Journal of Coastal Research	14	3	1119–1133	Royal Palm Beach, Florida	Summer 1998

The Arthropod Community, Especially Crustacea, as a Bioindicator in Algeciras Bay (Southern Spain) Based on a Spatial Distribution

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ABSTRACT

SÁNCHEZ-MOYANO, J.E. and GARCÍA-GÓMEZ, J.C., 1998. The arthropod community, especially crustacea, as a bioindicator in Algeciras Bay (southern Spain) based on spatial distribution. *Journal of Coastal Research*, 14(3), 1119–1133. Royal Palm Beach (Florida), ISSN 0749-0208.

Spatial variation of the arthropod communities of the alga *Halopteris scoparia* in relation to the influence of environmental factors in the Algeciras Bay (Southern Spain) was investigated by means of multivariate analyses. We have been able to determine a clear separation in composition of communities between external and internal areas of the bay, with hydrodynamism and algal morphology being the most determinant factors. In the external zone a greater number of species appear, whose quantitative dominances are more even than among the species of the internal zone, where some clearly dominate over the others, e.g., the amphipods *Corophium acutum* and *Jassa marmorata*. Crustaceans show in a clear way the differences among the localities and are useful in characterization studies of environmental quality of coastal waters because of the abundance, high species richness and the wide environmental spectrum in the epiphytic communities

ADDITIONAL INDEX WORDS: *Epifauna, environmental factors, hydrodynamism, sedimentation, habitat complexity, canonical correspondence analysis, Halopteris scoparia, Southern Spain.*

INTRODUCTION

The arthropods, and more specifically the crustaceans, have been often used in macrophytobenthic studies (BIBILONI, 1981; JIMENO, 1993; CASTELLÓ *et al*, 1987; GARCÍA-RASO, 1988; COSTELLO and MYERS, 1987) to show various relationships of predation and competition (NELSON, 1979a and b; COEN *et al*, 1981; GUNNILL, 1984; EDGAR, 1990a and b; HOLMLUND *et al*, 1990; POORE, 1994) or to establish the environmental patterns that control the communities (BELLAN-SANTINI, 1964, 1966; FENWICK, 1976; STONER, 1983; AOKI, 1988; PROCACCINI and SCIPIONE, 1992; RUSSO, 1989; AOKI and KIKUCHI, 1990; ARRONTES and ANADÓN, 1990; CONRADI, 1995; among other). In this sense, the crustacean communities have been considered as one of the most sensitive to the changes produced by environmental variables (DOMMASNES, 1968, 1969; DESROSIERS *et al*, 1982, 1986 and 1990; MOORE, 1986; GRAHAME and HANNA, 1989).

Our objective has been to analyze variation in the composition of arthropod communities (mainly crustaceans) associated with the alga *Halopteris scoparia* (L.) Sauvageau (Phaeophyta, Sphacelariales) in relationship to the various environmental conditions found in the Bay of Algeciras (Southern Spain). The selection of this algal species was to eliminate the variations in structure of the community provoked by configuration of the alga, assuming, of course, that the intraspecific variations provoked as well by the different environmental conditions will be less than among various substrata (SÁNCHEZ-MOYANO, 1996). According to HACKER and STENECK (1990), it is a branching alga within a small space. This means, on the one hand, that the abundance of individuals will be high because of the great quantity of available microhabitats, in addition to constituting a good sediment and periphyton trap (especially diatoms which constitute the diet of most of the epifauna—Orth and Van Montfrans, 1984), and additionally, it restricts the size of the organisms. It is one of the most abundant algal species and most widely distributed in Algeciras Bay. This bay, located in the most eastern zone of the Strait of Gibraltar, is composed of heterogeneous environments imposed by the natural configuration of the coast as well as by intense port and industrial activity. This makes diverse environmental conditions in spite of its relatively small extent (approximately 30 km long with a width of 8 km at its extreme), something which must influence the composition of the associated arthropod communities.

MATERIALS AND METHODS

A total of 13 sampling stations were chosen and grouped in five areas distributed along the coast of the Bay of Algeciras in order to encompass the broadest range of environmental conditions (Figure 1). Island las Palomas (IP) is a photofile rock zone and located in the extreme west of the bay.

97091 received 11 June 1997; accepted in revision 5 October 1997.

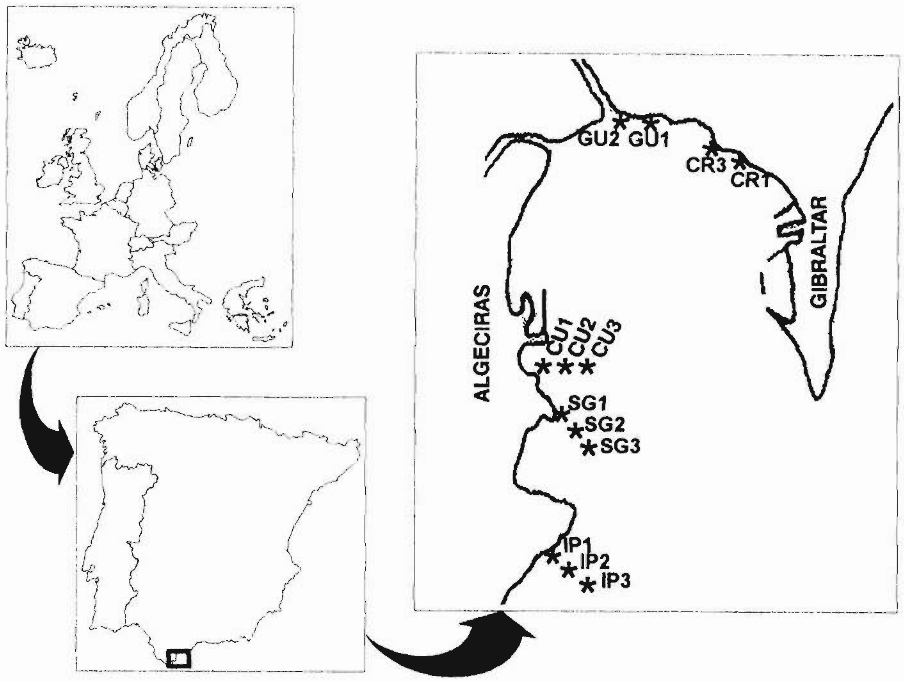

Figure 1. Location of the sampling stations in Algeciras Bay.

Punta de San García (SG), with similar characteristics, though a sciafile environment in more shallow waters. In both areas, the stations were established in a transect 200 meters long and 5, 8 and 10 meters deep. Inlet of the Cucareo (CU), nearby area to the Port of Algeciras, is located on a wide platform that varies between 3 and 5 meters deep. The stations were established on a transect of 200 meters. All stations were numbered beginning from the most shallow. Los Rocadillos (Guadarranque) (GU) is located in the internal zone of the bay, near the mouth of the Guadarranque River on a natural rock band along the coast, between 3 and 5 meters deep. Unable to establish transects in depth, the two stations were located according to their distance from the outlet: GU1, the fartherest; and GU2. In the internal zone, Crinavis (CR) is a artificial substratum belonging to a shipyard in disuse. The stations were located along this breakwater, to a depth of 5 meters.

Four replicate samples were taken at each station during five samplings throughout one year (September 92; December 92; March 93; June 93; and September 93). Each sample consists of an alga specimen, pocketed *in situ* and extracted from the bottom by SCUBA diving.

The samples were put through a sieve of 0.5 mm of light mesh and were then separated, classified and quantified into the different species. The abundance data were in terms of number of individuals per 100 dry weight grams of alga.

Once the fauna were separated, a series of statistics was calculated for each alga: wet and dry weight, maximum height, diameter and volume. The volume was estimated by water displacement of the alga in a manometer. Assuming that *H. scoparia* adopts a geometric form in the environment like a paraboloid, the theoretical volume was calculated from this. Deducting the real volume from the theoretical one we obtained the interstitial volume, which represents the living space. The relationship between the theoretical volume and the real one gives an idea of the level of compactness of the alga (Index of Compactness), in such a way that how much more is approximated to one it will be more compact. This compactness can measure the habitat complexity.

In order to establish which parameters influence the composition of the arthropods communities some concrete modules were sounded along the arch of the Bay (Figure 2). The samplings were taken monthly from November of 1992 until November of 1993.

The variables measured were: maximum and minimal temperature, hydrodynamism, sedimentation rate, % organic matter of the sedimentation, solid and % of organic matter in suspension.

For hydrodynamism (or water movement), the method of "plaster dissolution" described by MUUS (1968) and modified by GAMBI *et al* (1989) was used, measured as "equivalent speed of the water" (V) (BAILEY-BROCK, 1979).

The sedimentation rate was measured by the placement of sediment traps (six bottles of a liter capacity in our case). Part of the sedimentation is used to calculate the % of organic matter through calcination at 500° C. The data are expressed as gr/m^2/month.

