Surf zone suprabenthos of two Galician beaches (NW Spain): A temporal study

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Suprabenthic communities have been studied in different geographic areas, i.e. the Baltic Sea, (Beyst *et al*. 2001), the English Channel, (Dauvin *et al*. 2000) and different depths (Frutos 2006) but they have received less attention than other marine communities. The only available data from research carried out on Spanish beaches occured on the Catalan coast (Munilla & San Vicente 2005) and the Hendaya beach (San Vicente & Sorbe 2001). Thus, this is the first study of the suprabenthos from the beach surf zone of Galicia in northwest Spain.

The present study analyzes the suprabenthic communities at the surf zone of two exposed sandy beaches (Fig.1), Altar (Barreiros, Lugo, Cantabric coast) and Corrubedo (Riberia, A Coruña, Atlantic coast) whose macroinfauna is well known (Junoy & Viéitez 1990, Junoy *et al* 2005).

The objectives are to understand the suprabenthic community of the beaches and the temporal variations, comparing them from a structural point of view while checking the role of the environmental parameters as well.

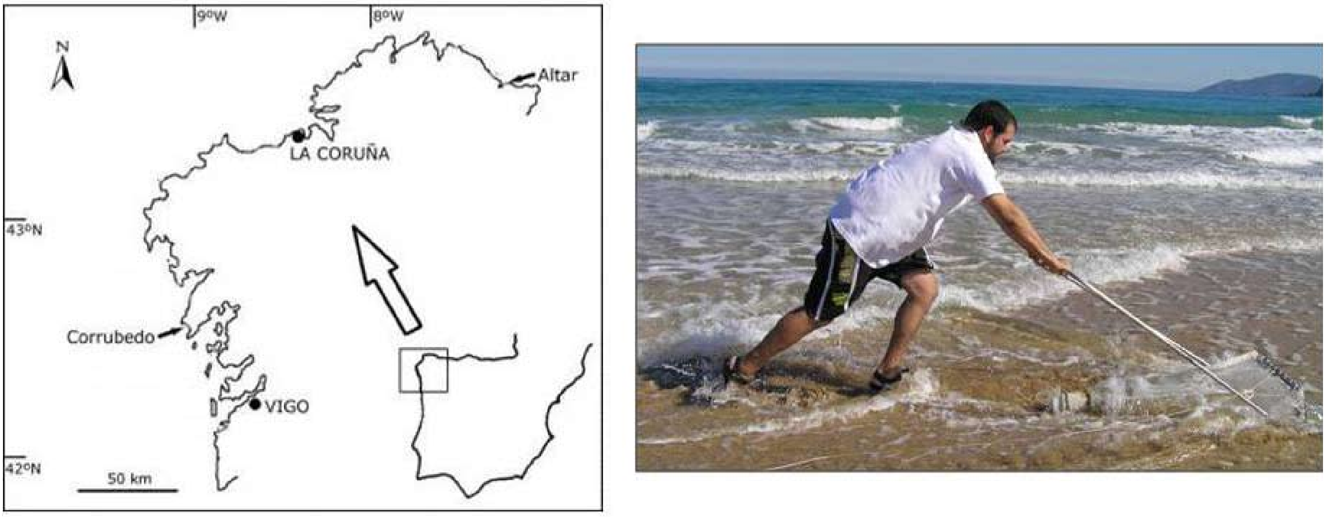

Figure 1. Left, location of the studied sandy beaches, Corrubedo (42.33ºN 9.02ºW) and Altar (43.34ºN 7.14ºW), NW Spain. Right: sampling with the suprabenthic sledge.

Three monthly samples were taken from September 2005 to August 2007 (24 months) in both beaches, with a suprabenthic sledge. The sledge, 50cm wide and 20 cm high, was designed to skim over the surface of the sediment in order to collect the swimming fauna within the 0-20cm near-bottom water layer. It was equipped with a 0.5 mm mesh size net. All samples were taken at the surf zone (< 0.5 m deep) in a 1 hour period before and after the low tide. Each sample was taken by a single operator towing the sledge along 40 meters of the shoreline. The animals were sorted out and identified, excluding from the study epibenthic fishes (*Echiichthys vipera*) and surf clams (*Donax trunculus*)

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as well as true planktonic species (i.e. copepods). Data of the environmental variables (water and air temperature, water salinity, sun hours, daily global irradiance (D.G.I), precipitations, wind speed, and irradiation) were taken from the oceanographic buoys and weather stations close to the sampling areas. Hydrodynamic variables such as wave height at the breaking zone and the Dean´s parameter were calculated.

Spatio-temporal patterns of the multivariate suprabenthonic fauna assemblages (SFA) were examined using different multivariate analyses techniques PERMANOVA (Anderson 2001), PERMDISP (Anderson 2006), DISTLM (Legendre & Anderson 1999, McArdle & Anderson 2001) and CAP (Anderson & Robinson 2003, Anderson & Willis 2003).

