira. The pollution grade was evaluated as (2) for heavy polluted beaches, (1) for light polluted beaches and (0) for all beaches before the spill.

Table 3 shows the number of species, diversity, evenness and Bray-Curtis similarity for the 18 beaches in both sampling periods. The total number of species encountered in the beaches was 67 (Appendix A). About

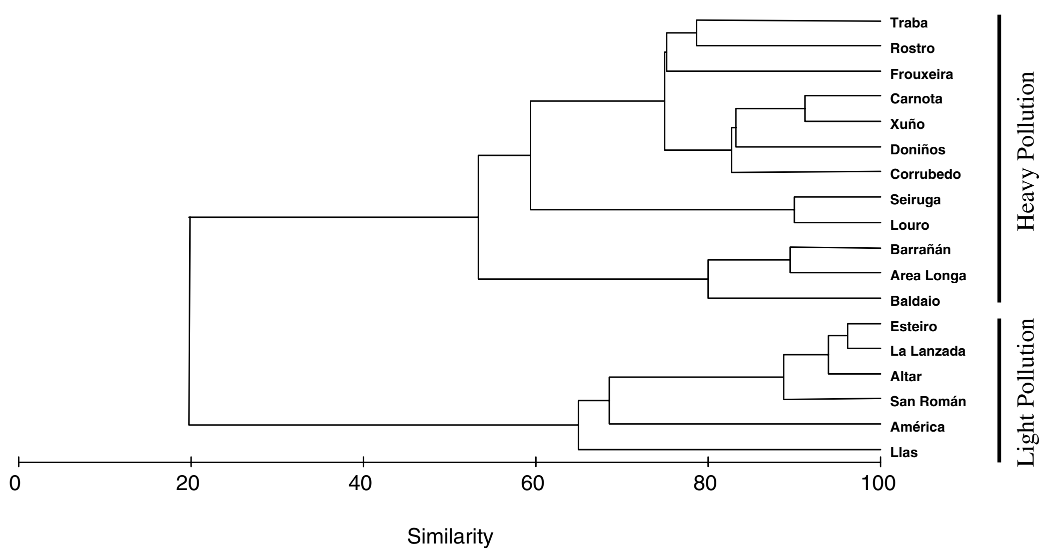

Fig. 2. Cluster dendrogram showing the two groups of beaches according their pollution grade (data from Spanish Ministerio de Medio Ambiente).

Table 3
Species number, diversity, evenness and Bray-Curtis similarity on the 18 beaches in both sampling periods

Beach	Species number		Diversity		Evenness		Similarity
	Before	After	Before	After	Before	After	
América	18	12	2.4	1.9	0.63	0.48	54.5
La Lanzada	15	11	1.9	1.7	0.29	0.55	45.1
Corrubedo	23	20	3.2	3.1	0.50	0.81	73.9
Xuño	15	13	2.8	1.6	0.80	0.25	70.9
Louro	20	15	3.5	2.8	0.67	0.70	61.1
Carnota	26	18	3.7	2.9	0.66	0.63	57.1
Rostro	14	5	2.2	0.8	0.54	0.16	45.4
Area Longa	19	17	2.7	2.6	0.57	0.71	75.6
Traba	14	11	2.1	1.8	0.67	0.70	53.3
Seiruga	16	15	1.9	2.1	0.22	0.47	58.8
Baldaio	20	13	3.1	2.3	0.61	0.72	56.4
Barrañán	15	16	2.5	3.0	0.52	0.67	57.1
Doniños	16	9	2.6	1.3	0.76	0.50	57.1
Frouxeira	14	8	2.3	1.5	0.55	0.40	42.8
San Román	17	21	2.4	3.4	0.47	0.70	65.1
Esteiro	23	16	3.8	2.9	0.77	0.66	58.5
Llas	18	11	3.2	1.9	0.78	0.61	60.6
Altar	16	12	2.6	2.0	0.85	0.71	70.9
Mean (s.d.)	17.7 (3.5)	13.5 (4.1)	1.7 (0.5)	1.5 (0.5)	0.59 (0.02)	0.58 (0.02)	

half of these (33 species) were rare, and their presence in the samples was accidental, with a low number of specimens. The community consists of typical psammophilous species dominated by crustaceans (25 species), and polychaetes (26 species).