The solids and organic matter in suspension were measured according to the method of STRICKLAND and PARSON (1969).

The possible spatial variations of these variables were tested through one-way ANOVA, after verifying normality (Kol-

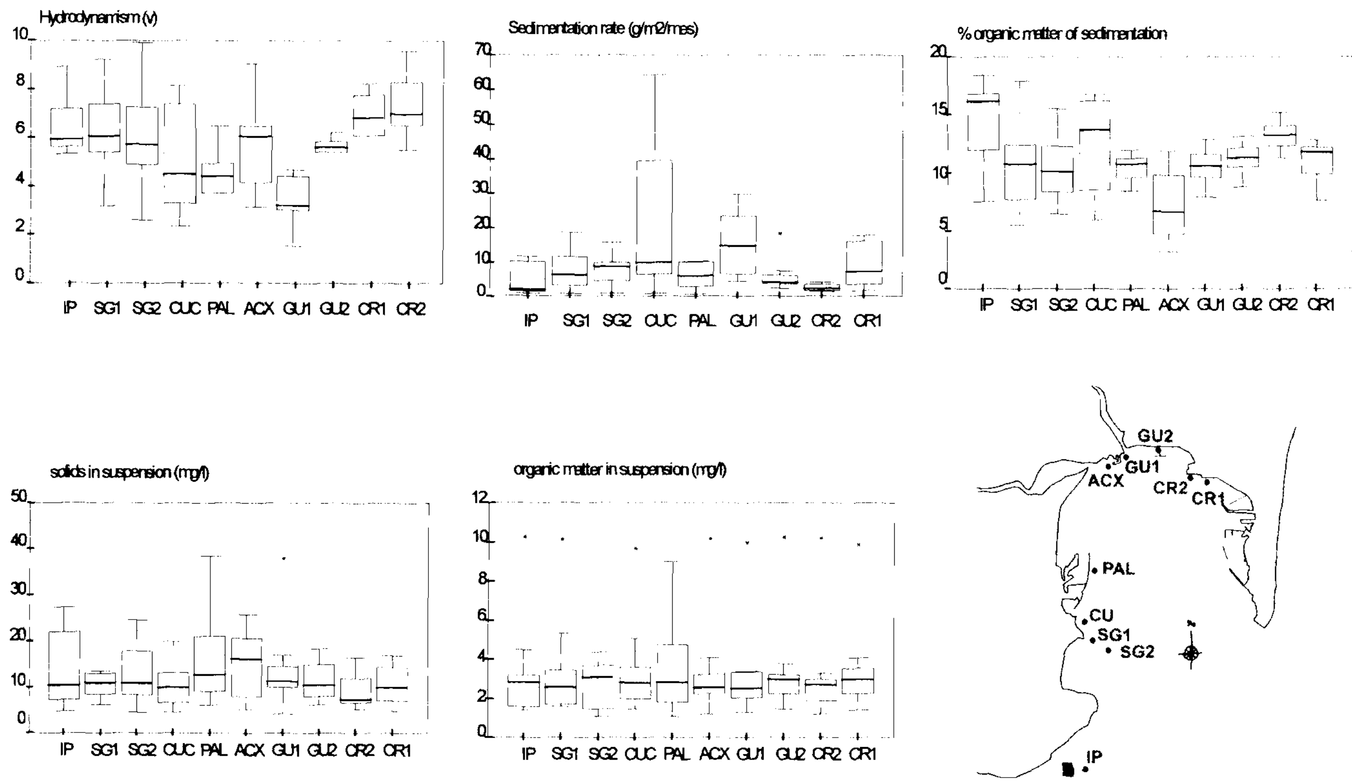

Figure 2. Variation of the environmental parameters in the stations. The thick line corresponds to the median; the rectangles contain 50% of the values, between 1st and 3rd quartile; the thin lines connect the extreme values, unless located at a distance superior to 3 times the height of the rectangle than they are indicated by an asterisk.

mogorov-Smirnov test) and variances homogeneity (Barlett test). The homogeneous groups were separated by the Tukey test.

The affinities between stations were established through a cluster analysis using the UPGMA method (unweighted pair-group method using arithmetic averages) (SNEATH and SOKAL, 1973) and based on the index of similarity of Bray-Curtis (BRAY and CURTIS, 1957). The data of abundance were transformed by the fourth root ($\sqrt[4]{x}$). In order to confirm the results of the cluster, an MDS analysis (non-metric multidimensional scaling) was used. To test the veracity of ordination, the stress coefficient of Kruskal was employed (KRUSKAL and WISH, 1978).

To determine the responsible species for the groupings, the analysis of percentages of similarity or SIMPER (PRIMER package) was used. It calculates the contribution of each species either to the dissimilarity between different groups (discriminating species) or for similarity within a group (typical species). The differences in community composition were tested through the non-parametric ANOSIM test from the PRIMER package (CLARKE and GREEN, 1988).

To determine if environmental variables influence the composition of the community, we applied two techniques: BIO-ENV analysis and canonical correspondence analysis (CCA). The BIO-ENV analysis (CLARKE and AINSWORTH, 1993) consists of the comparison through the harmonic rank correlation coefficient of Spearman of the rank similarity matrix (based on the index of Bray-Curtis) accomplished with the data of abundance of species and the rank similarity matrix obtained through euclidean distances with the abiotic variables, and thus establishing that environmental variables favor the maximum correlation between the two.

The canonical correspondence analysis (CCA) is a direct gradient technique where it is obtained by graphic representation where the stations and/or species are shown by points and the environmental factors by arrows. The station points and species together represent the dominant model in the composition of the community in each zone so much as can be explained by the environmental variables, while the species and the arrows reflect the distribution of the species throughout environmental gradients (TER BRAAK, 1986, 1990). In order to avoid the distortion provoked in the analysis by the rare species, these were downweighted. To verify the statistical significance of the analysis, the Monte Carlo test for the first axis was applied.

RESULTS

Environmental Variables

The general trend of abiotic variables throughout the bay is shown in Figure 2 and the significant differences among sites in Table 1. The most external zones of the bay present

Table 1. *Results of the one-way ANOVA for the environmental variables. df: degrees of freedom; (MS) Squared of the average; (F) statistic; *: P < 0.001; **: P < 0.05; ns: not significant. The homogeneous group according to the Tukey test (P < 0.05) are indicated with a continuous line.*

	df	MS	F	Homogeneous Group
Hydrodynamism	9	0.307	29.66*	CR1 CR2 IP SG1 SG2 ACX CU PAL GU2 GU1
Sedimentation	9	80.211	171.97*	IP SG1 SG2 PAL CR1 CR2 GU2 GU1 CU ACX
Org. mat. sediment.	9	23.607	2.54**	ACX IP SG1 SG2 CU PAL CR1 CR2 GU2 GU1
Solids suspension	9	45.185	1.09ns	
Org. mat. suspens.	9	0.016	0.08ns	

a greater hydrodynamism (water movement) with a clear trend to reduce toward the interior, a rise in the area of Crinavis (CR1 and CR2) again, due to the existing tidal currents in the bay. These tidal currents are conditioned by the circulation of Atlantic and Mediterranean water masses through Strait of Gibraltar (in direction to East or West according to the flow or ebb state of the tide (GARCÍA, 1986). Thus, in flow state (high tide), a current is originated surrounding the whole interior of the bay, entering by the area of the Island Las Palomas and leaving by Punta Europa (Gibraltar). While, in ebb state, the superficial current of the Strait is divided into two branches, one enters by Gibraltar and other by Island Las Palomas, so that two currents are originated with parallel circulation to both margins of the bay and that are meeting in the interior (area of Crinavis), originating a new current of direction South by the central zone joining with the general current of the Strait. The sedimentation rate has a slightly inverse behavior, with a greater rate in the most internal zones, especially those located in the influence areas of the outlets of the rivers Palmones (ACX) and Guadarranque (GU1). In the case of the Inlet of Cucareo (CUC) a lot of movement on the bottom is joined to the sedimentation rate due to its shallow depth (5-3 m) and to the influence of the surge provoked by the strong prevailing east winds in the zone. The solids in suspension behave similarly (although not statistically significant), with a trend to increase toward the interior and with a notable influence of the presence of the rivers (ACX and GU1) and of the proximity to urban sewage; for example, in the external dike of the Port of Algeciras (PAL).

With respect to the morphological characteristics of the algae (Table 2), a trend toward a greater interstitial volume (direct measurement of the useful vital space, considering the surface of the fronds as well as the existing spaces between them) was observed, as well as compactness in the external zone and a gradual decrease toward the optimum growth was shown by small-sized samples, with branches close together, presumably caused by great turbidity provoked by the river.

Faunal Analysis

A total of 107 taxa were identified at 13 stations: 6 Pantopoda; 1 Insecta; and 100 Crustacea (61 Amphipoda, 5 Cumacea, 12 Decapoda, 13 Isopoda, 1 Leptostraca, 1 Mysidacea and 6 Tanaidacea) (Table 3).

