Effects of granulometric gradient on macrofaunal assemblages in Los Cristianos harbour (Tenerife, Canary Islands)

RODRIGO RIERA, ÓSCAR MONTERROSO & JORGE NÚÑEZ

Riera, R., Ó. Monterroso & J. Núñez (*in press*). Effects of granulometric gradient on macrofaunal assemblages in Los Cristianos harbour (Tenerife, Canary Islands). *Arquipelago*. Life and Marine Sciences 29: 33-41 .

Along the rapid increase of coastal tourism worldwide, evidence is accumulating on the numerous environmental coastal impacts that it causes on marine environments. One of the most important anthropogenic pressures is the construction of marinas or recreational harbours. Typically, most of the studies provide snapshots of the spatial distribution of macrobenthic communities inside and outside of the marina area. However, there is no much information about sedimentary dynamics inside the harbour and their effect on macroinfaunal In the innermost stations of Los Cristianos harbour a different macrofaunal community was present, dominated by the amphipods *Cheirocratus assimilis* and *Corophium acutum* and the polychaete *Nainereis laevigata*. Changes in macrofaunal assemblages could be used as early warnings in identifying environmental impacts before they cause major shifts in the marine environment.

Key words: Harbour, Macrofauna, soft-bottoms, Los Cristianos, Canary Islands, Atlantic

Rodrigo Riera (e-mail: rodrigo@cimacanarias.com) & Óscar Monterroso, Centro de Investigaciones Medioambientales del Atlántico (CIMA SL), C/Arzobispo Elías Yanes, 44, 38206 La Laguna, Tenerife, Canary Islands, Spain; Jorge Núñez, Laboratorio de Bentos, Departamento de Biología Animal, Facultad de Biología, Universidad de La Laguna, 38206 La Laguna, Tenerife, Canary Islands, Spain.

INTRODUCTION

In recent years, the increase of recreational uses of coastal areas has led to a greater demand for boat-mooring facilities. To meet this demand, the number of marinas or recreational harbours has rapidly increased and concerns about their environmental impacts are growing (e.g. Chapman et al. 1987; Guerra-García & García-Gómez, 2005; Callier et al. 2009)

Harbours are enclosed areas with low rates of water renewal, and characterized by high sedimentation rates, presence of persistent contaminants in water and sediments, such as, hydrocarbons and heavy metals, and low values of oxygen in the water column (Estacio et al. 1997). Moreover, the accumulation of contaminants (mainly heavy metals and hydrocarbons) is potentially high in marinas (McGee et al. 1995) and are likely to be contaminated by a mixture of organic and inorganic chemicals, such as, trace elements (Hall *et al*. 1992), tributyltin (Alzieu 2000), biocides encountered in antifouling paints (Thomas et al. 2002), polychlorinated biphenyls and chromated copper arsenate (Lenihan et al. 1990; Weis & Weis 1992).

Benthic fauna is particularly vulnerable to the former sources of contaminants, especially the infaunal species which are constantly in contact with sediment particles and interstitial water (Traunspurger & Drews 1996). Macrobenthic animals (> 0.5 mm length) have been traditionally used as bioindicators of environmental changes (Pearson & Rosenberg 1978).

An ecological assessment in Los Cristianos harbour, located inside Los Cristianos Bay, was conducted in order to characterize macrofaunal communities inside the dock and the implications of creating a new artificial beach inside the bay. The northern part of the bay present a very busy harbour with ferries and heavy maritime traffic, connecting Tenerife and other minor islands (La Gomera, La Palma and El Hierro), whale watching boats and yachts. The inner part of the bay is partially covered by a fine-sandy beach, named Los Cristianos beach. The southern part of the bay is occupied by natural rocky substrates and a very coarse sand beach. Los Cristianos harbour is characterized by the presence of a dense *Cymodocea nodosa* meadow, with a long leaf length (25-35 cm). In terms of exposure, Los Cristianos Bay is considered to be an enclosed bay protected from the dominant north-west winds, named "Alisios".

