SUPPORTING INFORMATION AVAILABLE

Assessment of cleanup needs of oiled sandy beaches: Lessons from the *Prestige* oil spill

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Beaches studied and location of cores

Fig. S1 shows satellite photographs of the five Galician and three Basque beaches that were studied. The Galician beaches were, from north to south, Nemiña, O Rostro, Arnela, Mar de Fora and Figueiras; all except Figueiras are located on the Costa da Morte, the area most affected by the POS. The three beaches examined in the Basque Country were, from west to east, Bakio, Laida and Laga.

Nemiña Beach, located between Cape La Vela and Cape Barra, is 1500 m long and 25 m wide. Three areas can be distinguished: the northern sector, which lies among rocky outcrops and is bounded inland by a wall and a parking lot; the central sector, in which the supratidal zone is bounded by dunes; and the southern sector, which features the mouth of the River Castro.

O Rostro lies at the southern end of the Ría de Lires. It is 2000 m long and 50 m wide. The northern, central and southern sectors of this beach are crossed by three slow-flowing rivers. Landwards, it is bounded by a wide dune field.

Arnela is a pocket beach 150 m long and 40 m wide. It is a high-energy sandy beach facing northwest, and thus exposed to the most frequent waves on this coast.

Mar de Fora Beach is located in Finisterre, between Cape Nave to the north and Cape Coidos to the south. It is 500 m long and 40 m wide.

The Cíes Isles are a group of small islands at the mouth of the Ría de Vigo that belong to the Atlantic Islands National Park. Figueiras Beach is located in the northern of the two main islands, facing the Ría. It is 300 m long and 30 m wide at its southern end, where it is terminated by Cape Muxeiro.

Bakio is an urban beach 840 m long and 65 m wide, backed by an esplanade. The western sector has numerous rocky outcrops and is terminated by high cliffs.

Laida Beach is a spit located in the mouth of the Urdaibai estuary. It is 812m long and 166 m wide. The central area of the spit is formed of vegetation-covered dunes.

Laga Beach is located to the east of the mouth of the Urdaibai estuary, and is 574 m long and 110 m wide.

Figure S1. Satellite pictures of the eight beaches studied (courtesy of http://earth.google.com), showing the points at which cores were extracted (for the year of extraction, see the key).

Figure S2. (a) and (b) Scale drawing of the BOSC (Beach-Optimized Suction Corer). This device is made up of three elements: the aluminum pushing head, a PVC casing tube, and the piston. For normal operation the casing, a 1.5-3.0 m PVC tube, is inserted into the bottom end of the aluminum head until it hits the stop. The piston is then introduced from the top end until it reaches the far end of the casing, and the casing is pushed into the sediment by two people holding the handles on the pushing head, while a third pulls the piston slightly in the opposite direction (c) until the head reaches the top of the sediment (d). For the piston and casing we generally use 3 m lengths of PVC tubing 3 mm thick (EU standard UNE - EN 1.329), with outer diameters of 32 mm for the piston and 50 mm for the casing. (e) Core halves, showing clean sand (top 10 cm) overlying more than 1.5 m of a grey sand belt composed of oil-coated grains. A 4 cm tar ball can be seen about 0.75 m from the core top.

