

SUBTIDAL SOFT-BOTTOM MACROINVERTEBRATE COMMUNITIES OF THE CANARY ISLANDS. AN ECOLOGICAL APPROACH

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A B S T R A C T

The Canary archipelago is characterized by a mosaic of soft-bottoms such as *Cymodocea nodosa* meadows, *Caulerpa* spp. meadows, maërl bottoms, sabellid fields and bare sandy seabeds, including various macroinfaunal communities. Vegetated habitats (e.g. *Cymodocea* and *Caulerpa*) maintain more diverse communities than the non-vegetated seabeds. The results indicated that *Caulerpa* meadows and, to a lesser extent, *Cymodocea nodosa* and sabellid fields are the richest and most diverse ecosystems in the study area. Moreover, biodiversity differences among islands could be detected with maximum values on the eastern islands (Lanzarote and Gran Canaria) and lowest values on the western ones (La Palma).

R E S U M O

O arquipélago das Canárias é caracterizado por um mosaico de fundos inconsolidados contendo bancos de *Cymodocea nodosa*, *Caulerpa* spp., fundos calcários, bancos de sabelídeos e sedimento não biogênico, que abrigam diferentes comunidades da macrofauna. Ambientes vegetados (*Cymodocea* e *Caulerpa*) possuem comunidades mais diversificadas quando comparados aos ambientes de fundos não vegetados. Os resultados do presente estudo indicaram que os bancos de *Caulerpa*, primeiramente, e em seguida os bancos de *Cymodocea nodosa* e de sabelídeos, formam os sistemas mais ricos e diversificados da área. Além disso, puderam também ser detectadas diferenças de biodiversidade entre as ilhas do arquipélago, sendo os valores mais altos localizados nas ilhas ao leste (Lanzarote e Gran Canaria) e os menores nas ilhas à oeste (La Palma).

Descriptors: Soft-bottoms, meadows, *Cymodocea*, *Caulerpa*, macrofauna, Canary Islands, Atlantic Ocean.

Descritores: Fundos inconsolidados, baixios vegetados, *Cymodocea*, *Caulerpa*, macrofauna, Ilhas Canárias, Oceano Atlântico.

I N T R O D U C T I O N

In the Canary Islands, *Cymodocea nodosa* seagrass meadows (regionally legislated as an endangered species) usually grow on a high proportion of sandy substrates, where currents are moderate and a high sedimentation rate exists (REYES et al., 1995). For that reason it is located mainly along the eastern and southern coast of the islands, from 0 a 30 m depth, forming extensive subtidal meadows (REYES et al., 1995; PAVÓN-SALAS et al., 2000). In some locations, *C. nodosa* meadows are mixed with the green alga *Caulerpa* (*C. prolifera* and *C. racemosa*) (PAVÓN-SALAS et al., 2000), this green alga usually substitutes in depth to *Cymodocea* in the coarse sandy substrates. We also observed in some areas that mixed communities (*C. nodosa* and *Caulerpa* spp.) are present together with the seagrass *Halophila decipiens*

and even eel-garden (*Heteroconger longissimus*) assemblages (MONTERROSO et al., 2004).

Canarian macroinfauna seems to be characterized by local patches of high densities (> 100 ind/m²) separated by a fairly variable inter-patch distance (HERRANDO-PÉREZ et al., 2001). Brito et al. (2005) studied the temporal variability of interstitial polychaetes on a *Cymodocea nodosa* meadow during a year. The dominant polychaete species were syllids (*Streptosyllis bidentata*, *Exogone parahomoseta mediterranea* and *Streptosyllis campoyi*) and paraonids (*Aricidea assimilis* and *Cirrophorus perdidoensis*). Unfortunately, scarce ecological data exist about the remaining studied seabeds (*Caulerpa* spp. meadows, Maërl, Sandy bottoms, Sabellids field and mixed, with *Cymodocea* and *Caulerpa*) and this information is provided by qualitative data from campaigns of seabed characterization. Thus, there are

no available quantitative data for comparison from other Canary areas.

In oceanographic terms, canarian macrofaunal communities should be characterized by having low abundances because of the presence of oligotrophic atlantic waters, being richer in the proximity of the african coast by the presence of the saharian upwelling (BARTON et al., 1998).