The main aims of the present study are (i) to study the macrobenthic assemblages of Los Cristianos Bay and (ii) the environmental consequences of the granulometric gradient due to the presence of Los Cristianos Harbour inside the bay.

MATERIAL AND METHODS

STUDY AREA

This study was conducted in Los Cristianos Bay, a locality on the south coast of Tenerife (Canary Islands, NE Atlantic Ocean) (Fig. 1). There is no previous information about macrofaunal assemblages of this bay, although seasonal variations of meiofauna have received attention in a recent study (Riera et al. in press).

The study site is located in a sheltered bay, with a recreational harbour in the northern half of the bay. Los Cristianos beach can be classified as ultradissipative (*sensu* Short, 1999), characterized by the presence of fine sands and a semidiurnal 2 m tide range.

Sediment samples were collected manually by SCUBA divers at a range of 5-15 m depth in January 2005 (Table 1). Sediment cores (20 cm inner diameter) were pushed into the sediment to a depth of 20 cm (surface = 0.04 m^2). All abundance data are refereed to the unit sampled area (0.04 m^2). Three replicates per station were collected for faunistic analysis and an adjacent sample was taken for sediment analysis (granulometry and organic matter content).

ANALYSIS OF MACROFAUNA

Samples were preserved in 10% seawater formaldehyde solution and decanted through a 0.5 mm mesh sieve. This sieve has been extensively used in the Canarian archipelago with good results (Riera et al. 2011, 2012). The fraction remaining on the mesh sieve was separated into different taxonomic groups under a binocular microscope and preserved in 70% ethanol. Macrofaunal specimens were determined to species level, whenever possible, by means of a binocular microscope and a LEICA DMLB microscope equipped with Nomarski interference contrast.

GRANULOMETRY AND ORGANIC MATTER

The granulometry of the sediment was obtained from subsamples of 100 g. Samples were dried at air temperature, sieved on a stack of graded sieves ranged from 0.063 mm and 2 mm mesh, and the residue on each sieve weighted (Buchanan & Kain, 1971). The percentage of organic matter was determined according to the method of Walkley (1947), adapted and modified by Jackson (1960).

STATISTICAL ANALYSES

Biological descriptors of the community (abundance, Shannon´s diversity and Pielou´s evenness) were calculated. Differences on univariate indices among stations were tested with non-parametric Kruskal-Wallis test. The affinities among communities based on species composition were established using a dendrogram and a MDS (non-metric multidimensional scaling). The Bray-Curtis similarity index was used to compare communities. The abundance data were square

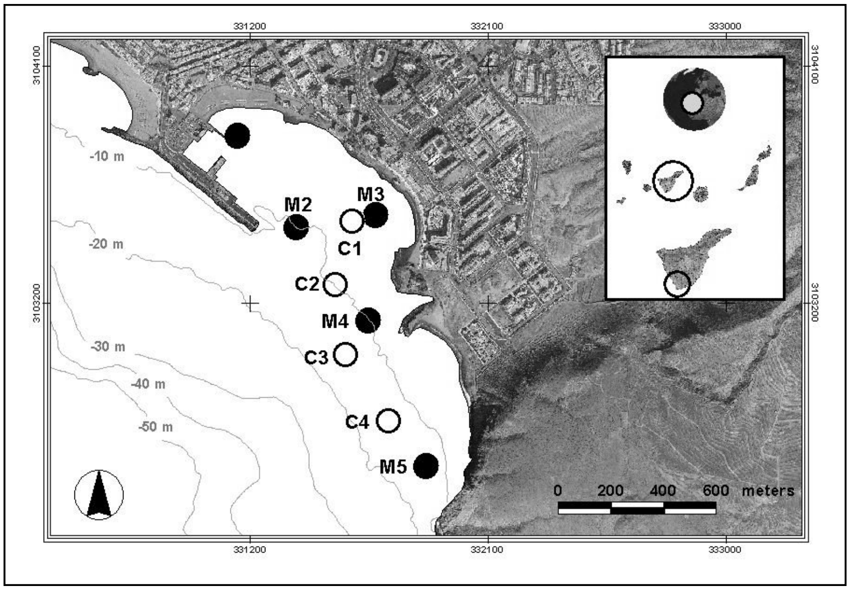

Fig. 1. Location of sampling sites; M, Sandy bare bottoms; C, *Cymodocea nodosa* meadows.