The number of species by beach ranges from 5 (Rostro-After) to 26 (Carnota-Before). Except for Barrañán and San Román, all beaches had more species before the spill. The differences between the number of species by beach in the two periods were statistically significant (ANOVA, F-ratio = 10.82; $p = 0.0023$). There was also a negative relation between the degree of pollution and species numbers (ANOVA, F-ratio = 4.42, $p = 0.0104$), being lower in heavy polluted beaches (Fig. 3).

The Shannon diversity index ranges from 0.80 (Rostro-After) to 3.80 (Esteiro-Before). On the beaches of América, La Lanzada, Corrubedo, Area Longa, Seiruga, Barrañán, and San Román, diversity was higher after the spill, but there was not a statistically significant difference between the two sampling times, pollution grade nor among different beaches. Evenness ranges from 0.16 (Rostro-After) to 0.85 (Altar-Before). Differences among sites, pollution grade, and sampling time were not statistically significant.

Except for two heavily polluted beaches, Rostro and Frouxeira, and for La Lanzada, Bray-Curtis similarity between the two periods on every beach was always more than 50%, reaching more than 70% in four beaches: Corrubedo, Xuño, Area Longa, and Altar (Table 3).

The abundance of the macroinfauna varied from 99 individuals (Rostro-After, Frouxeira-After) to 2548 individuals (Seiruga-Before). Fig. 4 shows the total abundance (no. individuals/1.5 m^2) of macrobenthos in the beaches before and after the oil-spill. Except for Xuño (where an unusual but abundant population of Oligochaetes was found on the drift line during the After period) and Doniños beaches, the abundance was significantly reduced after the spill in all of them (ANOVA, F-ratio = 6.3; $p = 0.017$).

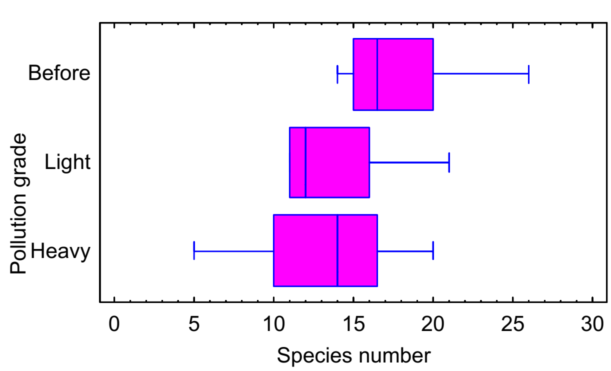

Fig. 3. Number of species before, and after on light and heavily polluted beaches. Shown are the 25% and 75% limits (box) and the range of values (whiskers).

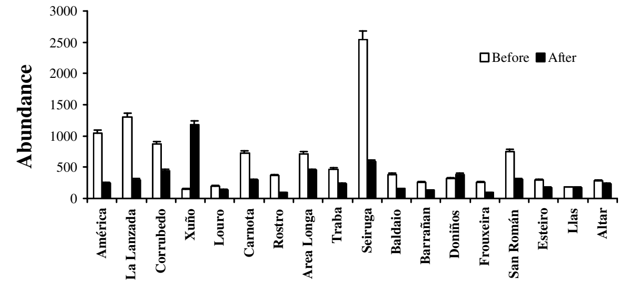

Fig. 4. Total abundance (no. individuals/1.5 m^2) of macrobenthos in the different beaches before and after the *Prestige* oil-spill.