The present study is the first attempt to characterize macrofaunal communities from different islands of the Canary archipelago (Lanzarote, Gran Canaria, Tenerife and La Palma), as well as, from different seabeds (*C. nodosa* meadows, *Caulerpa* spp. meadows, Maërl, Sandy bottoms, Sabellids fields and mixed (*C. nodosa* and *Caulerpa*). The studied areas are considered suitable for aquaculture cages and thus, the main aim of the present work is to evaluate macrofaunal diversity from sandy seabeds of the Canary Islands in order to

consider these communities for future environmental monitoring assessments.

MATERIAL AND METHODS

The present study was conducted at five coastal areas of Lanzarote, Gran Canaria (South-east and North-west), Tenerife and La Palma, where large sandy unvegetated habitats exist, crucial for the settlement of aquaculture cages. Six different seabeds were present in the studied areas: *Cymodocea nodosa* meadows, *Caulerpa* spp. meadows, Maërl, Sandy bottoms, Sabellids fields and mixed (*C. nodosa* and *Caulerpa* spp.). A total of 166 sites were sampled in the present study, 76 in sandy bottoms, 56 in *Caulerpa* meadows, 16 in *C. nodosa* meadows, 8 sabellids fields, 8 mixed (*C. nodosa* and *Caulerpa*) and 2 maërl bottoms (Fig. 1).

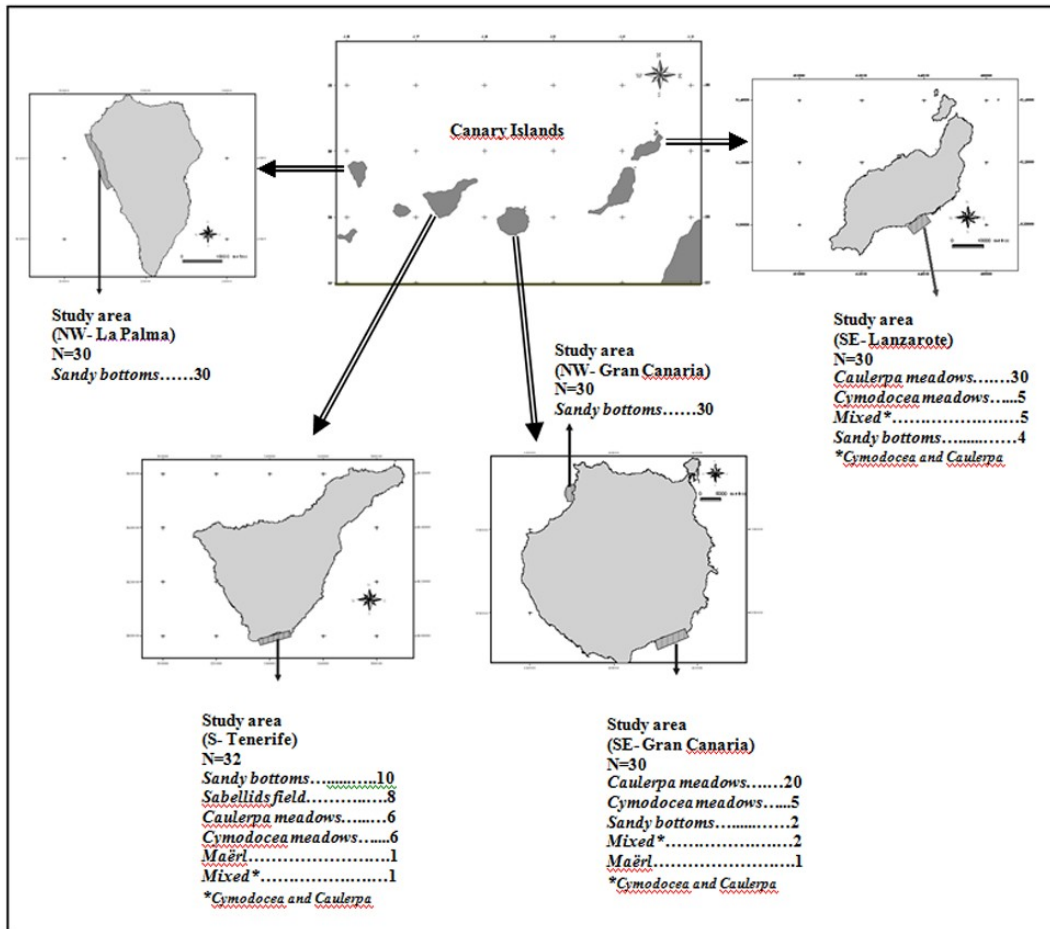


Fig. 1. Location of the study area and sampling sites, showing total number of sites per island (N) and number of sites per habitat in each island.