Table 1. List of sampling stations.

Stations	UTM coordinates	Depth (m)	Seabeds	% Silt/clay	% Fine sands
M1	28º04’59’’N, 16º71’78’’W	8	Sandy bottoms	38.74	39.62
M2	28º04’63’’N, 16º71’56’’W	8	Sandy bottoms	4.7	71.71
M3	28º04’65’’N, 16º71’25’’W	10	Sandy bottoms	3.37	69.98
M4	28º04’28’’N, 16º71’28’’W	10	Sandy bottoms	2.19	78.29
M5	28º03’79’’N, 16º71’05’’W	12	Sandy bottoms	6.98	80.66
C1	28º04’63’’N, 16º71’34’’W	5	Seagrass	2.37	63.27
C2	28º04’41’’N, 16º71’41’’W	5	Seagrass	3.9	74.95
C3	28º04’17’’N, 16º71’36’’W	8	Seagrass	4.39	78.37
C4	28º03’94’’N, 16º71’19’´W	8	Seagrass	6.32	72.24

root transformed because the data were not normally distributed. Non-parametric tests were preferred since they are free of assumptions about the distribution of the data or variance homogeneity (Lehmann 1975).

Dominance curves represented the rate of abundance of the dominance species in the whole macrofauna community structure. The ANOSIM routine (Clarke 1993) was used to analyse differences between stations and soft-bottom communities, to identify the macrobenthic species responsible for the observed trends indicated by the SIMPER routine. Multivariate analyses were carried out using the PRIMER 5.2. Package (Plymouth Routines In Multivariate Ecological Analysis) (Clarke & Warwick 1994).

Spearman correlation analyses were used to examine relationships between macrofaunal data and sedimentary analyses (organic matter and granulometry).

RESULTS

A total of 1.101 specimens were collected during the study; the tanaid *Apseudes talpa* was the most abundant species with 141 specimens (13% of the overall abundance). The second and the third species were the amphipod *Ampelisca brevicornis* and the polychaete *Aponuphis bilineata* with 122 and 117 individuals, respectively (Table 2; Anex).

In terms of species richness, 72 taxa were collected, belonging to 14 taxonomic groups. The most abundant groups were polychaetes with 365 specimens (33.2% of overall abundance), followed by amphipods and tanaids with 290 (26.3%) and 198 (18%) individuals, respectively.

The abundance was low in all sampling stations (< 50 individuals/unit area (0.04 m^2)), with the exception of station M1 with a mean of 125 specimens/unit area (Fig. 2). The species richness presented low variations, except the station M1 with the maximum value (20 taxa), with an overall mean of 10 species (Fig. 3). Shannon´s diversity (H´) varied between 1.60 in station M5 and 2.69 in station M1; no significant differences were found among sampling stations (Kruskal-Wallis test, H = 14.82, p = 0.063) (Fig. 4).

Table 2. List of collected species. Abundances, species richness, Shannon´s diversity (H´) and Pielou´s evenness (J´) of the sampling stations.