The PERMDISP tool from PERMANOVA v.6 was used to check the assumption of homogeneity of variances of beach and season. PERMANOVA was employed to check the existence of significant differences between the beaches and the seasons. Subsequent separate canonical analyses were done to visualize, in each case, the potential relationship between the whole multivariate variations in SFA according to: (i) Environmental variables (ii) group Beach-Season. Furthermore, others analyses were done to relate the main taxonomic rank orders with the environmental variables: (i) amphipods (ii) cumaceans (iii) isopods (iv) mysids.

Previously, a correlation study among the environmental variables was carried out to determine which variables were correlated between them in order to avoid redundant information. Furthermore environmental variables with negative estimates for components of variation (Fletcher and Underwood 2002) or with P-value > 0.25, “rule-of-thumb” (Winer *et al*. 1991, Underwood 1997) were removed. These screens were performed by means of Draftman plot and DISTLM.

The selection process of environmental variables was based in the ability to explain the greatest amount of variance for the suprabenthic data cloud through DISTL. The methodology employed was “BEST” selection procedure and R^2 (Sokal & Rohlf 1981), “An Information Criterion” AIC (Akaike 1973) and “Bayesian Information Criterion” ,BIC, (Schwarz 1978) which were chosen because they would show the finest model of these variables. DISTLM tool was used to find the environmental variables according to: i) Beach-Season ii) taxonomic rank order iii) beach abundance iv) beach richness.

Additionally, the fauna vectors, from Beach-Season CAP analysis, which were correlated more than |0.4| for the beach axe and |0.3| for season axe, was selected for individual contrast PERMANOVA analysis to check the possibility of fauna seasonally.

A total of 101 species were collected, 46 in Altar beach and 87 in Corrubedo beach, with 32 species being common to the two beaches. The amphipods were the most abundant group (number of species, monthly densities) at Altar beach and the isopods at Corrubedo beach (Table 1). Average monthly density was higher in Corrubedo beach (26.95 ± 40.99 indv.m^{-2}) than in Altar beach (4.33± 3.80 indv.m^{-2}). The amphipod *Pontocrates arenarius* was collected every month at the two beaches (occurrence 100 %). Other frequent species collected were the mysids *Gastrosaccus roscoffensis* (75 % Altar beach; 90 % Corrubedo beach.) and *Schistomysis parkeri* (96 % Altar beach; 88 % Corrubedo beach.)

The number of species was higher in the summer and autumn months (Fig. 2), and the Shannon-Wiener´s diversity index shows the maximum values at summer and winter (Fig.3).

Noticeable differences were found regarding the densities of abundance and the diversity between the two beaches seasonally. CAP analyses showed a significant effect of the beach with a squared canonical correlation of $\delta^2 = 0.8516$, as well as a significant effect of Season $\delta^2=0.6805$.

Subsequent analyses of the orders showed a seasonal distribution for isopods order in the summer (p=0.024) and for amphipods order in the summer (p=0.015) and winter (p=0.032). Nevertheless cumaceans order presented a less signification in the summer (p= 0.09) and winter (p= 0.07) whilst mysids order didn’t show any significant difference seasonally.