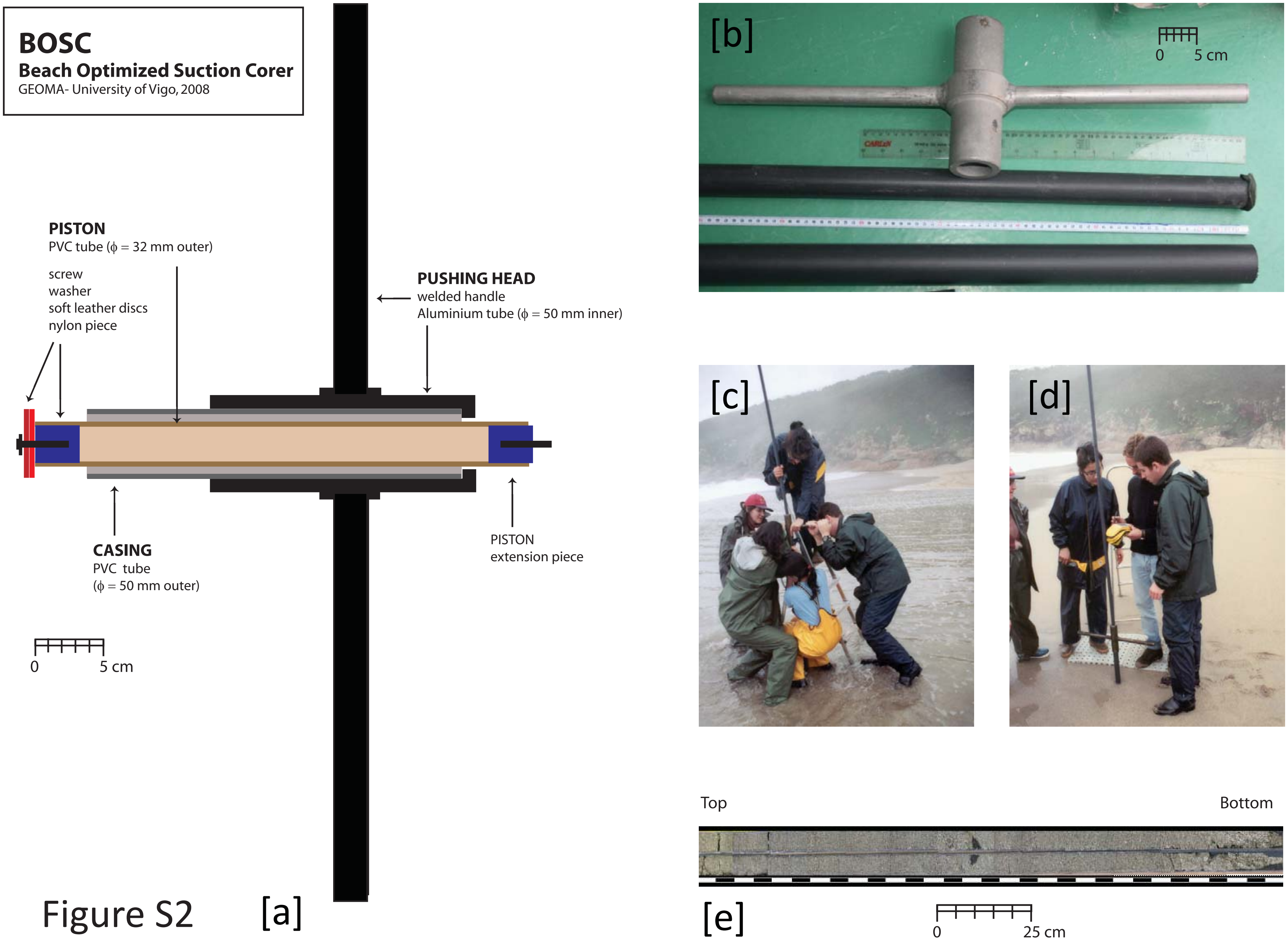

BOSC
Beach Optimized Suction Corer
GEOMA- University of Vigo, 2008
PISTON
PVC tube (ϕ = 32 mm outer)
screw
washer
soft leather discs
nylon piece
PUSHING HEAD
welded handle
Aluminium tube (ϕ = 50 mm inner)
CASING
PVC tube
(ϕ = 50 mm outer)
PISTON
extension piece
0
5 cm
[a]
[b]
0
5 cm
[c]
[d]
Top
Bottom
[e]
0
25 cm

Figure S2

Table S1. Samples taken and analyses performed. For each sampling campaign (both winter and mild-weather periods were included) the table lists the region concerned (Galicia or the Basque Country); the beach; the number of cores extracted from each beach; the minimum and maximum core lengths; and the analyses performed. Note that the use of the BOSC allowed extraction of cores of up to 3.74 m in length. Abbreviations used: NEM, Nemiña; RO, O Rostro; ARN, Arnela; MF, Mar de Fora; FI, Figueiras; BAK, Bakio; LAI, Laida; AGA, Laga.