Sediment samples were taken during summer 2002 (July and August). Samples were collected by hand drilling into the sediment with a square metallic core (20 x 20 cm, volume of the area unit = 800 cm³), to a depth of 20 cm. Only infaunal specimens were identified, not epifaunal specimens of seagrass (*C. nodosa*) or *Caulerpa* meadows, and abundances were represented by area unit. All sampling stations are subtidal (20-30 m). Three replicates were collected from each site for faunal analysis. No data concerning sedimentary properties of the seabed were sampled. Samples were preserved in 10% seawater buffered formaldehyde solution and sieved through a 1 mm mesh, commonly used in monitoring studies (less time-consuming). Specimens were sorted and counted under a binocular microscope and finally stored in 70% ethanol until microscopical analysis. Specimens were mounted in glycerine jelly on slides and examined by means of a LEICA DMLB microscope equipped with Nomarski interference contrast for their identification to species level, whenever possible.

Two different approaches were used to analyse the data:

1. Univariate analysis of macroinfaunal community descriptors (abundance, species richness, Margalef's richness and Shannon's diversity) using variance (Hierarchical ANOVA) to test the null hypothesis that the macroinfaunal community structure was similar across habitat within islands. The experimental design considered two factors: (a) habitat (H), with six treatments (*Cymodocea* meadows, *Caulerpa* meadows, Maërl, Sandy bottoms, Sabellids field and mixed, with *Cymodocea* and *Caulerpa*) and (b) site (S), with five treatments (SE-Lanzarote, NW-Gran Canaria, SE- Gran Canaria, S-Tenerife, NW-La Palma). Locations were nested in habitats.
2. Multivariate analysis of the similarities among communities based on species composition were established using n-MDS (non-metric multidimensional scaling). Data were square-root transformed and the Bray-Curtis similarity index was used. The ANOSIM routine (CLARKE, 1993) was used to analyze differences between islands and soft-bottoms communities, being identified the macrobenthic species responsible for the observed trends by means of SIMPER routine. Multivariate analyses were carried out using the PRIMER 5.2. package (Plymouth Routines In Multivariate Ecological Analysis) (CLARKE; WARWICK, 1994).

Differences between localities and communities in community descriptors (abundance,

species richness, Margalef's richness and Shannon's diversity) were analyzed by means of one-way analysis of variance (ANOVA), after verifying normality using the Kolmogorov-Smirnov test and Levene test for homogeneity of variances. Data were square-root transformed to meet the assumptions of normality and homocedasticity required for parametrical analyses (UNDERWOOD, 1997).

RESULTS

A total of 2,991 specimens were collected, belonging to 232 species and 15 taxonomic groups (Polychaetes, Oligochaetes, Turbellarians, Nematodes, Nemertean, Amphipods, Cumaceans, Isopods, Misids, Decapods, Bivalves, Ophiuroids, Echinoids, Cephalochordates and Phoronids) (Table 1). Polychaetes were the most abundant group with 2,234 individuals, representing the 74.7% of the total abundance. The second most abundant group were amphipods with 433 individuals (14.5% of the total abundance). These two groups accounted together the 89.2% of the overall abundance. Tanaids were the third group in terms of abundance and represented 3% of the total abundance. The remaining taxonomic groups were scarce. In terms of species richness, polychaetes were the most diverse group with 131 taxa, followed by amphipods with 29 species.

The most abundant species was the sabellid *Chone* sp. with 305 individuals, followed by the onuphid *Aponuphis bilineata* and the paraonid *Cirrophorus armatus*, with 265 and 232 ind, respectively. In contrast, a total of 73 taxa were represented by one single specimen (Table 1).

Table 1. List of macrofaunal species collected at sampling stations [N IND total number of specimens; DOM Soyer's dominance (D dominant; d non-dominant); FREQ frequency, (A accessory; a accidental); Mean number of specimens (ind m⁻²) ±SE (Standard Error).