Multivariate Analysis

Through the classification analysis of the stations according to the annual average abundance of the different species, we obtain a clear separation between the stations located at the external extreme of the Bay (Island Las Palomas, San García and Cucareo) and those situated close to the internal zone (Guadarranque and Crinavis) (Figure 3). The same occurs among the stations within each group, especially in the external stations. In these, there is a separation between the subgroup of Island Las Palomas and San García (both areas

Table 2. *Average values of algal parameters. (CI) compactness; (INTV) interstitial volume (ml).*

	SEP92		DEC		MAR		JUN		SEP93	
	CI	INTV	CI	INTV	CI	INTV	CI	INTV	CI	INTV
IP1	119.91	680.50	72.69	567.03	51.28	608.38	54.10	655.26	34.75	431.25
IP2	104.47	835.81	60.95	750.60	66.53	852.77	59.23	778.56	50.20	516.68
IP3	64.53	510.60	62.63	883.28	92.86	914.09	67.64	902.93	48.46	358.77
SG1	29.61	502.43	105.56	799.29	100.72	677.91	—	—	29.78	275.43
SG2	43.54	444.30	91.08	660.90	97.95	724.93	—	—	—	—
SG3	39.16	333.12	76.75	682.30	—	—	—	—	—	—
CU1	45.14	614.32	49.18	614.65	87.24	1,029.06	64.46	809.58	38.35	593.90
CU2	53.00	484.84	63.34	519.85	72.59	737.50	60.19	824.81	35.95	615.66
CU3	51.26	618.51	83.60	766.15	60.06	805.53	33.26	430.62	23.81	455.42
GU1	33.17	282.17	47.12	374.38	37.89	443.76	13.94	148.95	25.10	281.02
GU2	32.68	149.80	81.31	489.92	19.42	237.37	46.34	431.05	—	—
CR1	33.11	385.41	39.09	479.23	22.92	429.23	33.85	363.09	17.17	175.88
CR3	54.27	392.12	57.36	490.58	43.54	403.40	4.16	43.64	17.97	168.50

Table 3. *Annual average abundance (number of individuals/100 g dry alga weight) of the different species.*

Species	IP1	IP2	IP3	SG1	SG2	SG3	CU1	CU2	CU3	GU1	GU2	CR1	CR3
Pantopoda													
Achelia sp (ACL)	98.68	29.71	190.99	221.13	286.59	388.07	58.70	228.66	157.60	550.66	419.14	325.85	221.44
Callipallene tiberi (CLL)	56.95	109.91	107.94	219.54	145.95	281.25	143.13	48.89	40.98	138.83	29.26	156.70	54.00
Endeis charybdaea (END)	0.00	2.73	11.16	1.31	9.70	5.06	8.33	0.00	0.00	0.00	0.00	0.00	0.00
Nymphon gracile (NYM)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.00	0.00	0.00	0.00	0.00
Anoplodactylus angulatus (ANA)	8.33	9.52	11.08	16.45	68.42	40.25	12.65	25.52	28.21	20.26	23.09	15.31	6.67
Anoplodactylus virescens (ANV)	2.33	0.00	0.00	0.00	0.00	0.00	3.22	1.44	11.21	2.50	0.00	0.00	3.97
Amphipoda													
Iphimedia minuta (IPM)	0.00	10.79	31.68	18.63	123.06	85.97	26.69	15.01	30.78	2.23	0.00	45.73	138.06
Ampelisca cf. *unidentata* (AMP)	6.02	0.00	1.66	0.00	10.21	0.00	6.06	16.78	6.49	0.00	0.00	0.00	0.00
Amphilochus neapolitanus (APN)	268.05	248.86	220.44	369.13	446.10	214.56	334.16	211.89	255.76	0.00	0.00	0.00	0.00
Amphilochus picadurus (APP)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.64	0.00	2.08	0.00
Peltocoxa gibbosa (PEL)	8.78	2.24	12.55	1.31	14.26	43.08	0.00	0.00	0.00	0.00	0.00	6.34	0.00
Ampithoe ramondi (AMR)	607.32	301.67	201.84	336.47	392.85	54.51	238.14	1,115.28	601.64	0.00	0.00	39.06	47.47
Aora spinicornis (AOR)	146.16	26.13	60.38	69.14	217.24	238.81	94.92	378.46	74.89	345.37	499.56	526.05	1,328.92
Lembos viguieri (LEV)	22.60	2.65	0.00	102.07	0.00	73.55	0.00	10.04	0.00	0.00	6.89	0.00	0.00
Lembos websteri (LEW)	31.28	47.08	119.40	37.46	226.43	35.96	13.22	19.01	4.06	56.62	55.37	180.90	261.29
Leptocheirus guttatus (LEG)	1.82	2.85	3.29	0.00	0.00	5.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leptocheirus pectinatus (LEP)	15.66	0.00	6.58	4.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.45
Microdeutopus armatus (MIA)	0.00	0.00	0.00	0.00	34.78	0.00	1.62	0.00	0.00	46.80	20.45	0.00	0.00
Microdeutopus chelifer (MIC)	0.00	0.00	0.00	11.66	0.00	0.00	45.17	105.77	78.69	228.07	118.13	34.72	64.10
Microdeutopus stationis (MIS)	7.18	12.91	0.00	55.76	0.00	2.65	13.42	26.64	15.24	5.25	40.93	14.60	24.72
Microdeutopus versiculatus (MIV)	0.00	4.15	0.00	0.00	8.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.79
Aoridae (AOD)	544.54	398.84	395.51	1,037.47	854.50	1,180.67	296.68	1,840.58	1,081.08	967.20	1,656.86	1,981.44	2,353.82
Apherusa bispinosa (APB)	571.08	432.46	554.58	211.94	442.67	1,050.02	434.53	500.89	234.27	7.52	0.00	62.12	104.84
Apherusa sp. (APH)	834.42	57.30	8.85	22.37	31.10	47.90	2,514.47	2,557.99	1,495.42	3.24	0.00	0.00	0.00
Caprella acanthifera acanthifera (CAA)	11.88	3.07	0.00	0.00	0.00	0.00	86.61	49.48	16.14	0.00	0.00	5.86	6.67
C. acanthifera discrepans (CAD)	390.92	520.71	1,201.99	446.60	345.84	122.49	0.00	0.00	0.00	0.00	0.00	2.15	0.00
C. acanthifera typica (CAT)	26.46	3.05	0.00	34.39	75.55	0.00	55.49	35.39	13.16	0.00	0.00	163.13	23.40
Caprella grandimana (CAG)	55.56	11.32	0.00	119.01	0.00	0.00	10.68	0.00	0.00	0.00	0.00	0.00	0.00
Caprella liparotensis (CAL)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	76.51	0.00
Caprella mitis (CAM)	0.00	0.00	0.00	0.00	0.00	0.00	39.95	167.47	60.55	0.00	0.00	0.00	0.00
Caprella penantis (CAP)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.98	2.22
Colomastix pusilla (COL)	0.00	0.00	0.00	3.74	0.00	0.00	0.00	0.00	0.00	0.00	6.72	0.00	0.00
Corophium acutum (COA)	444.93	799.54	1,188.27	384.06	141.72	62.88	2,310.63	4,573.93	2,271.24	3,498.93	3,387.38	5,087.33	4,773.03
Corophium sextonae (COS)	0.00	0.00	0.00	16.00	2.85	13.31	0.00	0.00	0.00	3.77	24.02	141.71	150.18
Ericthonius brasiliensis (ERI)	0.00	0.00	0.00	0.00	5.10	10.59	0.00	1.87	0.00	1,331.99	2,528.90	2.25	358.53
Siphonoecetes sp. (SIP)	11.03	0.00	0.00	0.00	0.00	0.00	165.43	1.37	9.72	0.00	10.35	0.00	20.00
Cressa cristata (CRC)	0.00	0.00	8.70	9.75	2.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cressa mediterranea (CRM)	0.00	8.47	55.53	0.00	0.00	13.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dexamine spiniventris (DXS)	57.06	41.89	47.37	65.23	26.15	153.86	48.12	32.73	12.19	0.00	0.00	7.19	5.19
Dexamine spinosa (DXP)	227.50	179.17	165.04	298.67	364.15	211.92	476.62	234.88	234.57	110.05	18.70	108.56	53.58
Guernea coalita (GUE)	373.99	396.94	245.07	25.26	11.27	10.12	12.41	2.88	15.12	0.00	0.00	0.00	0.00
Tritaeta gibossa (TRI)	0.00	0.00	0.00	5.54	0.00	0.00	0.00	0.00	5.15	0.00	0.00	5.61	29.33