Sampling date	Area studied		No. of cores	Min-max core length (m)	Analyses performed
	Region	Beaches			
January 04	GALICIA	Nemiña	11	0.38-2.16	• Visual description and oil identification: all cores • Grain size analysis: all cores • Elemental analysis, TOC, IC: NEM, RO, MF cores • Hydrocarbon analysis: NEM core
		O Rostro	9	1.31-2.38	
		Arnela	4	2.07-2.34	
		Mar de Fora	4	1.26-2.30	
Feb-March 05	GALICIA	Nemiña	5	0.58-3.74	• Visual description and oil identification: all cores • Grain size analysis and hydrocarbon analysis: 23 samples (one core per beach): BAK (sample depth: 7, 23, 42.5 cm), LAI (3.5, 115, 215 cm), AGA (5.5, 104, 218.5 cm), NEM (3.5, 123,170.5,210,216 cm), FI 1 (3, 64.5, 112 cm), FI 3 (4.5, 13.5, 61.5, 117, 123, 130 cm)
		Figueiras	6	0.44-2.42	
	BASQUE COUNTRY	Bakio	4	0.57-1.17	
		Laida	4	1.36-2.24	
		Laga	7	1.09-2.28	
June 06	GALICIA	Nemiña	3	1.02-1.77	• Visual description and oil identification: all cores • Grain size analysis: 2 samples per core
		O Rostro	6	1.16-2.33	
May 07	GALICIA	Nemiña	3		• *In situ* visual inspection and oil identification

Table S2. Basic sediment characteristics. Abbreviations: TOC, total organic carbon; MWS, moderately well-sorted; PS, poorly sorted.

Area studied		Median grain size D_{50} (mm)	Sorting	$CaCO_3$ (%)	TOC (%)
Galicia	Nemiña	0.374	0.65 (MWS)	50	0.54
	O Rostro	0.497	0.603 (MWS)	51.6	0.46
	Arnela	0.541	1.55 (PS)	--	--
	Mar de Fora	0.554	1.58 (PS)	44.9	0.28
	Figueiras	0.4	0.7 (MWS)	19.7	0.05
Basque Country	Bakio	0.5	1.1 (PS)	28.0	0.4
	Laida	0.3	0.7 (MWS)	28.4	0.2
	Laga	0.5	1.0 (PS)	62.0	0.6

Table S3. Detailed descriptions of cores identified by sampling date, region, beach, beach sector, position on beach profile, and geographical coordinates: core length, depth of occurrence of oil, and oil form. HTZ, MTZ, LTZ: high, mid- and low tidal zones, respectively. Asterisks indicate observations made during the preprocessing of sand samples in the laboratory.