COMMUNITY DESCRIPTORS

Islands

The highest abundances with a mean of 29.37 ind/area unit (800 cm³) were obtained in Lanzarote, followed by the south-east Gran Canaria with 24.8 ind/area unit. Tenerife and north-west Gran Canaria were characterized by having intermediate values, 17 and 16.5 ind/area unit, respectively. The lowest abundances were found in La Palma, with a mean of 10.5 ind/area unit (Fig. 2). However, no significant differences were found among islands (One-way ANOVA, $F = 0.75$, $p = 0.43$).

As occurred to the abundance, the highest values of Margalef's richness were obtained in Lanzarote, with a mean of 11.30, followed by south-east Gran Canaria with 10.63. Tenerife and north-west Gran Canaria were characterized by having

intermediate values, with 7.16 and 6.13, respectively. In La Palma were obtained the lowest richness with a mean of 4.16. No significant differences were recorded among islands (One-way ANOVA, $F = 0.88$, $p = 0.76$).

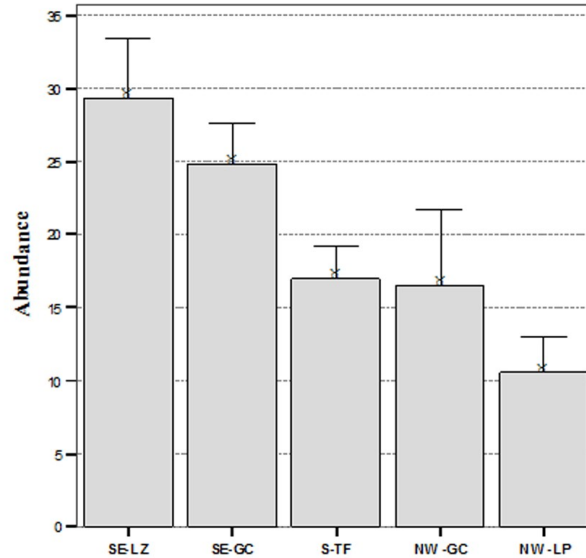


Fig. 2. Mean abundances (per area unit: 800 cm³) of total sampling stations (\pm 1SE) per site (SE-LZ, southeast Lanzarote; SE-GC, southeast Gran Canaria; S-TF, south Tenerife; NW-GC, northwest Gran Canaria; NW-LP, northwest La Palma).

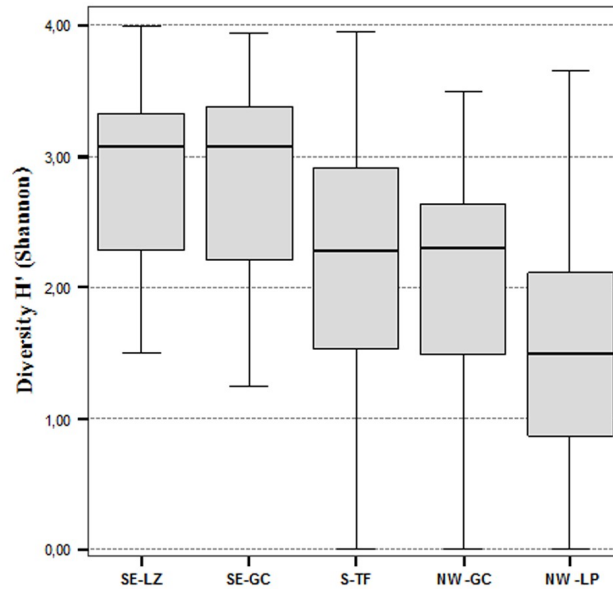


Fig. 3. Shannon's Diversity of total sampling stations (H') per site (SE-LZ, South-East Lanzarote; SE-GC, South-East Gran Canaria; S-TF, South Tenerife; NW-GC,

North-West Gran Canaria; NW-LP, North-West La Palma). Box-plot showing median (black line) and upper and lower quartiles of the data.

In terms of Shannon’s diversity (H' , log basis ln) highly significant differences were found among islands (One-way ANOVA $F=10.181$; $p < 0.0001$). The highest diversity was found in Lanzarote with 2.75, followed by Gran Canaria and Tenerife with 2.42 and 2.19, respectively. The lowest diversity was obtained in La Palma with 1.46 (Fig. 3).

Pielou’s evenness showed high values in all studied islands, ranging from 0.72 in La Palma to 0.86 in Gran Canaria. No significant differences were found among islands (One-way ANOVA, $F = 0.92$; $p = 0.70$).