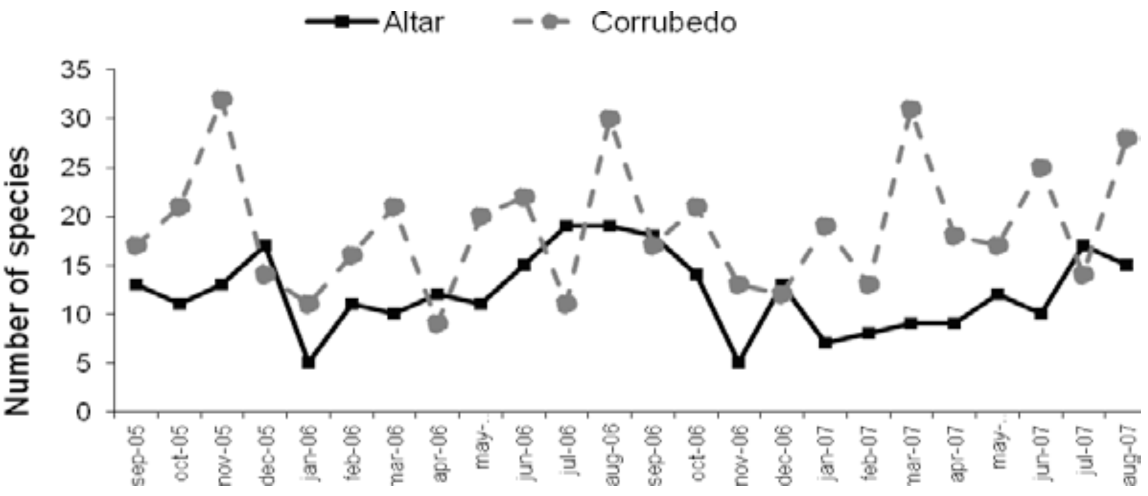

Figure 2. Variation of the number of species during the study period

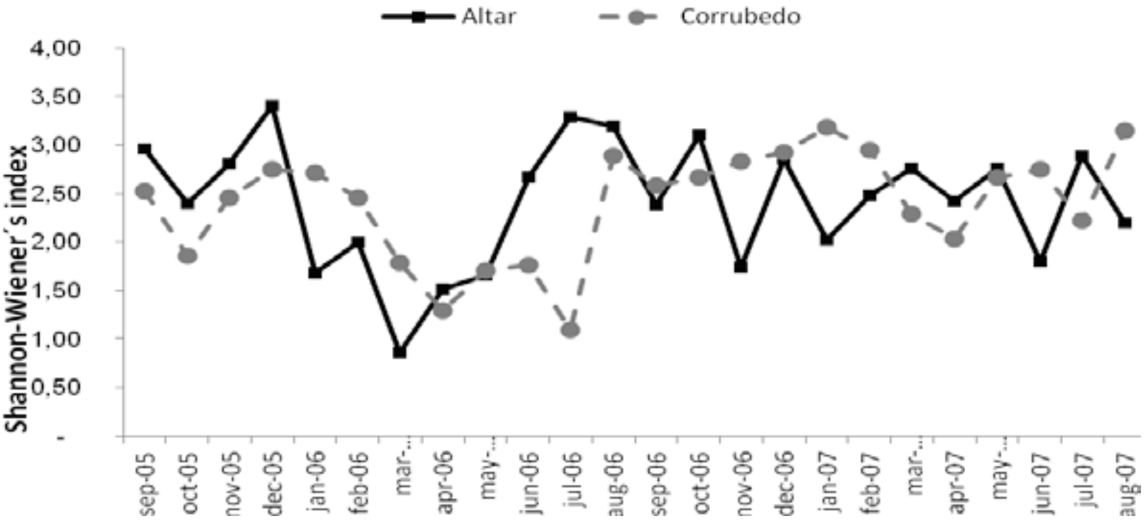

Figure 3. Variation of the Shannon-Wiener´s index during the study period

Table 1. Main species and taxa from Altar and Corrubedo beaches . Avg- average; SD- standard deviation; Freq.(%)-Frequency; Avg% contrib.- Average percentual contribution.

	Altar beach				Corrubedo beach			
	Density (ind m^{-2})		Freq.(%)	Avg.% cont.	Density (ind m^{-2})		Freq.(%)	Avg.% cont.
	Avg.	SD			Avg.	SD		
Amphipoda								
Atylus swammerdami	0,48	1,45	63	12,16	0,32	0,59	63	1,19
Bathyporeia sarsi	0,02	0,03	46	0,58	0,00	0,02	8	0,02
Gammarus sp.	0,13	0,34	58	3,17	0,01	0,05	13	0,04
Pontocrates arenarius	1,10	1,85	100	28,02	1,14	1,38	100	4,22
Other Amphipoda	0,07	0,12	83	1,85	0,36	0,48	96	1,35
Total Amphipoda				45,79				6,82
Isopoda								
Eurydice affinis	0,00	0,01	8	0,07	5,92	16,40	100	21,44
Eurydice naylori	0,01	0,02	25	0,19	0,35	1,10	58	1,31
Eurydice pulchra	0,03	0,05	50	0,79	0,36	0,63	75	1,35
Gnathia sp.	0,03	0,05	33	0,65	0,03	0,05	50	0,11
Idotea balthica	0,20	0,63	63	4,97	0,01	0,03	21	0,03
Idotea pelagica	0,15	0,52	24	3,75	3,09	14,88	54	11,38
Lekanesphaera weilli	0,03	0,06	42	0,88	0,39	1,10	71	1,45
Other Isopoda	0,03	0,10	33	0,83	0,30	1,12	67	1,15
Total Isopoda				12,14				38,22
Cumacea								
Cumopsis fagei	0,12	0,27	63	2,98	4,39	7,71	96	16,29
Cumopsis goodsir	0,12	0,17	75	3,08	0,04	0,20	13	0,16
Cumopsis longipes	0,08	0,12	58	2,12	3,57	8,26	92	13,15
Other Cumacea	-	-	-	-	0,03	0,09	33	0,12
Total Cumacea				8,17				29,72
Mysida								
Gastrosaccus roscoffensis	0,67	1,96	75	16,96	5,00	8,09	96	18,49
Paramysis arenosa	-	-	-	-	0,20	0,85	13	0,76
Schistomysis parkeri	0,53	0,61	96	13,37	1,38	2,66	88	5,12
Schistomysis spiritus	0,00	0,01	4	0,04	0,11	0,48	17	0,39
Other Mysida	0,03	0,04	50	0,69	0,11	0,17	63	0,40
Total Mysida				31,05				25,16
Caridea								
Philocheras trispinosus	0,06	0,10	42	1,43	0,01	0,04	29	0,05
Other Caridea	0,06	0,14	29	1,41	0,01	0,03	21	0,04
Total Caridea				2,85				0,09
Total				100,00				100,00