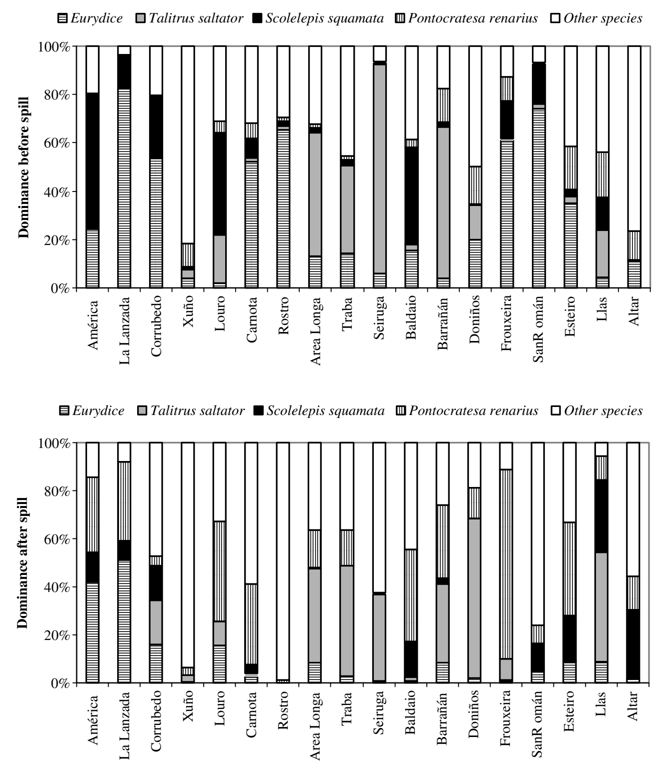

Fig. 5. Dominance of the genus *Eurydice*, *Talitrus saltator*, *Scolelepis squamata*, *Pontocrates arenarius*, and the remaining species (label: other species) in the different beaches before (up) and after (down) the *Prestige* oil-spill.

The most frequent species were the amphipod *Pontocrates arenarius* (100%), the isopod genus *Eurydice* (97.2%), the spionid polychaete *Scolelepis squamata* (86.1%), and the talitrid amphipod *Talitrus saltator* (80.5%). These four taxa are also the most abundant, accounting for 68.8% of all collected specimens. Fig. 5 and Fig. 6 respectively show their dominance and abundance in the beaches before and after the oil-spill. Other "common" taxa were *Gastrosaccus roscoffensis* (77.7%), *Nemertea* spp. (75.0%), Oligochaeta spp. (69.4%), *Lekanesphaera* spp. (66.6%), larvae of Diptera spp. (66.6%), *Talorchestia brito* (55.5%), and *Tylos europaeus* (52.7%).

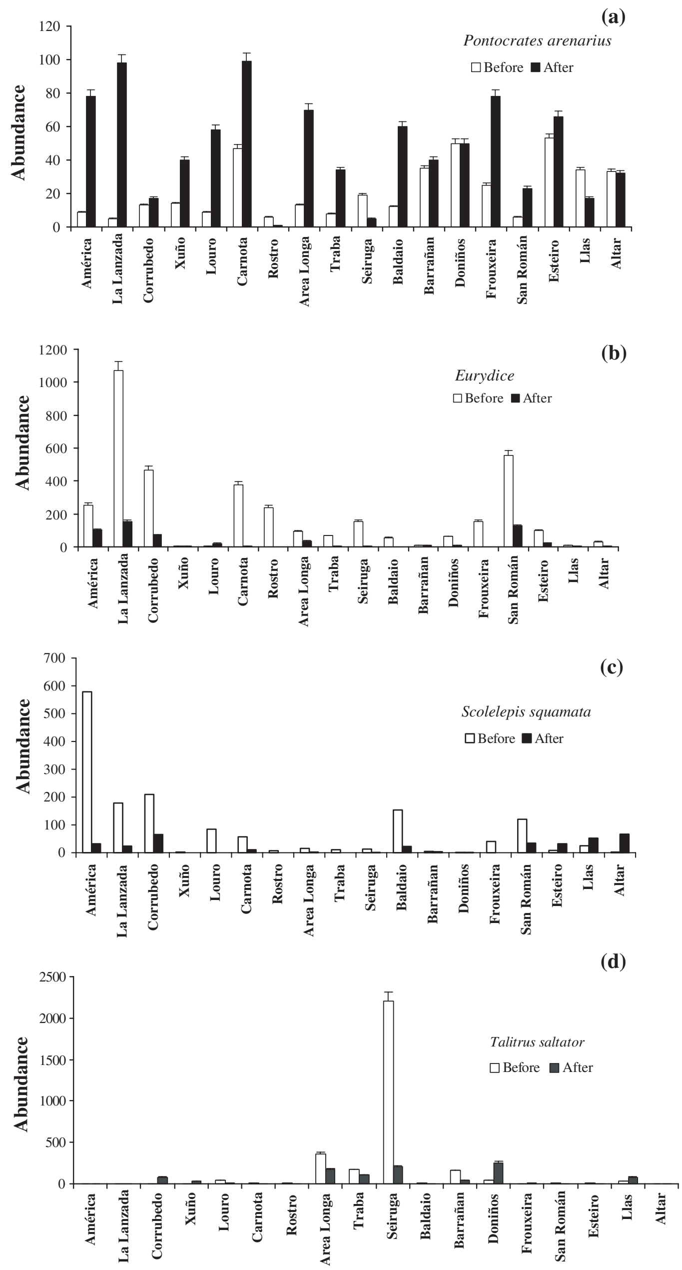

Fig. 6. Abundance (no. individuals/1.5 m^2) of (a) *Pontocrates arenarius*, (b) genus *Eurydice*, (c) *Scolelepis squamata* and (d) *Talitrus saltator* in the different beaches before and after the *Prestige* oil-spill.