Habitats

Mixed seabeds (*Cymodocea* and *Caulerpa*) harbour the highest abundances (28.12 ind/area unit), followed by *Caulerpa* meadows and Sabellids fields, with 25.97 and 25.17 ind/area unit, respectively. To the contrary, the lowest abundances were found in sandy bare seabeds (14.09 ind/area unit). No significant differences were found among islands (One-way ANOVA, $H = 0.88$; $p = 0.55$).

Margalef’s richness varied among the studied habitats, ranging from 1.79 in sandy bare seabeds to 3.46 in mixed communities (*Cymodocea* and *Caulerpa*). No significant differences were found among habitats (One-way ANOVA, $F = 0.95$; $p = 0.85$).

The mixed community *Caulerpa-Cymodocea* obtained the highest diversity ($H'=3.17$), followed by *Caulerpa* meadows community ($H' =$

2.76). Intermediate diversity values were recorded in Maërl (2.26), *Cymodocea nodosa* seagrass meadows (2.20) and Sabellids field (2.30). The sandy bare seabed community harboured the lowest diversity ($H' = 1.86$), however, no significant differences were found among habitats (One-way ANOVA, $F = 0.98$; $p = 0.73$). All habitats showed high evenness values ranged from 0.79 in sandy bottoms to 0.90 in mixed community (*Caulerpa-Cymodocea*), indicating the absence of species that clearly dominate the macrofaunal community. No significant differences were found among the studied habitats (One-way ANOVA, $F = 0.79$; $P = 0.52$) (Table 2).

Macrofaunal Community Structure

A non-parametric multidimensional scaling (n-MDS) revealed differences among the five different locations (La Palma, North-West Gran Canaria, South-East Gran Canaria, Lanzarote and Tenerife) (Fig. 4). ANOSIM results obtained significant differences ($R = 0.212$, $p = 0.001$) among locations, being clearly separated macrofaunal communities of La Palma (NW-LP) from the remaining ones.

A non parametric multidimensional scaling (MDS) revealed slight differences, as shown as not significant in ANOSIM results ($R = 0.055$, $p = 0.08$) among the six different soft-bottom communities, although *Caulerpa* meadows communities were clearly separated from the remaining seabeds (Fig. 5).

Table 2. Minimum, maximum and mean values of community descriptors (Shannon’s diversity, Pielou’s evenness and Margalef’s richness) of the six different habitats. SD: Standard Deviation; n: number of sampling locations.

		Min.	Max.	Mean	SD
<i>Caulerpa</i> meadows (n = 56)	Diversity (H')	0	3.95	2.76	1.02
	Evenness (J')	0	1.00	0.83	0.24
	Richness (d)	0	5.67	3.03	1.39
<i>Cymodocea</i> meadows (n = 16)	Diversity (H')	0	3.37	2.20	1.03
	Evenness (J')	0	1.00	0.81	0.24
	Richness (d)	0	5.07	2.36	1.39
Maërl (n = 2)	Diversity (H')	1.74	2.78	2.26	0.74
	Evenness (J')	0.75	0.88	0.82	0.09
	Richness (d)	1.36	2.82	2.09	1.03
Mixed (n = 8)	Diversity (H')	2.24	3.99	3.17	0.58
	Evenness (J')	0.81	0.98	0.90	0.06
	Richness (d)	2.06	5.3	3.47	1.11
Sabellid fields (n = 8)	Diversity (H')	1.44	3.06	2.30	0.57
	Evenness (J')	0.61	0.96	0.81	0.13
	Richness (d)	1.41	3.32	2.08	0.66
Sandy bottoms	Diversity (H')	0	3.88	2.86	1.00
	Evenness (J')	0	1	0.79	0.30
	Richness (d)	0	5.02	1.86	1.16

(n = 76)

Macroinfaunal species that accounts for the similarities between all studied samples were the polychaetes *Aponuphis bilineata* and *Chone* sp., although several species were typical of one single seabed, such as, *Glycera oxycephala* in *Caulerpa* meadows, *Galatowenia oculata* in *Cymodocea* meadows, *Bispira viola* in sabellids field and the amphipod *Urothoe marina* in sandy bare seabeds (Table 3).