Table 3. *Continued.*

Species	IP1	IP2	IP3	SG1	SG2	SG3	CU1	CU2	CU3	GU1	GU2	CR1	CR3
Eusiroidae sp. (EUD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.54	0.00	0.00
Eusiroides dellavallei (EUS)	2.14	7.42	0.00	38.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.21	0.00
Cheirocratus sundevalli (CHE)	0.00	10.78	4.95	0.00	0.00	54.76	1.76	0.00	0.00	0.00	0.00	0.00	0.00
Elasmopus sp. (ELA)	157.15	32.98	7.68	39.32	27.32	77.45	97.58	61.74	38.54	88.64	156.68	1.04	0.00
Gammarella fucicola (GAM)	0.00	0.00	0.00	0.00	0.00	0.00	1.11	1.37	1.83	28.37	10.35	4.03	86.21
Gammaropsis maculata (GMM)	89.38	62.36	142.91	1,195.32	778.62	2,184.60	34.41	267.04	237.18	1,487.34	1,512.24	547.41	519.32
Gammaropsis palmata (GMP)	320.75	492.53	1,152.35	1,404.81	891.61	1,684.53	519.14	3,947.78	1,035.56	53.52	63.84	2,800.17	6,017.42
Megamphopus cornutus (MEG)	0.00	7.59	4.95	0.00	363.07	8.01	0.00	0.00	1.05	0.00	0.00	1.04	5.15
Microprotopus (MTP)	206.92	310.53	308.31	362.96	381.41	390.21	254.62	211.07	199.36	2.65	0.00	3.76	0.00
Photis longipes (PHO)	21.04	3.68	56.86	24.65	48.03	198.81	0.00	2.02	0.87	0.00	0.00	0.00	0.00
Isaeidae sp. (ISA)	0.00	0.00	0.00	30.13	0.00	15.65	2.70	3.78	3.15	0.00	0.00	1.04	0.00
Ischyrocerus inexpectatus (ISC)	1.82	4.61	5.10	3.06	18.17	39.72	3.75	0.00	0.00	5.82	65.39	25.31	14.18
Jassa marmorata (JAS)	9.38	0.00	0.00	0.00	40.77	0.00	0.00	0.00	0.00	2,934.65	7,896.63	2,266.99	991.57
Leucothoe spinicarpa (LEU)	1.44	1.34	3.31	24.59	17.73	32.57	47.39	34.29	44.14	2.23	13.44	4.32	19.69
Lysianassa costa cf. (LYS)	13.06	85.84	62.94	30.80	33.07	33.86	3.30	11.16	5.62	0.00	0.00	4.46	20.69
Orchomene sp. (ORC)	8.48	12.21	21.60	7.47	6.17	23.45	24.15	16.62	62.47	7.60	47.38	32.49	83.37
Synchelidium longidigitatum (SYN)	2.53	2.16	1.66	0.00	0.00	0.00	6.30	3.90	2.99	27.24	2.59	13.47	18.91
Pariambus typicus (PAR)	0.00	0.00	0.00	0.00	5.10	123.41	0.00	4.25	5.11	6.81	23.44	1.74	9.52
Pedoculina garciagomezi (PED)	0.00	32.03	47.11	13.22	125.43	427.31	0.00	0.00	8.92	0.00	0.00	0.00	0.00
Pseudoprotella phasma minor (PPM)	0.00	18.97	32.98	13.36	14.37	7.94	2.44	11.34	1.62	3.31	3.36	0.00	0.00
P. phasma quadrispinis (PPQ)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37	9.03	0.00
P. phasma typica (PPT)	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00	0.00	0.00	0.00	6.89	0.00
Perionotus testudo (PER)	14.93	16.08	79.42	37.74	108.35	101.28	10.44	13.26	9.33	0.00	0.00	16.55	18.57
Harpinia sp. (HAR)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.00	0.00	3.45
Phtisica marina (PHT)	299.23	541.83	831.09	860.33	737.61	946.33	209.91	543.01	132.94	1,471.91	1,708.92	1,664.88	1,430.36
Podocerus variegatus (POD)	10.80	10.16	0.00	45.45	6.69	36.59	12.49	14.50	22.27	325.15	217.78	59.57	75.35
Stenothoe dolfusi (STD)	0.00	0.00	0.00	6.72	0.00	47.67	0.00	0.00	1.19	0.00	0.00	0.00	0.00
Stenothoe monoculoides (STM)	357.10	509.27	421.88	853.64	654.43	608.52	965.21	1,736.97	1,224.28	3,572.51	1,424.82	1,029.14	362.20
Hyale schmidti (HYA)	517.72	469.85	471.92	196.96	620.74	2,299.16	79.87	304.01	88.02	0.00	0.00	4.03	0.00
Cumacea													
Iphinoe sp. (IPH)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.45
Vaunthompsonia sp. (VAU)	0.00	0.00	8.98	0.00	3.35	0.00	0.00	0.00	6.14	0.00	0.00	0.00	0.00
Cumella limicola (CUL)	77.69	122.31	65.78	30.49	56.09	27.58	109.01	42.45	69.29	1,356.10	659.74	244.89	234.78
Nannastacus ungliculatus (NAN)	124.47	153.60	227.21	166.13	364.15	284.71	63.08	59.36	61.52	8.28	0.00	24.85	49.41
Scherocumella longirrostri (SCH)	3.25	3.11	11.76	0.00	6.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decapoda													
Athanas nitescens (ATH)	0.00	0.00	0.00	0.00	0.00	0.00	1.87	0.00	2.99	7.97	3.12	0.00	10.34
Dardanus sp. (DAR)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.50
Hippolyte sp. (HIP)	43.70	71.31	22.18	121.11	123.35	121.63	155.28	30.87	30.41	20.30	23.51	74.29	291.91
Thoralus cranchii (THO)	0.00	5.79	5.16	22.10	6.38	17.83	2.09	8.43	5.50	0.00	3.12	11.77	11.43
Achaeus sp. (ACH)	0.00	5.11	2.31	8.96	26.80	0.00	6.72	7.12	7.31	18.12	19.73	30.95	11.82
Macropodia sp. (MAC)	0.00	0.00	0.00	9.53	1.77	0.00	0.00	4.08	0.00	18.17	11.39	11.18	20.16
Pisa carinimana (PIC)	2.33	0.00	0.00	8.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.48
Pisa tetraedon (PIT)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.58	0.00	0.00	0.00	0.00
Paguridae (PAG)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.28
Periclimenes sp. (PEC)	0.00	0.00	0.00	0.00	2.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sirpus zariquieyi (SIZ)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.94	0.00	0.00	0.00
Pilumnus sp. (PIL)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.02	0.00	1.81	6.06

Table 3. *Continued.*

Species	IP1	IP2	IP3	SG1	SG2	SG3	CU1	CU2	CU3	GU1	GU2	CR1	CR3
Isopoda													
Astacilla cf. *axeli* (ASA)	7.72	14.72	20.65	17.08	26.74	0.00	0.00	1.24	0.00	0.00	0.00	0.00	0.00
Astacilla sp. (AST)	0.00	0.00	0.00	8.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gnathia sp. (GNA)	7.33	3.05	9.80	0.00	17.73	0.00	1.82	2.04	7.52	15.19	0.00	1.12	6.07
Idotea cf. *neglecta* (IDN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.75	0.00	0.00	0.00	0.00	0.00
Idotea cf. *viridis* (IDV)	1.44	1.34	4.52	0.00	0.00	0.00	0.00	0.00	3.48	0.00	0.00	0.00	0.00
Synisoma capito (SYC)	2.92	2.58	0.00	0.00	0.00	0.00	3.16	1.34	7.83	0.00	0.00	0.00	0.00
Zenobiana prismatica (ZEP)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.74	0.00	0.00	0.00	0.00
Jaeropsis brevicornis (JAE)	12.94	5.27	4.88	2.71	2.85	0.00	1.87	5.13	1.01	0.00	0.00	0.00	0.00
Janira maculosa (JAN)	11.39	5.22	44.84	12.27	0.00	0.00	0.00	1.37	0.00	0.00	0.00	9.03	0.00
Munna sp. (MUN)	4.12	7.34	17.77	0.00	33.57	23.72	0.00	9.26	0.00	21.42	8.47	2.59	11.69
Paranthura nigropunctata (PTH)	282.67	260.24	387.37	456.76	383.21	443.61	432.45	395.01	329.09	19.73	7.14	317.87	198.59
Cymodoce sp. (CYM)	20.62	28.01	9.90	53.73	71.86	20.62	66.53	61.10	32.02	41.80	3.50	230.63	326.31
Dynamene sp. (DYN)	84.06	14.46	4.72	39.31	14.62	6.68	158.60	324.38	141.68	401.06	54.08	26.97	151.39
Leptostraca													
Nebalia bipes (NEB)	0.00	0.00	0.00	0.00	0.00	10.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mysidacea													
Siriella sp. (SIR)	19.67	5.26	6.94	2.62	23.64	0.00	1.62	5.41	1.74	0.00	0.00	7.12	0.00
Tanaidacea													
Apseudes talpa (APS)	0.00	0.00	0.00	0.00	0.00	0.00	6.05	3.05	5.23	0.00	0.00	0.00	10.34
Parapseudes latifrons (PPS)	0.00	0.00	9.76	3.06	17.73	22.03	3.70	3.05	0.00	124.95	294.84	13.43	0.00
Leptochelia dubia (LCH)	331.79	678.04	1,034.95	845.97	1,162.92	1,502.95	1,006.70	1,660.98	2,261.98	802.99	1,010.87	1,051.14	666.17
Tanais dulongii (TAN)	914.15	169.38	417.32	2,193.72	1,823.29	1,711.14	826.59	514.00	125.50	4.86	9.58	7.29	0.00
Zeuo coralensis (ZEC)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	916.52	638.05	27.90	0.00
Zeuo normani (ZEN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	226.54	41.36	281.99	121.14
Insecta													
Chironomidae (CHI)	36.16	27.87	30.76	41.11	24.69	18.52	1.76	2.02	3.57	8.80	0.00	2.02	3.45