Beach	Beach sector	Position on profile	Geographical coordinates	Core length (cm)	Depth of oil location (cm)	Appearance of oil
			January 2004			
			GALICIAN COAST			
NEMIÑA	**North**	HTZ	43º 0.723 N 9º 16.102 W	35	Whole core 20-21	Oil coatings or grey sand More intense grey
		MTZ	43º 0.720 N 9º 16.102 W	112.5	4,37,39, 60, 65 40-70 * Whole core	Tar balls (cm) (*Fig S3a*) Abundant tar balls (mm) (*Fig. S3b*) Oil coating, more intense towards the core bottom
		LTZ-1	43º 0.674 N 9º 16.119 W	191	120-130 From 114 to the bottom Whole core	Tar balls (cm) Abrupt change of colour from gold to grey Stained tube
		LTZ-2	43º 0.674 N 9º 16.119 W	157	76, 100 100-140 * 20-60 *	Tar balls (cm) Abundant tar balls (mm) Moderately abundant tar balls (mm) (*Fig S3c*)
	Central	HTZ	43º 0.491 N 9º 15.675 W	108	No oil detected	
		MTZ	43º 0.485 N 9º 15.697 W	184	158 From 160 to the bottom 60-70,100-110,140-150 * 80-90,120-130,160-175 * From 50 to the bottom	Tar ball (mm) Oil coatings Abundant oil tar balls (mm) Moderately abundant tar balls (mm) Stained tube
		LTZ-1	43º 0.522 N 9º 15.740 W	156.5	40 0-10, 40-50 * 60-70, 100-110 *	Tar ball Abundant tar balls (mm) Moderately abundant tar balls (mm)
		LTZ-2	43º 0.521 N 9º 15.749 W	142.5	100-bottom * Whole core	Moderately abundant tar balls (mm) Emulsion
	South	HTZ	43º 0.383 N 9º 15.596 W	62	0-35	Oil coatings (grey sand)
		MTZ	43º 0.379 N 9º 15.676 W	146	9, 103 0-10, 80-110 * 85-90	Tar balls Abundant tar balls (mm) Grey sand belt
		LTZ	43º 0.370 N 9º 15.596 W	214.5	80-90, 160-170 *	Moderately abundant tar balls (mm)
O ROSTRO	**North**	HTZ	42º 58.377N 9º 15.681 W	161	No oil detected	
		MTZ	42º 58.393N 9º 15.732 W	234	No oil detected	
		LTZ	42º 58.409N 9º 15.790 W	95	No oil detected	
	Central	HTZ	42º 58.005 N 9º 15.927 W	164	No oil detected	
		MTZ	42º 58.019 N 9º 15.974 W	161.5	60-110 *	Moderately abundant tar balls (mm)

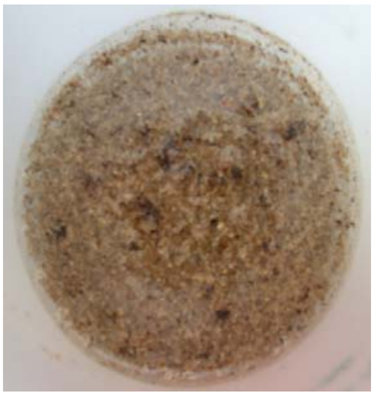
					109-113 cm	Oil coatings
		LTZ	42º 58.034 N 9º 16.014 W	166	35-37, 40, 60, 80 cm	Tar balls (mm)
	South	HTZ	42º 57.714 N 9º 16.195 W	187	No oil detected	
		MTZ	42º 57.735 N 9º 16.237 W	148	112-118 0-10, 100-110 * 0-10, from 100 to bottom	Tar ball Moderately abundant tar balls (mm) Stained core
		LTZ	42º 57.752 N 9º 16.260 W	204	19-26 7, 32, 66, 178 30-40 0-30, 60-70, 180-190 * The rest of the core *	Oil lens Tar balls (cm) Tar balls (mm) Abundant tar balls (mm) Moderately abundant tar balls (mm)
ARNELA	East	HTZ	42º 56.539 N 9º 16.980 W	226	No oil detected	
		LTZ	42º 56.548 N 9º 16.990 W	218	No oil detected	
	West	HTZ	42º 56.524 N 9º 17.026 W	232.5	96, 110 30,90,170	Oil lens Stained core
		LTZ	42º 56.536 N 9º 17.037 W	207	No oil detected	
MAR DE FORA	North	HTZ	42º 54.581 N 9º 16.534 W	182	23-25 and 40-50	Tar balls (cm)
		LTZ	42º 54.579 N 9º 16.586 W	207.5	9, 104, and from 200 to the bottom	Tar balls
	South	HTZ	42º 54.460 N 9º 16.530 W	123.5	100	Tar ball (cm)
		LTZ	42º 54.478 N 9º 16.601 W	243	112, 139, 182 200-210	Stained core
				February 2005		
				GALICIAN COAST		
NEMIÑA	North	HTZ	43º 0.716 N 9º 16.111 W	169.5	No oil detected	
		MTZ	43º 0.712 N 9º 16.109 W	198	From 145 to the bottom	Oil coatings
		LTZ	43º 0.679 N 9º 16.130 W	58.5	From 21 to the bottom	Oil coatings
	Central	HTZ	43º 0.666 N 9º 15.887 W	224	135-143 From 149 to the bottom 0-55, 103-149 From 130 to the bottom	Tar balls (mm) Moderately abundant tar balls (mm) Abundant tar balls (mm) Oil coatings
		LTZ	43º 0.489 N 9º 15.755 W	375	From 290 to the bottom	Oil coatings
FIGUEIRAS	North	HTZ	42º 13.809 N 8º 53.983 W	242		
		LTZ	42º 13.906 N 8º 54.051 W	115	50, 65 From 15 to the bottom	Tar balls Moderately abundant tar balls (mm)
	Central	HTZ	42º 13.872 N 8º 54.044 W	97		
		LTZ	42º 13.834 N 8º 53.989 W	44	Core bottom	Oil coatings
	South	HTZ	42º 13.784 N 8º 53.970 W	184		
		LTZ	42º 13.826 N 8º 53.982 W	141	132 cm From 123 to the bottom 30-63, 84-117 From 120 to the bottom	Tar ball Abundant tar balls (mm) Moderately abundant tar balls (mm) Oil coatings
				BASQUE COUNTRY		
BAKIO	East	HTZ	43º 25.923 N 2º 48.133 W	57	No oil detected	
		LTZ	43º 25.931 N	75	No oil detected	