Table 4 shows the mean abundance of these 11 taxa in both periods and the results of the ANOVA analyses. The abundance of *Eurydice*, *S. squamata*, the nemerteans and the Diptera were significantly reduced after the spill and were related with the pollution gradient. The abundance of *P. arenarius* was significantly higher but this increase was not related with the pollution gradient. Four taxa were absent on some beaches in the two sampling periods: *T. saltator* (absent in América and Altar beaches), *G. roscoffensis* (in América, Llas, and Altar), *Lekanesphaera* sp. (in Rostro, Traba and Doniños), and *T. europaeus* (América, La Lanzada, Corrubedo, Carnota, Baldaio, Froixeira, and Altar). These four taxa showed significant differences among sites (beaches).

The almost complete absence of mollusks is a characteristic feature of these beaches. Only *Donax trunculus* was collected at six beaches (América, La Lanzada, Corrubedo, Louro, Carnota and Altar) before, and only in one beach (Altar) after the spill.

Fig. 7 shows an MDS plot of beaches before and after the spill. Two intermingling sample groups are identifiable, corresponding to the two periods: beaches before the spill are situated up in the MDS space; beaches after are situated down. Except for Altar and Xuño, all beaches are more similar to others of the same sampling

Table 4
Summary of ANOVAs comparing common species abundance in the Galician beaches over before and after oil-spill, grade of pollution, and beach

Rank	Taxon	Mean (s.d) abundance per 1.5 m^2		ANOVA F test		
		Before	After	Before–After	Pollution grade	Beach
1	*Pontocrates arenarius*	21.72 (16.23)	48.11 (29.84)	5.71*	3.06	1.14
2	*Eurydice*	206.38 (271.37)	32.88 (48.14)	13.63***	9.38***	1.07
3	*Scolelepis squamata*	84.00 (140.52)	19.33 (23.26)	3.02*	9.53***	1.71
4	*Talitrus saltator*	171.11 (515.62)	56.61 (80.72)	0.21	3.54*	6.18***
5	*Gastrossacus roscoffensis*	9.00 (8.61)	13.00 (13.01)	0.13	2.63	3.61***
6	*Nemertea* sp.	6.33 (6.00)	2.50 (4.61)	7.59***	3.89*	0.81
7	*Oligochaeta* sp.	12.72 (20.89)	61.78 (241.32)	0.61	0.88	0.95
8	*Lekanesphaera* sp.	15.83 (31.52)	4.83 (7.50)	2.54	1.49	2.5*
9	*Diptera* sp.	7.33 (7.01)	0.44 (0.61)	40.5***	19.95***	0.27
10	*Talorchestia brito*	7.83 (19.38)	23.33 (64.48)	0.95	4.46*	1.02
11	*Tylos europaeus*	28.11 (43.98)	11.44 (24.60)	1.73	1.94	3.87***

Significance levels for F-test are indicated by: $^{***}p < 0.001$; $^{**}0.001 < p < 0.01$; $^{*}p < 0.05$.