GROUP	**SPECIES**	**C1**	**C2**	**C3**	**C4**	**M1**	**M2**	**M3**	**M4**	**M5**
Amphipoda	*Ampelisca brevicornis*	15	4	3	0	3	3	8	42	44
Amphipoda	*Amphilochus neapolitanus*	0	0	0	0	1	0	0	0	0
Amphipoda	*Bathyporeia* sp.	3	0	0	0	0	0	0	0	0
Amphipoda	*Cheirocratus assimilis*	0	0	0	0	50	0	0	0	0
Amphipoda	*Corophium acutum*	0	0	0	0	81	0	0	0	0
Amphipoda	*Dexamine spinosa*	0	0	3	0	0	0	0	0	0
Amphipoda	*Elasmopus rapax*	0	0	0	0	1	0	0	0	0
Amphipoda	*Erichthonius brasiliensis*	0	0	4	0	1	0	0	0	0
Amphipoda	*Harpinia antennaria*	0	0	2	0	0	0	0	0	0
Amphipoda	*Phtisica marina*	0	0	5	2	0	0	0	0	0
Amphipoda	*Pontocrates arenarius*	0	0	0	0	0	0	4	0	0
Amphipoda	*Urothoe marina*	12	0	0	0	0	0	0	1	0
Bivalvia	*Abra alba*	0	0	0	0	7	0	0	0	0
Bivalvia	*Lucinella divaricata*	0	0	1	0	1	0	0	0	0
Bivalvia	*Mactra glabrata*	1	0	0	0	0	0	0	0	0
Bivalvia	*Parvicardium scriptum*	0	1	1	0	0	0	0	0	0
Bivalvia	*Solemya togata*	0	1	5	7	4	0	0	0	0
Cumacea	*Bodotria arenosa*	0	0	0	0	0	0	1	0	0
Cumacea	*Iphinoe canariensis*	1	0	0	0	3	0	1	6	2
Decapoda	*Palinus caronii*	0	0	1	0	0	0	0	0	0
Decapoda	*Philocheras bispinosus*	0	0	1	0	0	0	0	0	0
Decapoda	*Pisa nodipes*	0	0	0	2	0	0	0	0	0
Decapoda	*Polynices lacteus*	0	0	2	1	0	0	0	0	0
Decapoda	*Upogebia pusilla*	0	0	0	0	1	0	0	0	0
Echinodermata	*Brissus unicolor*	0	0	0	0	0	0	0	0	0
Gastropoda	*Atys macandrewi*	0	0	0	0	1	0	0	0	0
Gastropoda	*Bela ornata*	0	0	0	0	0	0	1	0	3
Gastropoda	*Bittium latreillii*	0	3	2	6	4	0	2	12	1
Gastropoda	*Haminoea hydatis*	0	0	0	0	1	0	0	0	0
Gastropoda	*Hastula lepida*	0	0	0	0	0	0	1	1	1
Gastropoda	*Jujubinus exasperatus*	2	1	0	0	0	1	0	0	0
Gastropoda	*Monophorus thiriotae*	0	0	0	0	0	0	0	0	1
Gastropoda	*Nassarius cuvierii*	0	1	4	4	6	3	0	1	1
Gastropoda	*Natica dillwynii*	0	0	0	3	0	0	0	0	0
Gastropoda	*Smaragdia viridis*	0	0	1	3	0	0	0	0	0
Gastropoda	*Tricolia pullus canarica*	0	1	0	0	0	2	0	0	0

Table 2. (continuation)