DISCUSSION

Six different soft-bottom habitats were sampled (*Caulerpa* meadows, *Cymodocea nodosa* meadows, Mixed community, Sabellids field, Mäerl and Sandy bare seabeds) and the highest

macroinfaunal diversity was recorded in mixed community (*Caulerpa* and *Cymodocea*) and *Caulerpa* meadows, intermediate values were recorded in *C. nodosa* meadows, Mäerl and Sabellids field. However, these results should be taken with caution, since *Caulerpa* meadows (56 stations) and sandy bare seabeds (76 stations) were sampled extensively compared with the remaining habitats. In contrast, mäerl, mixed community (*Caulerpa* and *Cymodocea*) and sabellids field were represented by a small number of stations. The main consequence of this unbalanced number of samples is the lack of significant differences among studied sandy seabeds, specially between vegetated (*C. nodosa*, *Caulerpa* and mixed communities) and unvegetated substrates.

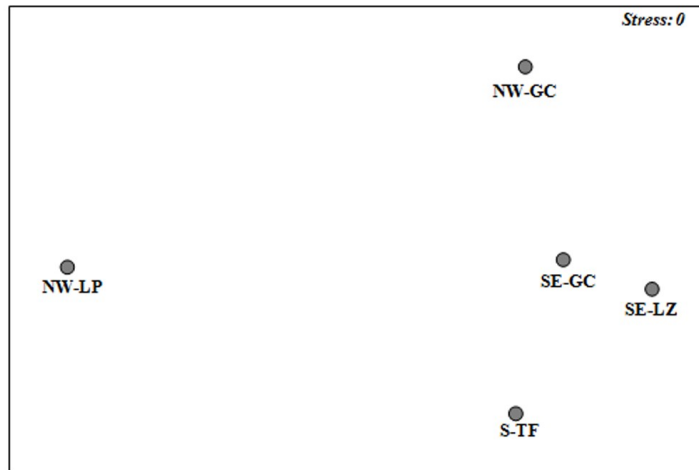


Fig. 4. Non multidimensional scaling (n-MDS) showing the five different sites (SE-LZ, South-East Lanzarote; SE-GC, South-East Gran Canaria; S-TF, South Tenerife; NW-GC, North-West Gran Canaria; NW-LP, North-West La Palma). Stress value = 0.15.



Fig. 5. Non multidimensional scaling (n-MDS) showing the six different habitats. Stress value = 0.11.

Table 3. Mean abundances of the species with the greatest similarity of all the groups obtained by the multivariate analyses according to the SIMPER routine. Mäerl community not represented because of scarcity of data. Contribution cutoff (5%).

	Species	Av. Abund	Av. Sim	Sim/SD	Contrib %	Cum. %
Caulerpa meadows	<i>Aponuphis bilineata</i>	3.12	3.8	0.76	27.9	27.9
	<i>Chone</i> sp	4.49	3.71	0.54	27.21	55.11
	<i>Chone collaris</i>	1.39	0.93	0.3	6.82	61.94
	<i>Cirrophorus armatus</i>	1.02	0.77	0.34	5.65	67.58
	<i>Aponuphis bilineata</i>	3.62	6.16	0.65	42.72	42.72
Cymodocea meadows	<i>Ampelisca brevicornis</i>	2.12	1.99	0.43	13.79	56.52
	<i>Chone</i> sp	0.75	1.39	0.4	9.66	66.17
	<i>Cirrophorus armatus</i>	2.94	1.31	0.41	9.05	75.22
	<i>Galathowenia oculata</i>	0.75	1.07	0.36	7.4	82.62
	<i>Chonesp</i>	1.88	1.83	0.49	13.89	13.89
Mixed	<i>Aponuphis bilineata</i>	1.88	1.79	0.49	13.57	27.46
	<i>Scoloplos (Leodamas)</i> sp	1.38	1.51	0.66	11.45	38.91
	<i>Cirrophorus perdidoensis</i>	3	1.5	0.34	11.37	50.27
	<i>Cirrophorus armatus</i>	0.88	1.36	0.45	10.3	60.58
	<i>Bispira viola</i>	7.38	10.69	0.79	35.93	35.93
Sabellid fields	<i>Cirrophorus armatus</i>	3.38	8.54	1.12	28.7	64.63
	<i>Chonesp</i>	5.88	6.76	0.92	22.73	87.36
	<i>Cirrophorus armatus</i>	1.45	1.11	0.28	23.38	23.38
	<i>Aponuphis bilineata</i>	0.71	0.7	0.23	14.78	38.16
	<i>Galathowenia oculata</i>	0.56	0.32	0.15	6.76	44.92
Sandy bottoms	<i>Urothoe marina</i>	0.43	0.32	0.15	6.7	51.62
	<i>Glycera oxycephala</i>	0.25	0.29	0.15	6.06	57.67
	<i>Prionospio steenstrupi</i>	0.27	0.27	0.13	5.56	63.23