			2º 48.144 W			
	Central	HTZ	43° 25.884 N 2° 48.238 W	85	No oil detected	
		LTZ	43° 25.896 N 2° 48.246 W	112	No oil detected	
LAIDA	**East**	HTZ	43° 24.099 N 2° 41.122 W	202	No oil detected	
		MTZ-1	43° 24.124 N 2° 41.131 W	136	No oil detected	
		MTZ-2	43° 24.124 N 2° 41.131 W	156	No oil detected	
		LTZ	43º 24.167 N 2º 41.132 W	223	No oil detected	
LAGA	**East**	HTZ	43° 24.595 N 2° 39.322 W	223.5	No oil detected	
		LTZ	43° 24.607 N 2° 39.334 W	137	No oil detected	
	Central	HTZ-1	43º 24.563 N 2º 39.473 W	212	No oil detected	
		HTZ-2	43° 24.577 N 2° 39.425 W	154.5	No oil detected	
		LTZ	43º 24.579 N 2º 39.474 W	228	No oil detected	
	West	HTZ	43º 24.557 N 2º 39.620 W	198	No oil detected	
		LTZ	43º 24,576 N 2º 39,621 W	109	No oil detected	
			June 2006			
			GALICIAN COAST			
NEMIÑA	**North**	HTZ	43º 0.723 N 9º 16.102 W	177	83-118 From 42 cm to the bottom	Moderately abundant tar balls (mm) Oil coatings
		MTZ	43º 0.720 N 9º 16.102 W	102	0-14 All core	Moderately abundant tar balls (mm) Oil coatings
		LTZ	43º 0.674 N 9º 16.119 W	145	0-15, 30-40, 53-66, 76-86, 106-116, 136 to the bottom From 30 to the bottom 27-30, 108-110 24-33	Moderately abundant tar balls (mm) Oil coatings (slightly greyish sand) Very grey layers Stained tube
O ROSTRO	**Central**	HTZ	42º 57.998 N 9º 15.940 W	203	0-15, 107-117, 144-155	Moderately abundant tar balls (mm)
		MTZ	42º 57.999 N 9º 15.945 W	233	139-151, 181-191	Moderately abundant tar balls (mm)
		LTZ	42º 58.012 N 9º 15.963 W	124	0-10 80-90	Tar ball Moderately abundant tar balls (mm)
	South	HTZ	42º 57.740 N 9º 16.199 W	169	65-80, 156-169	Moderately abundant tar balls (mm)
		MTZ	42º 57.740 N 9º 16.197 W	116	48-59, 105-116	Moderately abundant tar balls (mm)
		LTZ	42º 57.748 N 9º 16.205 W	185	77,96	Tar balls (cm)
			May 2007			
			GALICIAN COAST			
NEMIÑA	**North**	LTZ-1	43º 0.674 N 9º 16.119 W	0.50	Variable depth	Oil coatings
		LTZ-2	43º 0.656 N 9º 16.027 W	0.95	Variable depth	Oil coatings