GROUP	SPECIES	C1	C2	C3	C4	M1	M2	M3	M4	M5
Isopoda	*Anthura gracilis*	0	0	0	1	0	0	0	0	0
Isopoda	*Cymodoce truncata*	0	0	0	1	0	0	0	0	0
Isopoda	*Eurydice pulchra*	1	0	0	0	0	0	0	3	0
Misidacea	*Gastrosaccus sanctus*	7	0	0	0	0	0	5	0	0
Nematoda	*Synonchus fasciculatus*	1	1	0	0	7	0	0	0	0
Nemertea	*Nemertino* sp.1	1	0	0	0	2	3	0	0	0
Nemertea	*Nemertino* sp.2	1	0	0	0	0	0	0	0	0
Oligochaeta	*Grania* sp. 1	0	1	0	0	1	0	0	0	0
Oligochaeta	*Tubificidae* sp.1	0	1	2	0	7	0	0	0	0
Ostracoda	*Cypridina mediterranea*	1	19	20	2	25	0	1	7	0
Polychaeta	*Aponuphis bilineata*	9	20	15	39	7	14	0	9	4
Polychaeta	*Armandia polyophthalma*	1	1	0	0	0	0	0	0	0
Polychaeta	*Cauleriella bioculata*	0	2	0	0	8	0	0	0	0
Polychaeta	*Chone collaris*	0	1	0	0	0	0	0	0	0
Polychaeta	*Chone filicaudata*	0	0	0	0	0	11	0	0	0
Polychaeta	*Cirrophorus armatus*	2	2	0	0	9	5	0	0	1
Polychaeta	*Dispio uncinata*	0	0	0	0	0	1	3	0	0
Polychaeta	*Euclymene oerstedii*	0	0	0	0	1	0	0	0	0
Polychaeta	*Lumbrineris cingulata*	0	0	0	0	23	0	0	0	0
Polychaeta	*Megalomma vesiculosum*	0	0	0	0	0	1	0	0	0
Polychaeta	*Nainereis laevigata*	0	0	1	0	25	0	0	0	0
Polychaeta	*Nephthys cirrosa*	3	1	0	3	13	0	1	2	0
Polychaeta	*Onuphis eremita*	0	0	0	1	0	9	0	4	1
Polychaeta	*Platynereis dumerilii*	1	2	4	2	2	0	0	0	0
Polychaeta	*Poecilochaetous serpens*	0	0	0	0	0	2	0	0	0
Polychaeta	*Prionosprio steenstrupi*	2	1	0	0	2	11	15	1	4
Polychaeta	*Psammolyce arenosa*	0	0	1	0	0	0	0	0	0
Polychaeta	*Pseudomystides limbata*	0	0	0	1	0	0	0	0	0
Polychaeta	*Schistomeringos albomaculata*	0	0	1	0	0	0	0	0	0
Polychaeta	*Scoloplos armiger*	3	2	0	0	8	1	17	1	3
Polychaeta	*Sigalion squamatum*	2	0	1	0	0	5	2	6	1
Polychaeta	*Spio filicornis*	0	0	0	0	0	0	1	0	0
Polychaeta	*Syllis prolifera*	0	0	0	0	6	0	0	0	0
Polychaeta	*Trichobranchus glacialis*	0	0	0	0	0	0	0	1	0
Tanaidacea	*Apseudes talpa*	4	48	46	22	6	9	0	0	6
Tanaidacea	*Leptochelia dubia*	0	1	0	0	55	1	0	0	0
	Abundance	73	115	126	100	372	82	63	97	73
	Species richness	21	22	23	17	33	17	15	15	14
	Shannon Diversity (H´)	2.58	2	2.28	2.04	2.69	2.48	2.16	1.98	1.6
	Pielou Evenness (J´)	0.85	0.65	0.73	0.72	0.77	0.88	0.8	0.73	0.61

HABITAT (MEADOWS VS. BARE BOTTOMS)

Sampling stations were divided into two groups depending on the bottom type: *Cymodocea nodosa* meadows (stations C1, C2, C3, C4M) and Sandy bare bottoms (stat. M1, M2, M3, M4, M5). A high homogeneity was found among stations of the same habitat, especially in *Cymodocea nodosa* meadows. Significant differences were found in macrofaunal community structure between *Cymodocea nodosa* meadows and sandy bare bottoms (one-way ANOSIM, R = 0.276; p = 0.2%). The tanaid *Apseudes talpa* and the polychaete *Aponuphis bilineata* were the most abundant species in *Cymodocea nodosa* meadows whilst sandy bare bottoms were populated by the amphipod *Ampelisca brevicornis* and the polychaetes *Scoloplos armiger* and *Prionospio steenstrupii*.

The abundance of individuals was not significantly different between the two habitats (Mann-Whitney test; U = 81.50, p = 0,678), being slightly higher in sandy bottoms with a mean of 45.8 specimens/unit area compared to *Cymodocea nodosa* meadows (34.5 individuals/unit area) (Fig. 2).