According to the explicative models, the environmental variables selected for the DISTLM analyses were: wind speed, air temperature, D.G.I, wave height, water temperature, salinity and Dean's parameter. D.G.I was the most employed parameter for the analyses, whilst wave height and Dean's parameter were exclusively selected for the abundance and richness analyses. The sun hours variable was the unique variable that was not chosen for any model. (Table. 2)

Table 2. Environmental variables selected by the criterion AIC, BIC and R^2. AIC = An Information Criterion. BIC= Bayesian Information Criterion. D.G.I = Daily Global Irradiance. Altar abundance (Alt.abund). Corrubedo abundance (Crb abund). Altar richness (Alt. richness). Corrubedo richness (Crb. richness)

	Wind speed	Air T^a	Hours of sun	D.G.I	Wave height	Water T	Salinity	Dean	AIC	BIC	R^2
Total community				X			X		363.2	368.9	0.190
Amphipoda	X			X					358.9	364.5	0.111
Cumacea				X			X		357.8	363.4	0.214
Isopoda				X			X		370.5	376.1	0.211
Mysida		X				X			356.1	356.1	0.117
Alt. abund		X		X	X				151.6	0.271	156.4
Crb. abund				X				X	156.3	158.0	0.193
Alt. richness	X			X			X	X	128.5	130.9	0.288
Crb.richness					X		X	X	132.3	137.0	0.331

Two environmental variables (D.G.I and salinity) were employed for the integration of the two communities. These factors explain the 25.28% of the total sample variation. Further, others environment factors were linked individually with the orders; the percentage of data cloud explained were from 27.77% for amphipods to 93.80% for Corrubedo richness. Nevertheless, higher values of explanations were obtained for abundance and richness data which reached more than 80%. (Table.3)

Table 3. Results of canonical analysis of principal coordinate (CAP) analysis examining the environment models from DISTLM for each taxonomic rank order and for the abundance and richness of Altar an Corrubedo. %Var = percentage of the total variation explained by the first *m* principal coordinate axes. δ^1 = canonical correlation. δ^2 = squared canonical correlation. m= number of orthonomal PCO axes used. p = p-value of trace test statistic.

Factor	**m**	**%Var**	**δ^1**	**δ^2**	**P**
Amphipoda	4	27.77	0.698	0,487	0,0002
Cumacea	2	45.56	0.669	0.448	0.0001
Isopoda	4	33.57	0.724	0,524	0.0001
Mysida	4	40.55	0.692	0,479	0.0002
Alt. abundance	2	87.1	0.715	0.511	0.0036
Crb. abundance	2	82.04	0.727	0.528	0.0002
Altar richness	2	92.76	0.657	0.432	0.0029
Corrubedo richness	1	93.8	0.5849	0.3421	0.033

Contrast analyses from PERMANOVA showed a significant seasonal change for some suprabenthonic species, like *Atylus swammerdami*, *Idotea balthica* or *Eurydice pulchra*.

The suprabenthic fauna assemblages researched show a clear faunistic seasonal pattern related to specific environmental variables, especially during the winter and summer, with the spring and autumn as change periods. Some resident species, like *Atylus swammerdami, Eurydice pulchra and Cumopsis goodsir* have been identified as seasonal due to their abundance and frequency during some months while not in others, which is in concordance with previous studies.

In contrast with other studies, amphipods and isopods were the dominant groups, meanwhile the mysids takes a secondary role in the suprabenthic community.

Abundance and richness of each beach are mainly influenced by hydrodynamic factors like wave height and Dean's parameter. Nevertheless, the most important factor for the complexity and dynamics of the community is daily global irradiation which could be an indirect measure of the chlorophyll .

The resultant models have a wide capacity of explanation from the sample variation. These models can explain from 28% for amphipods variation to 94% of the variability in Altar richness. This research reveals that factors like D.G.I, wind speed or wave height are useful in explaining the suprabenthic community complexity.

Furthermore, CAP analysis has proved to be better than MDS analysis to test the temporal suprabenthic fauna assemblages. The former show more variance and grouping for the samples in higher-dimensional context, moreover it is a good modeling and classification tool. This conclusion coincides with others researches (Willis & Anderson. 2003).

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