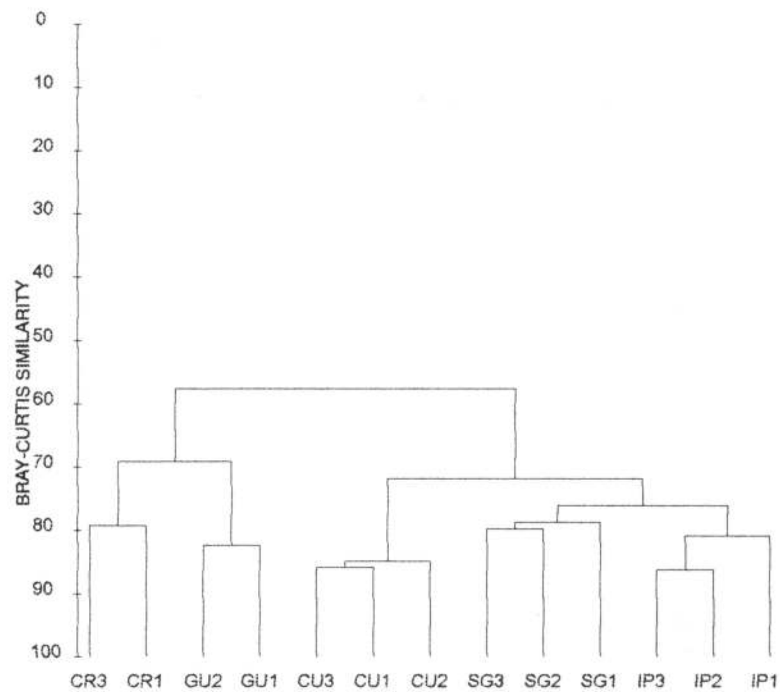

Figure 3. Dendrogram of similarity between the different stations in base to the annual average abundance of the species. (IP) Island of Las Palomas; (SG) San García; (CU) Cucareo; (GU) Guadarranque; (CR) Crinavis.

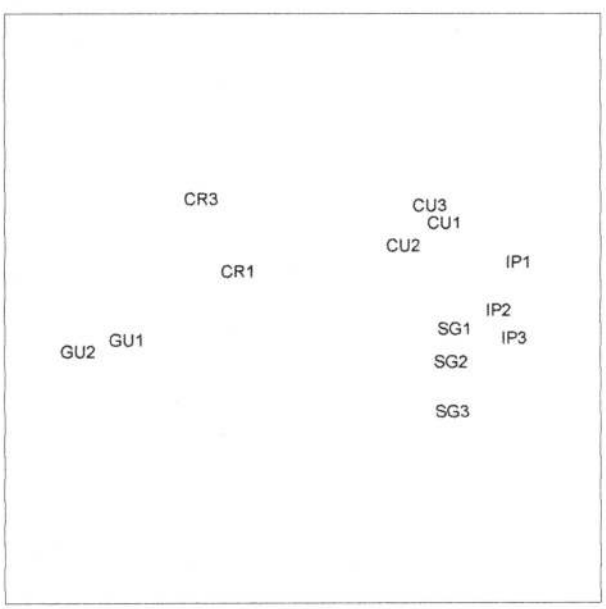

Figure 4. MDS ordination of the stations according to the annual average of abundance (Stress: 0,032). (IP) Island of Las Palomas; (SG) San García; (CU) Cucareo; (GU) Guadarranque; (CR) Crinavis.

have similar characteristics and are far from antropogenic influence zones) and Cucareo (an area that suffers the influence of the nearby Port of Algeciras). Along the same line, the similarity of the stations within a specific area is greater among those located at more depth (IP2 and IP3; SG2 and SG3) than those more shallow (IP1 and SG1). In the case of the stations of Cucareo, these are found at a similar depth. With the two-dimensional representation of the ordination analysis MDS (Figure 4), the two groups and the different affinities among stations are confirmed.

With the SIMPER analysis it was possible to determine the species responsible for these groupings, those typical of a group as well as those discriminating among these groups. Among the typifying species of the external stations (Table 4), the isopod *Paranthura nigropunctata* stands out. Of relatively less importance, the amphipods *Microprotopus* sp., *Dexamine spinosa, Amphilochus neapolitanus, Stenothoe monoculoides* and Aoridae sp. and the pantopoda *Anoplodactylus angulatus*. At the internal stations (Table 5), the important species is the amphipod *Corophium acutum* and secondarily, the amphipods *Phtisica marina,* Aoridae sp. and *Aora spinicornis,* the tanaid *Leptochelia dubia* and the decapod *Macropodia* sp. The discriminating species (Table 6) are: *Amphilochus neapolitanus* and *Zeuxo normani,* as well as *Jassa marmorata* and *Microprotopus* sp.

In order to test the spatial differences, a one way ANOSIM was employed. In Table 7 the statistic values are shown at the spatial level and for each samplings. Generally, the differences are clear between the external and internal bay stations, which confirmed the results obtained by the previous

Table 4. *Average abundance ($\overline{Y}_A$) of the most relevant species of the stations located in the external areas (Island of Las Palomas, San Garcia and Cucareo). Species are listed in decreasing order according to its contribution to the average of the similarity ($\overline{S}_i$)* among stations until 75% of the accumulated total similarity ($\Sigma\overline{S}_i\%$). The total mean similarity among stations is 75.53%.

Species	$\overline{Y}_A$	$SD(\overline{Y}_a)$	$\overline{S}_i$	$SD(\overline{S}_i)$	$\overline{S}_i/SD(\overline{S}_i)$	$\overline{S}_i\%$	$\Sigma\overline{S}_i\%$
Leptochelia dubia	1,165.14	574.31	3.0	0.32	9.17	3.91	3.91
Gammaropsis palmata	1,272.12	1,097.83	2.8	0.31	9.11	3.75	7.66
Stenothoe monoculoides	814.59	442.68	2.7	0.23	11.82	3.58	11.25
Aoridae sp.	847.77	498.58	2.7	0.27	10.01	3.54	14.78
Tanais dulongii	966.12	763.71	2.5	0.50	5.04	3.30	18.09
Corophium acutum	1,353.12	1,473.15	2.5	0.77	3.18	3.25	21.33
Apherusa bispinosa	492.49	243.87	2.4	0.25	9.78	3.21	24.55
Phtisica marina	566.92	299.50	2.4	0.34	7.07	3.18	27.72
Paranthura nigropunctata	374.49	69.92	2.4	0.09	28.68	3.17	30.90
Microprotopus sp.	291.71	76.69	2.2	0.11	19.87	2.94	33.83
Amphilochus neapolitanus	285.44	80.91	2.2	0.12	18.60	2.93	36.76
Ampithoe ramondi	427.75	313.63	2.2	0.41	5.28	2.86	39.62
Dexamine spinosa	265.84	99.47	2.1	0.11	19.52	2.83	42.45
Hyale schmidti	560.92	679.77	2.1	0.39	5.42	2.81	45.25
Gammaropsis maculata	554.64	724.56	1.8	0.42	4.41	2.45	47.70
Achelia sp.	184.46	113.51	1.8	0.28	6.22	2.33	50.03
Nannastacus ungliculatus	167.14	107.15	1.8	0.21	8.21	2.32	52.34
Callipallene tiberi	128.28	80.64	1.6	0.20	8.23	2.18	54.52
Aora spinicornis	145.13	113.46	1.6	0.23	7.08	2.15	56.67
Apherusa sp.	841.09	1,086.20	1.6	0.86	1.88	2.15	58.82
Cumella limicola	66.74	32.70	1.5	0.20	7.37	1.93	60.75
Hippolyte sp.	79.98	50.72	1.4	0.21	6.86	1.91	62.66
Dexamine spiniventris	53.84	40.79	1.3	0.18	7.48	1.75	64.41
Elasmopus sp.	59.97	45.53	1.3	0.24	5.45	1.73	66.14
Cymodoce sp.	40.49	22.95	1.2	0.17	7.30	1.64	67.78
Lembos websteri	59.32	70.98	1.2	0.24	4.81	1.54	69.32
Dynamene sp.	87.61	106.34	1.2	0.38	3.10	1.54	70.86
Perionotus testudo	43.43	41.25	1.1	0.18	6.17	1.49	72.36
Guernea coalita	121.45	168.07	1.1	0.44	2.51	1.46	73.82
Anoplodactylus angulatus	24.49	19.57	1.1	0.10	10.80	1.41	75.23