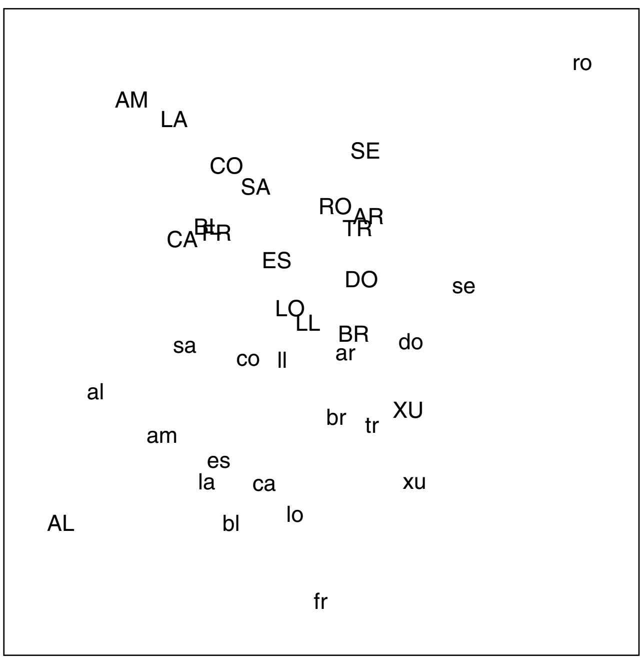

Fig. 7. NMDS plot for Galician beaches (stress = 0.16). Capital letters = before the oil-spill; Small letters = after the oil-spill. Beaches: AL-al = Altar; AM-am = América; AR-ar = Area Longa; BL-bl = Baldaio; BR-br = Barrañán; CA-ca = Carnota; CO-co = Corrubedo; DO-do = Doniños; ES-es = Esteiro; FR-fr = Frouxeira; LA-la = La Lanzada; LL-ll: Llas; LO-lo = Louro; RO-ro = Rostro; SA-sa = San Román; SE-se = Seiruga; TR-tr = Traba; XU-xu = Xuño.

period than themselves in the two periods. Rostro, a heavily polluted beach which still had oil in the sediment in June 2004 (Data from Spanish Ministery of Environment), is separated in the MDS space from the rest of the beaches.

4. Discussion

The beaches studied are all exposed environments, open to wave action, and even in calm weather, they are subject to considerable swell. The fauna showed very low diversity and consisted largely of small crustaceans (which were numerically dominant) and, to a lesser extent, polychaetes. Severe exposure restricts diversity, reducing the presence of sedentary forms, especially bivalve mollusks, and encourages the numerical dominance of agile swimmers, such as amphipods and isopods.

The talitrid amphipod *Talitrus saltator* is dominant in the high tidal level, whereas the amphipod *Pontocrates arenarius*, the different species of the isopod genus *Eurydice*, and the polychaete *Scolelepis squamata* dominate from mid tide level downwards. This group of species forms the bulk of the community in the exposed sandy beaches of Galicia. Some species regarded as typical of European sandy beaches (Eleftheriou and McIntyre, 1976; Dexter, 1988, 1990), as the amphipods of the genus *Bathyporeia* and *Haustorius arenarius*, or the polychaetes *Nephtys cirrosa*, *Paraonis fulgens*, and *Scoloplos armiger*, were also present in the Galician exposed beaches, but in comparatively low numbers.

The oil-spilled from the *Prestige* rapidly spread into the area east of the sunken site, reaching the coast on successive waves since November 16, 2002, onwards. Out of 723 beaches of Galicia, 503 beaches had signs of pollution (Xunta de Galicia, 2003b). All studied beaches were affected to some degree by the fuel; the most affected beaches, scored as heavily polluted, were those situated in the arc between Corrubedo and Frouxeira beaches. On these 12 beaches (Corrubedo, Xuño, Louro, Carnota, Rostro, Area Longa, Traba, Seiruga, Baldaio, Barrañán, Doniños and Frouxeira) the oil was retained in the sediments, and 10 of these beaches were totally covered with crude oil. On Rostro beach, big tar balls (diameter > 15 cm) were present during the samplings (May, 2003).

The decrease in the abundance of the macroinfauna observed after the spill appear to reflect the losses due to oiling toxicity or indirect effects of oiling and clean-up. Rare species, with very low density in the beaches, were eliminated, and thus, species number was lower after the spill. A total of 22 taxa vs. 7 taxa were recorded only in one sampling occasion, before and after the spill, respectively. However, the *Prestige* oil-spill did not markedly affect diversity values, a fact also observed in other spills (e.g., Pielou, 1975; Gómez Gesteira et al., 2003).

Gundlach and Hayes (1978) proposed an environmental classification in order of increasing vulnerability to oil-spill damage. Infaunal organisms are generally considered to be more sensitive to oil pollution than organisms in rocky intertidal areas (Ganning et al., 1984). This is partly due to fewer defense mechanisms for living in rigorous and variable environments. In subtidal sediment bottoms, the sensitivity is greater than in shallow sediment habitats since the organisms live in fairly stable environments.