However, significant differences were found among islands, with a trend from the eastern island (Lanzarote) to the western island (La Palma). This trend agrees well with the influence of the saharian upwelling (West coast of Africa), that directly affects the eastern islands of the archipelago (Lanzarote and Fuerteventura, and to a lesser extent, Gran Canaria), with rich and cold waters (BARTON et al., 1998). In contrast, the western islands (La Palma, La Gomera and El Hierro) are characterized by oligotrophic waters, without connection with richer water masses.

In this study, polychaetes characterized the macrofaunal community structure of the sampling stations (> 74% of the overall abundance). This

taxonomic group has been considered a reliable descriptor of soft-bottom communities, due to the great species diversification (SOMASCHINI et al., 1994). Brito et al. (2005) demonstrated the presence of a diverse polychaetofauna in seagrass meadows (*C. nodosa*) of the Canary Islands, being usually much higher the abundance, species richness and diversity in the meadows that in the adjacent sandy bare sediments. However, other authors observed that most species inhabiting rhizomes of *Posidonia oceanica* (seagrass not present in the Canarian archipelago) are also typical of the soft bottoms that occur in the nearby sand (LANERA; GAMBI, 1993). Furthermore, important variations of the community structure has

been observed in seagrass meadows of the Canary Islands compared to adjacent areas (Mediterranean Sea) (BRITO et al., 2005) although the families Syllidae, Spionidae, Paraonidae and Capitellidae are considered the most abundant taxa among the polychaete fauna in both geographical regions (GIANGRANDE; GAMBI, 1986).

The habitat structure of *Caulerpa prolifera* beds, with developed and declined cover on a small spatio-temporal scale, leads to a high degree of heterogeneity which must produce a spatio-temporal pattern of macrofaunal species distribution (SÁNCHEZ-MOYANO et al., 2007). The *C. prolifera* formations, even though they do not constitute such a rich and structured system as the seagrass meadows, allow the settlement of important macrofaunal communities. This phenomenon is more accused in impoverished environments with scarce water exchange and with considerable input of organic matter (e.g. harbours) (SÁNCHEZ-MOYANO et al., 2001). Even in some cases, *Caulerpa* beds show richer communities than more structured seagrass meadows. In other studies, 49 crustacean species were recorded in other *Caulerpa* beds at the southern Atlantic coast of Spain (LÓPEZ DE LA ROSA et al., 2002) or 45 crustacean taxa along a seasonal study basis in Algeciras Bay (Southern Spain) (SÁNCHEZ-MOYANO et al., 2007). In the present study, a total of 36 crustacean species were registered in *Caulerpa* meadows, showing a more diverse macrofaunal communities than other studies carried out in other *Caulerpa* species, such as, *C. racemosa* in the Eastern Mediterranean Sea (ARGYROU et al., 1999) and *C. taxifolia* at Mediterranean coast of France (BELLAN-SANTINI et al., 1996).

This contribution constitutes one of the first attempts on the macrofaunal community structure of the canarian soft-bottoms and thus, little is known about the ecology of the associated communities. Moreover, this paper groups the most important marine sandy seabeds of the Canary Islands (*Cymodocea nodosa* meadows, *Caulerpa* meadows, mixed communities, Mäerl bottoms, sandy bare sediments and sabellids fields).

In short, several general conclusions about community structure can be made. Species richness and diversity is higher in vegetated seabeds, especially in mixed community (*Cymodocea-Caulerpa*) and *Caulerpa* meadows, although intermediate values were found in *Cymodocea nodosa* meadows and sabellids field. Sandy bare sediments (non-vegetated) are characterized by low species richness and diversity, so habitat complexity determines infaunal community structure and increases the number of microhabitats that could be inhabited by different species. Moreover, a spatial trend can be discerned in the canarian archipelago, with highest abundances in eastern

islands (Lanzarote and Gran Canaria) and lowest densities in western islands (La Palma).

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