Table 5. *Average abundance ($\overline{Y}_B$) of the most relevant species of the stations located in the internal areas (Guadarranque y Crinavis). Species are listed in decreasing order according to its contribution to the average of the similarity ($\overline{S}_i$) among stations until 78% of the accumulated total similarity ($\Sigma\overline{S}_i\%$). The total mean similarity among stations is 73%.*

Species	$\overline{Y}_B$	$SD(\overline{Y}_b)$	$\overline{S}_i$	$SD(\overline{S}_i)$	$\overline{S}_i/SD(\overline{S}_i)$	$\overline{S}_i\%$	$\Sigma\overline{S}_i\%$
Corophium acutum	4,186.67	869.27	4.6	0.14	33.00	6.32	6.32
Jassa marmorata	3,522.46	3,025.48	3.8	0.62	6.08	5.18	11.50
Phtisica marina	1,569.02	138.35	3.7	0.20	18.64	5.06	16.56
Aoridae sp.	1,739.83	588.56	3.6	0.28	12.74	4.91	21.46
Leptochelia dubia	882.79	180.77	3.1	0.24	13.03	4.29	25.75
Stenothoe monoculoides	1,597.17	1,387.98	3.0	0.60	5.06	4.17	29.92
Gammaropsis maculata	1,016.58	558.17	3.0	0.48	6.30	4.12	34.04
Aora spinicornis	674.97	443.18	2.7	0.16	16.92	3.69	37.73
Cumella limicola	623.88	526.77	2.5	0.39	6.38	3.37	41.10
Achelia sp.	379.27	139.91	2.4	0.27	9.11	3.35	44.44
Gammaropsis palmata	2,233.74	2,834.25	2.1	0.98	2.11	2.82	47.26
Erichtonius barsiliensis	1,055.42	1,131.73	1.9	1.34	1.39	2.54	49.81
Podocerus variegatus	169.46	125.84	1.8	0.33	5.49	2.46	52.27
Zeuxo normani	167.76	107.48	1.8	0.29	6.23	2.45	54.72
Lembos websteri	138.54	100.81	1.7	0.17	10.21	2.35	57.07
Microdeutopus chelifer	111.25	85.20	1.6	0.27	5.91	2.21	59.28
Callipallene tiberi	94.70	62.53	1.6	0.23	6.91	2.14	61.42
Dynamene sp.	158.38	170.38	1.6	0.29	5.34	2.14	63.57
Dexamine spinosa	72.72	44.58	1.5	0.24	6.03	2.01	65.58
Hippolyte sp.	102.50	128.67	1.4	0.15	9.32	1.86	67.43
Cymodoce sp.	150.56	153.57	1.3	0.54	2.238	1.75	69.18
Paranthura nigropunctata	135.83	149.58	1.3	0.42	3.01	1.73	70.91
Orchomene sp.	42.71	31.69	1.2	0.26	4.64	1.68	72.59
Corophium sextonae	79.92	76.77	1.2	0.44	2.72	1.62	74.21
Achaeus sp.	20.15	7.96	1.2	0.11	10.23	1.60	75.81
Macropodia sp.	15.22	4.62	1.1	0.07	16.83	1.52	77.34

Table 6. *Average abundance of the most relevant species of the stations located in the internal* ($\overline{Y_R}$) *and external areas* ($\overline{Y_A}$). *Species are listed in decreasing order according to its contribution to the average of the dissimilarity* ($\overline{\delta_i}$) *between the two groups until 40% of the accumulated total similarity* ($\Sigma\overline{\delta_i}\%$). *The total average dissimilarity among stations is 42.38%.*

Species	$\overline{Y_R}$	$\overline{Y_A}$	$\overline{\delta_i}$	$SD(\overline{\delta_i})$	$\overline{\delta_i}/SD(\overline{\delta_i})$	$\overline{\delta_i}\%$	$\Sigma\overline{\delta_i}\%$
Jassa marmorata	3,522.46	5.57	2.00	0.56	3.58	4.71	4.71
Ericthonius brasiliensis	1,055.42	1.95	1.25	0.71	1.76	2.94	7.66
Hyale schmidti	1.01	560.92	1.18	0.37	3.19	2.79	10.44
Amphilochus neapolitanus	0.00	285.44	1.18	0.08	14.35	2.79	13.23
Tanais dulongii	5.43	966.12	1.14	0.37	3.08	2.69	15.93
Apherusa sp.	0.81	841.09	1.11	0.66	1.69	2.62	18.55
Zeuxo normani	167.76	0.00	1.00	0.16	6.13	2.35	20.90
Microprotopus sp.	1.60	291.71	1.00	0.22	4.57	2.35	23.25
Zeuxo coralensis	395.62	0.00	0.95	0.68	1.40	2.24	25.49
Ampithoe ramondi	21.63	427.75	0.90	0.47	1.90	2.12	27.61
Caprella acanthifera	0.54	336.51	0.85	0.61	1.40	2.00	29.61
Apherusa bispinosa	43.62	492.49	0.80	0.43	1.86	1.88	31.49
Gammaropsis palmata	2,233.74	1,272.12	0.78	0.33	2.35	1.83	33.31
Guernea coalita	0.00	121.45	0.77	0.37	2.11	1.82	35.14
Corophium acutum	4,186.67	1,353.12	0.77	0.45	1.72	1.81	36.95
Corophium sextonae	79.92	3.57	0.61	0.32	1.91	1.45	38.40
Microdeutopus chelifer	111.25	26.81	0.59	0.39	1.51	1.40	39.80

Table 7. *Values of the statistic R (A/OSIM) among the different stations during the period of study. $P < 0.05$; *: not meaningful. (I) Island of Las Palomas; (S) San García; (C) Cucareo; (G) Guadarranque; (CR) Crinavis.*