Main data on the effects of the oil-spills on the soft-bottom macroinfauna come from subtidal benthos. Accidental oil-spills may result in enhancing the abundance of some tolerant species and, in other cases, in a diffuse reduction of the abundance or in local extinction of more sensitive species (Spies and DesMarais, 1983; Peterson et al., 1996). But Kingston et al. (1995) noted that there were no significant changes in benthic community structure, characterized by species richness, individual abundance, and diversity after the Braer oil-spill (Shetland Isles, UK). According to Day et al. (1997) every oil-spill can be considered different, as a consequence of variations among organisms, environmental conditions, and types of oil. Thus, few valid generalizations about ecological effects can be applied to most spills.

Gómez Gesteira and Dauvin (2000) compared the effects of oil-spills on sublittoral soft-bottom communities polluted by the Amoco Cadiz spill in the Bay of Morlaix (western English Channel) and the Aegean Sea spill from the Ares Betanzos Ría (Galicia, north-western Spain). They noted that the effects of the spills were very similar in both regions, with a disappearance of amphipods just after the spill and the absence of significant proliferation of opportunistic species. Substantial mortalities of amphipods were reported in other spills (e.g., Lindén et al., 1979; Sanders et al., 1980; Elmgren et al., 1983; Kingston et al., 1995). This was not the case of the beaches studied, where the amphipod *Pontocrates arenarius* has increased its abundance. With the available data it is difficult to assess whether this species that has been favoured by the *Prestige* spill, is an opportunistic species. Bamber (1993), in a four year study of the sandy beach of Stanswood Bay (Hampshire, UK), observed that the populations of *Pontocrates arenarius* increased with time, but this fact cannot be explained from environmental nor biological data.

Eurydice and *Scolelepis squamata* have reduced significantly their numbers after the spill, and their decrease in abundance were related to the pollution grade. In the Atlantic beaches of the Iberian peninsula, the two most abundant species of *Eurydice*, *E. pulchra* and *E. affinis*, have peak abundances in the winter months (Dexter, 1990; Junoy, 1992). Since the main impact on the *Prestige* oil-spill occurred in these months, it is very probable that a high mortality of this genus occurred, and the densities were still low six months after the disaster. Brown and McLachlan (1990) suggested that *Eurydice* populations could be very affected by the oil-spills, due to its behaviour. This isopod displays a tidal cycle of migration into the water column and cannot survive after contact with crude oil.

Inasmuch as the beach fauna is mainly composed by very mobile crustaceans, sedentary species would provide the most reliable evidence of the effects of pollution. The abundance of the polychaete *Scolelepis squamata*, a species without swimming activity and with general low mobility, seems to have been influenced by the spill. Probably, the beach cleaning which involved the removal of the sand was more important than the toxic effects of the fuel. In this sense, polychaetes appear to be resistant to high levels of hydrocarbons in sediment (Gómez Gesteira and Dauvin, 2000), and *Scolelepis squamata* has been pointed out as an opportunistic species, which adapts easily to oil-spills (Rizzo and Amaral, 2001).

Species living in the upper level of the beach, as the talitrid amphipods *Talitrus saltator* and *Talorchestia brito* and the isopod *Tylos europaeus*, were not significantly affected. Only for the larvae of Diptera there were statistical differences in the abundance between the two sampling periods; beaches were sampled on fall before the spill and on spring after the spill. Probably this fact is more related with the season that with the oil-spill: from September onwards, decaying algae accumulated in the drift line increase the numbers of Diptera larvae (Junoy, unpublished observations).

Unfortunately there are no long-term studies on the macroinfauna of the Spanish beaches, and differences in the timing of sampling could be responsible to some degree for variations in the faunal composition and, more probably, in the densities between the two periods compared. Although macroinfauna populations could be undergoing slow or long term changes, these probably do not seriously affect the present study. Anyway, we should be aware of such difficulties involved in the interpretation and comparison of the two sets of data. There is simply no more information available to evaluate population and community level changes in the beach community in order to determine the effects of the *Prestige* oil-spill. Twenty years ago, Ganning et al. (1984), in their revision of habitats impacted by oil-spills yet suggested the need to conduct studies to define natural variability in the ecosystem, that would provide the basis on which to determine the potential seriousness of a perturbation.

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Appendix A

List of taxa collected in the Galician beaches. Before the oil-spill = B; After the oil-spill = A; and in both sampling occasions = *. Beaches: AM = América; LA = La Lanzada; CO = Corrubedo; XU = Xuño; LO = Louro; CA = Carnota; RO = Rostro; AR = Area Longa; TR = Traba; SE = Seiruga; BL = Baldaio; BR = Barrañán; DO = Doniños; FR = Frouxeira; SR = San Román; ES = Esteiro; LL = Llas; AL = Altar.