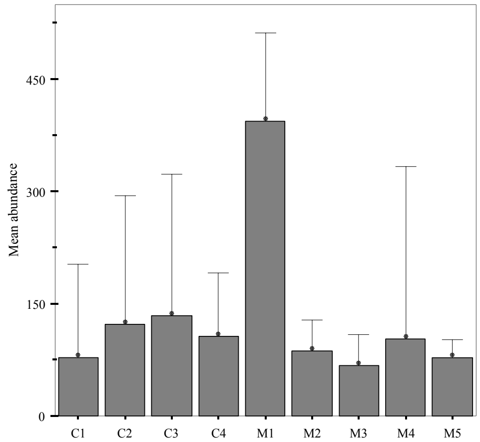

Fig. 2. Macrofaunal abundance ± standard errors of sampling stations (C, *Cymodocea nodosa* meadows, M, sandy bare bottoms). Abundances refere to unit area (0.04 m^2).

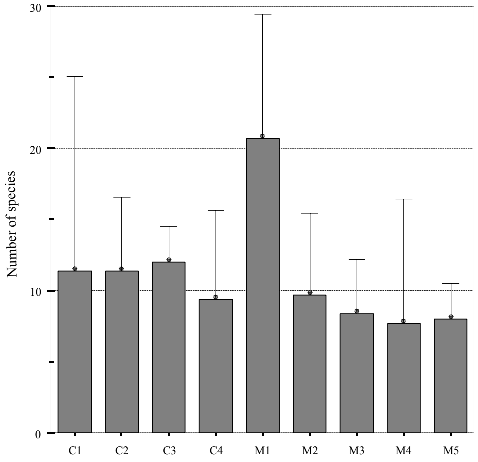

Fig. 3. Macrofaunal species richness ± standard errors of sampling stations (C, *Cymodocea nodosa* meadows, M, sandy bare bottoms). Species richness are refereed to unit area (0.04 m^2).

In terms of species richness, no significant differences were found between the two habitats (Mann-Whitney test, U = 67; p = 0.259), with a mean of 10.87 species in sandy bottoms and 11 species in *Cymodocea nodosa* meadows.

No significant differences were found in Shannon´s diversity (H´) between meadows and bare bottoms (Mann-Whitney test, U = 79, p = 0.591), with a mean of 1.91 in sandy bare bottoms and 1.85 in *Cymodocea nodosa* meadows.

Sampling stations were divided into two groups at 28.7% of similarity (Fig. 5). The first group consisted of the stations C2, C3, C4 y M1, and was characterized by high abundances of the ostracod *Cypridina mediterranea*, the polychaete *Aponuphis bilineata* and the tanaid *Apseudes talpa*. The station M1 was separated from this group at a 35% of similarity, due to high abundances and diversity (H´). The second group was formed by the remaining stations (C1, M2, M3, M4, M5) and was characterized by the presence of the polychaetes *Scoloplos armiger* and *Prionosprio steenstrupii*.

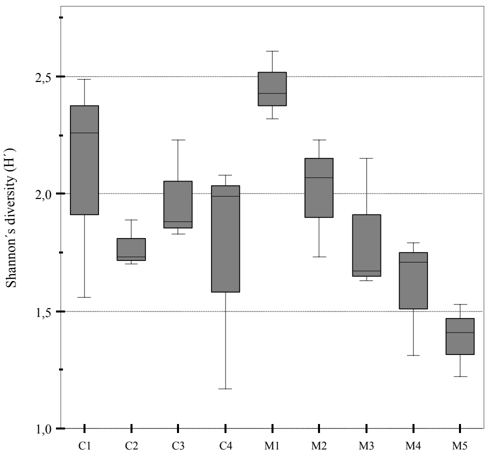

Fig. 4. Shannon´s diversity (H´) ± standard errors of sampling stations (C, *Cymodocea nodosa* meadows, M, sandy bare bottoms). Shannon´s diversity refers to unit area (0.04 m^2).