	SEP92	DEC92	MAR93	JUN93	SEP93		SEP92	DEC92	MAR93	JUN93	SEP93
(I1-I2)	0.28*	0.00*	0.82	0.24*	0.46	(S1-G2)	0.94	1.00	0.96*	—	—
(I1-I3)	0.25*	0.43	1.00	0.66	0.59	(S1-CR1)	1.00	1.00	0.68	—	1.00
(I1-S1)	0.66	0.40	0.89	—	0.70	(S1-CR3)	0.98	1.00	0.73	—	1.00
(I1-S2)	0.77	0.67	0.96	—	—	(S2-S3)	0.86	0.45*	—	—	—
(I1-S3)	0.90	0.70	—	—	—	(S2-C1)	1.00	0.69	0.76	—	—
(I1-C1)	1.00	0.72	0.91	0.57	0.79	(S2-C2)	1.00	0.80	0.76	—	—
(I1-C2)	1.00	0.70	1.00	0.66	0.84	(S2-C3)	1.00	0.80	0.90	—	—
(I1-C3)	0.99	0.58	0.96	0.81	0.56	(S2-G1)	1.00	1.00	0.96	—	—
(I1-G1)	1.00	0.99	1.00	1.00	1.00	(S2-G2)	0.95	1.00	1.00*	—	—
(I1-G2)	0.97	0.98	0.97	0.97	—	(S2-CR1)	1.00	1.00	0.92	—	—
(I1-CR1)	1.00	0.96	1.00	1.00	1.00	(S2-CR3)	0.96	1.00	0.96	—	—
(I1-CR3)	1.00	0.96	1.00	0.90*	1.00	(S3-C1)	1.00	1.00	—	—	—
(I2-I3)	0.28*	0.25*	0.49	0.22*	0.18*	(S3-C2)	1.00	0.98	—	—	—
(I2-S1)	0.79	0.25*	0.49	—	0.75	(S3-C3)	1.00	1.00	—	—	—
(I2-S2)	0.80	0.49	0.84	—	—	(S3-G1)	1.00	1.00	—	—	—
(I2-S3)	0.98	0.62	—	—	—	(S3-G2)	0.95	1.00	—	—	—
(I2-C1)	1.00	0.62	0.51	0.74	0.83	(S3-CR1)	1.00	1.00	—	—	—
(I2-C2)	1.00	0.64	0.68	0.68	0.93	(S3-CR3)	0.97	1.00	—	—	—
(I2-C3)	1.00	0.63	0.80	0.80	0.70	(C1-C2)	0.77	0.79	0.21*	0.08*	0.96
(I2-G1)	1.00	1.00	1.00	1.00	1.00	(C1-C3)	0.80	0.78	0.54*	0.17*	0.40
(I2-G2)	0.96	1.00	0.97	0.99	—	(C1-G1)	1.00	1.00	1.00	1.00	1.00
(I2-CR1)	1.00	0.96	1.00	1.00	1.00	(C1-G2)	0.96	1.00	0.95	0.98	—
(I2-CR3)	0.98	0.96	1.00	0.90*	1.00	(C1-CR1)	0.99	1.00	1.00	0.86	1.00
(I3-S1)	0.98	0.42	0.43*	—	0.84	(C1-CR3)	1.00	1.00	0.95	0.90*	1.00
(I3-S2)	0.89	0.84	0.77	—	—	(C2-C3)	0.27*	0.61	0.55	0.35*	0.56
(I3-S3)	0.95	1.00	—	—	—	(C2-G1)	1.00	1.00	1.00	1.00	1.00
(I3-C1)	1.00	1.00	0.93	0.87	1.00	(C2-G2)	0.96	1.00	0.95	0.97	—
(I3-C2)	1.00	1.00	0.90	0.79	0.95	(C2-CR1)	1.00	1.00	1.00	0.90	1.00
(I3-C3)	1.00	0.99	0.91	0.87	0.76	(C2-CR3)	0.96	1.00	0.95	0.90*	1.00
(I3-G1)	1.00	1.00	1.00	1.00	1.00	(C3-G1)	1.00	1.00	1.00	1.00	1.00
(I3-G2)	0.96	1.00	0.97	0.99	—	(C3-G2)	0.94	1.00	0.96	0.96	—
(I3-CR1)	1.00	1.00	1.00	1.00	1.00	(C3-CR1)	1.00	1.00	1.00	0.93	1.00
(I3-CR3)	1.00	1.00	1.00	0.90*	0.99	(C3-CR3)	0.94	1.00	1.00	0.90*	0.99
(S1-S2)	0.87	0.36	0.04*	—	—	(G1-G2)	0.01*	0.81	0.90	0.77*	—
(S1-S3)	0.98	0.57	—		—	(G1-CR1)	0.93	0.99	0.84	0.99	1.00
(S1-C1)	0.99	0.65	0.37	—	0.89	(G1-CR3)	0.95	0.98	0.99	0.90*	0.97
(S1-C2)	1.00	0.62	0.46	—	0.84	(G2-CR1)	0.95	1.00	0.96	0.94	—
(S1-C3)	1.00	0.59	0.54	—	0.88	(G2-CR3)	0.92	1.00	0.92	0.94*	—
(S1-G1)	1.00	1.00	0.95	—	1.00	(CR1-CR3)	0.31	0.69	0.61	0.70*	0.71

Table 8. *Results of the analysis BIO-ENV: variable combinations taking k every time, the higher values obtained in each combination being emphasized (in boldface the maximum value). (SED) sedimentation rate; (MSED) % organic matter of the sedimentation; (SUS) solid in suspension; (SUSM) organic matter in suspension; (HYD) hydrodynamism; (CI) compactness index; (INTV) interstitial volume.*

Harmonic Ranges of Spearman Correlation (ρ_w):

k	Better Variable Combinations						
1	INTV (0.567)	CI (0.517)	HYD (0.295)	SUS (0.236)	SUSM (0.218)	MSED (0.182)	SED (0.110)
2	HYD,INTV (0.737)	HYD,CI (0.724)	SUS,INTV (0.709)				
3	**HYD,CI,INTV (0.760)**	SUS,HYD,CI (0.696)					
4	SUS,HYD,CI,INTV (0.749)						

ordination and classification analysis and this shows the discriminating power among localities that possess this animal group.

Relationships Between Biotic and Abiotic Variables

The environmental variables used for BIO-ENV were: sedimentation rate, % of organic matter of the sedimentation, hydrodynamism, solid and organic matter in suspension, interstitial volume and compactness index. These last two, considered as components of the habitat, together with the sedimentation rate were previously transformed (log x + 1).

The better correlations obtained in the analysis are shown in Table 8. The maximum correlation is obtained for hydrodynamism, compactness and interstitial volume (0′760). Besides, good correlations of the combination of these parameters with the organic matter of the sedimentation and the solids in suspension are shown.

With the canonical correspondence analysis (CCA), it is possible to determine if these variables represent an environmental gradient throughout Algeciras Bay. In Figure 5 we observe that the stations of the Island Las Palomas are close to those of San García, while those of Cucareo are considerably more distant. Concerning the internal stations, Crinavis is relatively nearer to the external zone, due possibly to certain influences of the hydrodynamic forces (here, the tidal currents of the Strait converge during low tide). Table 9 shows that the gradient of the first axis of the analysis is practically determined by the compactness index. Hydrodynamism significantly influences distribution on the second axis, together with organic matter of the sedimentation.

With respect to the species composition, certain trends are indicated. In the area of Cucareo, there is a small group of species that are not abundant, such as *Caprella* cf. *mitis*, *Zenobiana prismatica* or *Pisa tetraedon*. But of more importance is the presence of typical soft-bottom species such as *Ampelisca* cf. *unidentata*, *Siphonoecetes* sp and *Apseudes talpa*; the motion of sands that are deposited on the algae making possible the settling of species of their characteristics.

Another noteworthy species is the amphipod *Apherusa* sp, characteristic of the shallow water stations of the external zones. It appears nearest to the stations of Cucareo. The zone occupied by the stations of the Island Las Palomas and San García shows a numerous group of common species to both sites with a notable influence of compactness index (a larger number of spaces favors swimming species). Some examples are: *Cressa cristata, Guernea coalita, Eusiroides delavallei, Amphilochus neapolitanus, Hyale schmidti, Apherusa bispinosa, Pereionotus testudo, Lembos viguieri, Pedoculina garciagomezi, Nebalia bipes*, etc. Another group, constituted by species living in moderate conditions of hydrodynamism, solids in suspension and compactness index are *Paranthura nigropunctata, Dexamine spinosa, Gammaropsis palmata, Thoralus cranchii, Hippolyte* sp, *Leptochelia dubia*. Species with higher requirements of organic matter in suspension and low hydrodynamism are *Cymodoce* sp, *Tritraeta gibbosa, Corophium acutum, Aora spinicornis, Stenothoe monoculoides* and *Orchomene* sp. Those of more hydrodynamism and a higher percentage of organic matter in the sediment are *Phtisica marina, Pariambus typicus, Ischyrocerus inexpectatus, Gammaropsis maculata*, etc. In the Crinavis area, the same as in Cucareo, there is a high number of typical soft-bottom species due to the fact that the algae are surrounded by a wide sandy bottom. Thus, *Corophium sextonae, Gammarella fucicola, Harpinia* sp, *Iphinoe* sp, *Dardanus* sp, *etc* are found. In the Guadarranque zone there is a predominance of deposit-feeder species such as *Jassa marmorata, Ericthonius brasiliensis* and *Zeuxo normani* and *Z. coralensis*, characterized by the highest values of organic matter in the sedimentation and with little interfrond spaces.

According to the Monte-Carlo test, ordination is significant for the first axis (F = 3′51, P = 0′05).

DISCUSSION AND CONCLUSIONS

The determining factors of the composition of the epiphytic arthropods community are hydrodynamism, sedimentation rate, solids in suspension, levels of nutrients and algal morphology (HAGERMAN, 1966; BELLAN-SANTINI, 1969; MOORE, 1972, 1986; RUSSO, 1989; etc). With this animal group there is a clear separation of the different species according to the prevailing environmental conditions in each zone. According to FENWICK (1976), the variety of microhabitats is larger in exposed coasts than in protected, thus a greater number of species appear in the external zone. The quantitative dominances of external-zone species are more spread out than among the species of the internal zone where there are some species that are clearly dominant over the others, as in the case of the amphipods *Corophium acutum* and *Jassa marmorata*. Both species, even though they can also be abundant in high hydrodynamism conditions (DIVIACCO, 1980; DIVIACCO and ARATA, 1988; JIMENO, 1993), proliferate more in this zone because of the high available sediment on the algae for the construction of their tubes and as food, being two species typical of port environments (TARAMELLI and SCIPIONE, 1977; CANDELA *et al*, 1983; PROCCACCINI and SCIPIONE, 1992). *J. marmorata* was also found in areas with high stress (LEDOYER and MENIOUI, 1983) and of high sedimentation (SCIPIONE *et al*, 1981; FRANZ, 1989; MYERS, 1989). *C. acutum* was also abundant in the external zone, which confirms its resistance to strong hydrodynamism.