Fig. S3 a) Tar ball in the LTZ core from the northern sector of Nemiña Beach (2004); b) Abundant tar balls (mm) in a sample from Figueiras Beach (2005); c) Moderately abundant tar balls (mm) in a sample from Nemiña Beach (2004).

a)

b)



c)

Table S4. Concentrations of individual PAHs (μg/kg) in cores from the high intertidal zones of Figueiras and Nemiña Beaches. Depths shown are the mean depths of the core section analysed. <dl: below detection limit (0.4 μg/kg).

		Figueiras (2005)					**Nemiña (2005)**				
Component		**Depth (cm)**					**Depth (cm)**				
	m/z	**13**	**61**	**117**	**123**	**130**	**5**	**123**	**170**	**210**	**216**
Naphthalene	128	<dl	0.7	<dl	<dl	1.1	<dl	0.9	0.8	0.9	<dl
Methylnaphthalenes	142	<dl	1.0	<dl	<dl	2.0	<dl	1.6	1.9	1.3	0.8
Dimethylnaphthalenes	156	<dl	1.2	4.3	10.8	213	<dl	3.0	4.5	5.5	1.6
Trimethylnaphthalenes	170	1.7	2.6	9.0	49.5	1560	1.1	6.6	6.5	17.8	2.7
Fluorene	166	<dl	<dl	<dl	<dl	18.8	<dl	1.4	0.7	0.5	<dl
Phenanthrene	178	1.43	2.1	2.8	10.1	119	1.3	3.9	4.2	1.9	1.9
Anthracene	178	<dl	<dl	<dl	5.5	54.7	<dl	<dl	<dl	33.7	<dl
Methylphenanthrenes	192	1.8	10.4	48.2	134	1350	1.8	2.8	12.6	100	7.7
Dimethylphenanthrenes	206	3.0	23.2	125	301	2249	5.2	2.7	10.5	108	11.1
Trimethylphenanthrenes	220	5.7	32.1	141	312	2644	9.9	4.2	12.0	267	22.6
Fluoranthene	202	<dl	<dl	<dl	4.9	49.1	<dl	<dl	1.2	4.5	1.4
Pyrene	202	<dl	3.6	10.9	24.8	195	1.1	<dl	2.3	23.0	4.1
Methylpyrenes	216	2.6	12.3	32.9	75.5	628	2.7	1.9	3.8	75.0	7.5
Dimethylpyrenes	230	6.8	24.0	51.3	109	802	4.9	3.5	6.4	107	13.0
Trimethylpyrenes	244	5	12.1	44.8	82.8	658	3.1	2.3	3.8	88.7	7.1
Dibenzothiophene	184	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl
Methyldibenzothiophenes	198	0.5	1.4	9.2	33.2	338	<dl	0.5	0.9	4.2	43.1
Dimethyldibenzothiophenes	212	1.1	7.5	46.6	89.7	802	<dl	2.1	5.5	69.4	12.2
Trimethyldibenzothiophenes	226	1.9	10.5	50.8	113	983	<dl	2.9	8.5	97.7	232
Benzo[a]anthracene	228	<dl	1.6	6.3	12.6	73.6	<dl	<dl	<dl	8.0	1.5
Chrysene	228	1.2	3.6	11.4	19.8	146	1.3	<dl	1.7	17.6	2.6
Methylchrysenes	242	4.1	14.3	37.8	71.5	475	4.4	2.9	4.9	68.5	9.8
Dimethylchrysenes	256	4.8	21.4	44.3	102	667	6.7	4.2	6.7	89.3	12.8
Trimethylchrysenes	270	5.9	16.4	53.8	59.9	891	4.7	3.7	6.3	58.3	9.5
Benzo[b]fluoranthene	252	<dl	1.6	<dl	2.8	27.6	<dl	<dl	<dl	4.1	<dl
Benzo[k] fluoranthene	252	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	6.1	<dl
Benzo[e]pyrene	252	1.5	3.2	6.2	11.3	62.2	<dl	<dl	1.6	9.3	2.0
Benzo[a]pyrene	252	<dl	1.9	4.3	7.8	42.0	<dl	<dl	<dl	6.6	1.3
Indeno[1,2,3-c,d]pyrene	276	<dl	<dl	<dl	<dl	15.8	<dl	<dl	<dl	1.8	<dl
Benzo[g,h,i]perylene	276	<dl	1.6	<dl	0.8	10.7	<dl	<dl	<dl	4.3	<dl
Dibenzo[a,h]anthracene	278	<dl	<dl	<dl	<dl	7.5	<dl	<dl	<dl	2.2	<dl
Benzonaphthothiophene	234	<dl	<dl	<dl	<dl	4.2	<dl	<dl	<dl	3.2	<dl
Total PAHs		**49**	**210**	**741**	**1644**	**15089**	**53**	**51**	**179**	**1285**	**408**