TAXA	BEACH																	
	AM	LA	CO	XU	LO	CA	RO	AR	TR	SE	BL	BR	DO	FR	SR	ES	LL	AL
Nemertea	A	A	*	*	*	B	B	*	*	B	*	B	B	*	B	*	B	*
Polychaeta																		
Saccocirrus cf. *Papillocereus*				*				B	B	B		*						
Lumbrineris impatiens								*			B						B	
Dispio uncinata					A										A	A		
Microphthalnus pseudoaberrans																A		
Nephtys cirrosa	B	B	*		*	*					*				*	B		*
Pomatoceros lamarckii			A															
Ophelia bicornis						B					B			B	*	B		
Ophelia neglecta				B	*			*	B			B	B			*		
Paraonis fulgens					B	B					*				A	A		*
Scolelepis squamata	*	*	*	B	B	*	B	*	B	*	*	*	*	B	*	*	*	*
Spiophanes bombyx	B					*												
Spio sp.							B											
Spio martinensis																		B
Malacoceros sp.								B										B
Scoloplos armiger											B							B
Sigalion sp.																		A
Protodriloides chaetifer					A							A						
Pisione remota				A				B										
Eteone longa						B												
Syllis sp.			B															
Odontosyllis sp.			B			B												
Capitelidae sp.																	B	
Harmothoe sp.			B															
Mediomastus sp.			B															
Capitomastus sp.					B													
Polygordiidae				B	B													
Oligochaeta	B	*	B	A	*	*	*	*	*	*	*	B	B		*	A	B	
Mollusca																		
Angulus tenuis	B	B				B												
Donax trunculus	B	B	B		B	B												*
Crustacea																		
Portumnus latipes	A		*		A	*										*		B

Appendix A (*continued*)

TAXA	BEACH																	
	AM	LA	CO	XU	LO	CA	RO	AR	TR	SE	BL	BR	DO	FR	SR	ES	LL	AL
Bathyporeia pelagica		B				*					B			B	*	B	B	*
Atylus swammerdammi	B		B										B	B			B	
Urothoe brevicornis																		B
Haustorius arenarius	*	*	A		A	*			B		B			B	*	B	*	A
Pontocrates arenarius	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Pontocrates altamarinus															A	B		
Talitrus saltator		B	*	*	*	*	B	*	*	*	*	*	*	*	B	*	*	
Talorchestia brito			*	*	*	A	B	A	A	*	A	A	*		*	B	B	
Talorchestia deshayesii			*		B	A	B	*	A	*		*	B				B	
Eurydice affinis	*	B	*	A		*	B	*	B	*	B	A	B	B	*	*		
Eurydice naylori	A	A	A	A	A	A		A	A	A	A	A		A		A	A	*
Eurydice pulcra	*	*	*	*	B	*	B	*	*	*	B	*	*	B	*	*	*	
Eurydice spinigera			B								B					B		
Lekanesphaera sp.	*	B	*	A	*	B		*		*	B	*		B	*	B	*	*
Tylos europaeus				*	B		*	*	*	*		A	*		*	B	*	
Tanaissus lilljeborgi																		B
Cumopsis fagei	*		*			*					*					A		A
Cumopsis longipes						A												
Eocuma dollfusi	B		*															
Iphinoe cf. *tenella*																		B
Gastrosaccus roscoffensis		*	*	*	*	A	B	*	*	B	*	*	*	*	*	*		
Gastrosaccus spiniger	A										A							
Leptomysis sp.	B																	
Hemimysis sp.																B		
Insecta																		
Anurida maritima	B					B						B	A		A	B		
Coleoptera spp.	B					B						B	A		A	B		
Staphilinidae spp.			A							A	B	A	A	*			*	
Helodidae sp.	B																	
Tenebrionidae spp.				B	B	B			B			B	B	A	B	B		
Histeridae spp.					B		A	A		A					A			
Diptera spp.	B	*	*	B	B	B	*	*	B	B	B	*	B	B	*	B	*	
Orthoptera sp.				B														
Hymenoptera spp.	B			B		B				B		*			B			
Araneae						B	B		A	A			B				B	
Pisces																		
Ammodytes tobianus			A					B		A				A				
Echiichthys vipera								B		B						B		

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