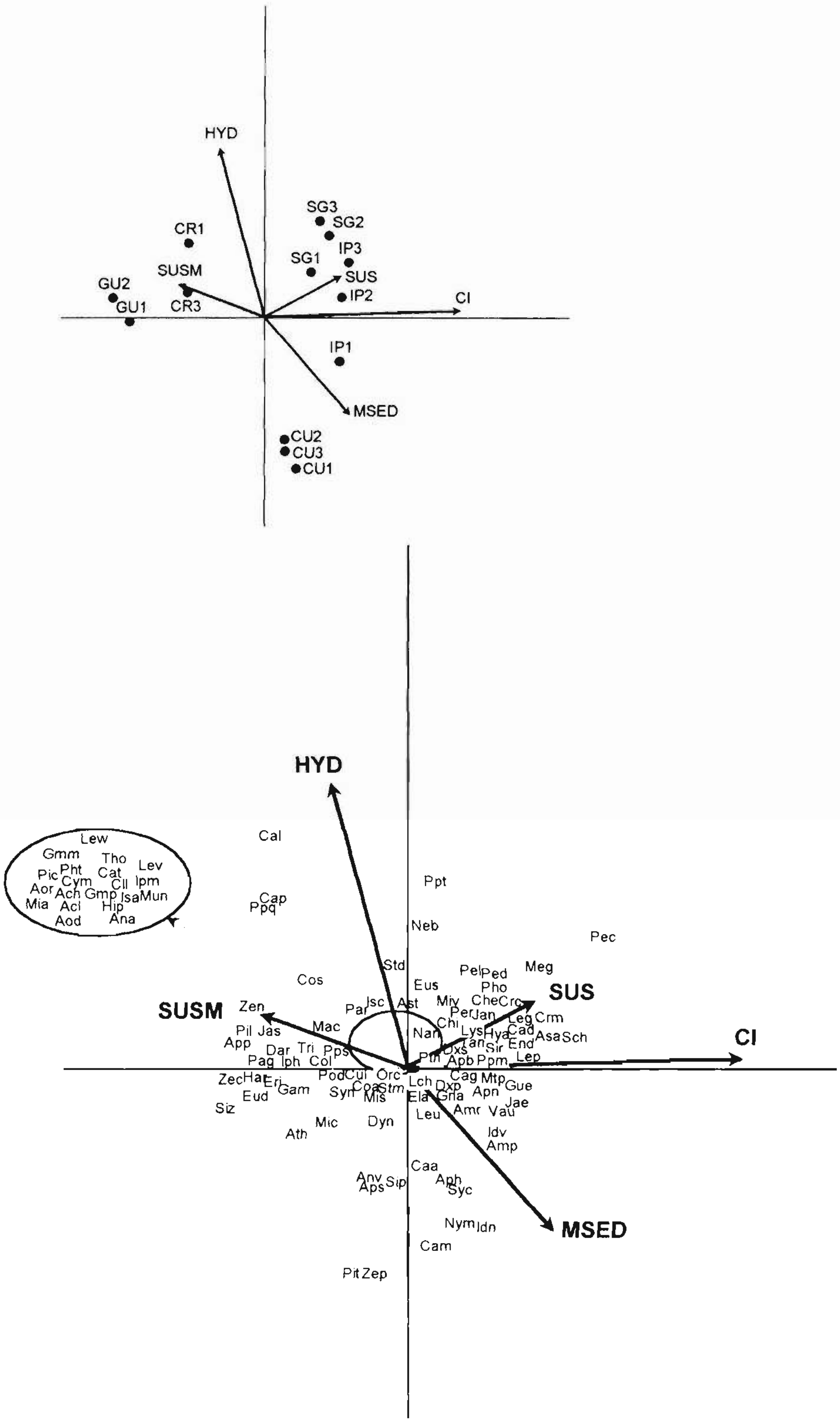

Figure 5. Graph representation of the stations and species with respect to the first two axes of the canonical correspondence analysis (CCA). (HYD) hydrodynamism; (SUS) solid in suspension; (SUSM) organic matter in suspension; (MSED) organic matter of the sedimentation; (CI) compactness. (Species key in Table 3).

Table 9. *Results of the canonical correspondence analysis.*

Intraset Values	Axis1	Axis2	Inflation
MSED	0.442	0.466	1.3426
SUS	0.372	0.197	1.6461
SUSM	−0.423	0.158	1.4838
HYD	−0.219	0.819	1.1641
CI	0.966	0.028	1.7876
		Axis1	Axis2
Species-environment correl.		0.905	0.914
Cumulative % variance			
of species data		33.4	45.7
of species-environment relation		51.1	69.9

Another reason to explain the preference of this species for the internal stations can be because of the existence of competition. Some spatio-temporal differences in the distribution or abundance of species with apparent similar food or habitat requirements suggest competition, present or past, due to limited resources (DIAMOND, 1975). An important species in the external zone and practically non-existent in the internal is the amphipod *Ampithoe ramondi*. It is often a territorial species (BRAWLEY and ADEY, 1981), builder of tubes and of aggressive behavior compelling other tubicolous species such as *Corophium* to occupy the distal and basal portions of the algae (GUNNILL, 1984). It is a species of relative large size and whose preference in our study was for algae with a lot of space and larger size. *C. acutum* is located in opposite conditions, together with other tubicolous species such as *Ericthonius brasiliensis*.

There are a great number of species under the same conditions as those of *A. ramondi*, with moderate and high hydrodynamism and a lot of space which should also favor swimming species (CRISP and MWAISEJE, 1989) such as *Apherusa bispinosa*, *Apherusa* sp., *Lembos viguieri*, *Amphilochus neapolitanus* or *Hyale schmidti* (this species sustains strong mechanical stress according to KRAPP-SCHICKEL (1975)). In intermediate conditions there are species such as the isopod *Paranthura nigropunctata*, abundant on macroalgae and seagrass and regularly associated with the sediment fraction (WAGELE, 1982; ARRONTES and ANADON, 1990); the decapods *Hippolyte* sp. and *Thoralus cranchii* are both swimming species and with need of space; etc. Between the species with requirements of low hydrodynamism and high percentages of organic matter in suspension we find the isopod *Dynamene* sp., which tends be tolerant of pollution (BELLAN-SANTINI, 1969; DESROSIERS *et al*, 1986), and the amphipod *Stenothoe monoculoides*, that seems to be indifferent to hydrodynamism (DOMMASNES, 1968; MOORE, 1986). In zones with higher incidence of currents but smaller suspension, for example, the amphipod *Pariambus typicus* stands out, in spite of being a typical soft bottoms species and sheltered areas as the *Caulerpa* and fanerogames meadows (SCIPIONE and CHESSA, 1986) with tolerance for high sedimentation rates (PROCCACCINI and SCIPIONE, 1992), and *Ischyrocerus inexpectatus* like most of the species of the Ischyroceridae family adjust well to high hydrodynamism (MOORE, 1973; VADER, 1983). At the opposite extreme, in conditions of smaller compactness index and more protected areas, the typical deposit-feeder species appear as mentioned above, *Jassa marmorata* and *Ericthonius brasiliensis* (TARAMELLI and PEZZOLI, 1986) or the tanaids *Zeuxo normani* and *Z. coralensis*, characteristic of shallow waters and higher temperatures (SANZ, 1993).

In conclusion, the different environmental conditions from each zone of the Bay of Algeciras determine the final composition of the community. Therefore, we can assert that this taxonomic group, thanks to its high richness in species with a wide environmental spectrum and its great quantitative importance in the epiphytic communities shows in a clear way the spatio-temporal differences among the different localities. Thus, it can be extremely useful in characterization studies of environmental quality of coastal waters.

ACKNOWLEDGEMENT

Appreciation to CEPSA (Compañía Española de Petróleos, S.A.), Sevillana de Electricidad, Excmo. Ayuntamiento de los Barrios, Mancomunidad de Municipios del Campo de Gibraltar for financial support of this work.

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SUMMARY

Se estudia la variación espacial de las comunidades de artrópodos asociadas al alga *Halopteris scoparia* en relación a la influencia de factores ambientales en la Bahía de Algeciras (Sur de España). Por medio de diversos análisis multivariantes, podemos constatar una clara diferencia en la composición de las comunidades de las áreas externas e internas de la bahía, siendo el hidrodinamismo y la morfología algal los principales factores determinantes de esta composición. En la zona externa se aprecia un mayor número de especies cuyas dominancias cuantitativas están más repartidas que entre las especies de la zona interna donde hay algunas que dominan claramente sobre las demás como es el caso de los anfípodos *Corophium acutum* y *Jassa marmorata*. Como conclusión, podemos afimar que este grupo animal, con una elevada riqueza de especies con un amplio espectro ambiental y con una gran importancia cuantitativa en las comunidades epífitas, muestra claramente las diferencias entre las distintas localidades, por lo que pueden ser de gran utilidad en estudios de caracterización de la calidad ambiental de las aguas litorales.