Table S5. Diagnostic ratios used as source and weathering indicators.

Diagnostic ion *m/z*	Index	Definition	Structures
191	%27Ts	100*Ts/(Ts+Tm)	Ts: 18α(H)-22,29,30-trisnorneohopane Tm: 17α(H)-22,29,30-trisnorhopane
191	%29αβ	100*29αβ/(29αβ+30αβ)	29αβ: 17α(H),21β(H)-30-norhopane 30αβ: 17α(H),21β(H)-hopane
217	%27dia	100*27d(R+S)/[27d(R+S)+27ββ(R+S)]	27d: 13β(H), 17α (H)-diacholestane (20S and 20 R) 27ββ: 14β(H), 17β(H)-cholestane (20R and 20 S)
217	%29ααS	100*29ααS/(29ααS+29ααR)	29αα: 24-ethyl-14α(H), 17α(H)-cholestane (20S and 20R)
217	%29ββ (R+S)	100*29ββ(R+S)/[29ββ(R+S)+ 29αα(R+S)]	29ββ: 24-ethyl-14β(H), 17β(H)-cholestane (20R and 20 S)
218	%27ββ	100*[27ββ(R+S)]/[27ββ(R+S)+ 28ββ(R+S)+ 29ββ(R+S)]	27ββ: 14β(H), 17β(H)-cholestane (20R and 20 S)
218	%28ββ	100*[28ββ(R+S)]/[27ββ(R+S)+ 28ββ(R+S)+ 29ββ(R+S)]	28ββ: 24-methyl-14β(H), 17β(H)-cholestane (20R and 20S)
218	%29ββ	100*[29ββ(R+S)]/[27ββ(R+S)+ 28ββ(R+S)+ 29ββ(R+S)]	29ββ: 24-ethyl-14β(H), 17β(H)- cholestane (20R and 20S)
192/242	P1/C1	100*P1/(C1+P1)	methylphenanthrenes (P1) and chrysenes (C1)
206/256	P2/C2	100*P2/(C2+P2)	dimethylphenanthrenes (P2) and chrysenes (C2)
220/270	P3/C3	100*P3/(C2+P3)	trimethylphenanthrenes (P3) and chrysenes (C3)
220/226	P1/D1	100*P1/(D1+P1)	methylphenanthrenes (P1) and dibenzothiophenes (D1)
206/212	P2/D2	100*P2/(D2+P2)	dimethylphenanthrenes (P2) and dibenzothiophenes (D2)
220/226	P3/D3	100*P3/(D3+P3)	trimethylphenanthrenes (P3) and dibenzothiophenes (D3)