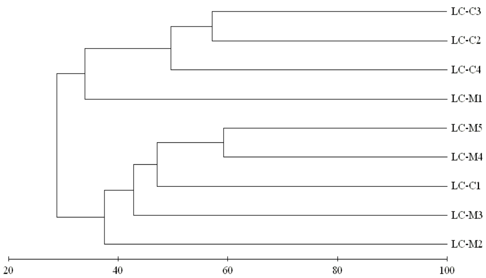

Fig. 5. Dendrogram of similarity of sampling stations and Bidimensional ordination (MDS) of sampling stations (stress = 0.02). LC, Los Cristianos; C, *Cymododea nodosa* meadows, M, sandy bare bottoms.

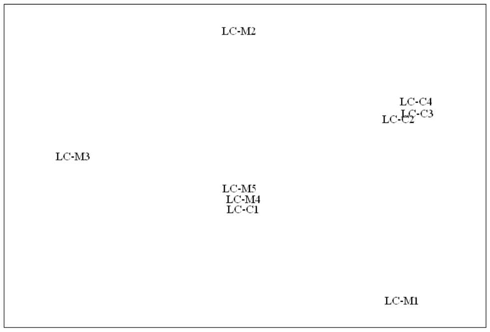

Fig. 6. Dendrogram of similarity of sampling stations and Bidimensional ordination (MDS) of sampling stations (stress = 0.02). LC, Los Cristianos; C, *Cymododea nodosa* meadows, M, sandy bare bottoms.

In the MDS (Fig. 6) sampling stations are separated into five groups, three of them consisted of only one station (M1, M2 and M3), belonging to sandy bottoms with a heterogeneous community structure. The remaining stations are separated in two distinct groups, the first (C2, C3 and C4), characterised by the dominance of the tanaid *Apseudes talpa* and high densities of the polychaete *Aponuphis bilineata*. The second group formed by stations C1, M4 and M5 is dominated by the amphipod *Ampelisca brevicornis*.

The station M5 is dominated by the amphipod *Ampelisca brevicornis* (60% of the overall abundance). At the level of 40% of dominance, four stations are found (C2, C3, C4 and M3), dominated by the tanaid *Apseudes talpa* (C2 and C3), the polychaete *Aponuphis bilineata* (C4) and the amphipod *A. brevicornis* (M4). The polychaetes *Scoloplos armiger* and *Prionospio steenstrupi* represented 50% of the overall abundance in station M3. The most abundant species in stations (C1, M1 and M2) represented 20% of the total abundance (*A. brevicornis* in station C1, the amphipod *Corophium acutum* in M1 and *A. bilineata* in station M2) (Fig. 7).

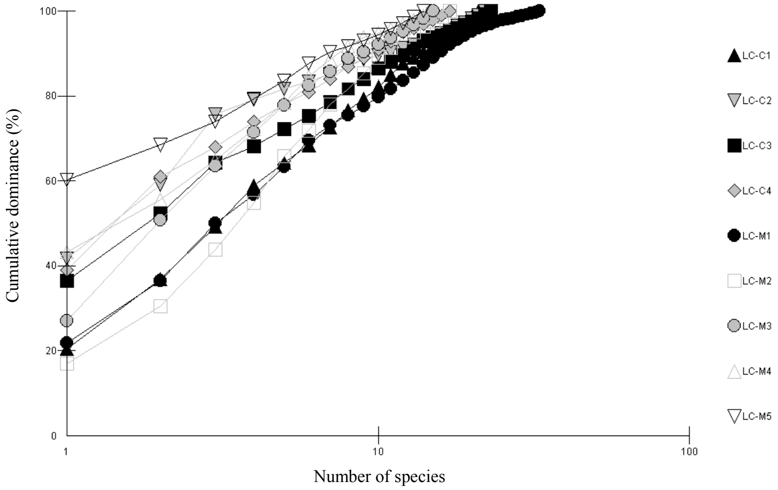

Fig. 7. Dominance curves of sampling stations.

The percentage of very fine sands and silt/clay were the abiotic factor that best explained the macrofaunal community structure in Los Cristianos. One of the main reasons is the presence of maximum values of diversity and abundance in station M1, characterized by a high content of silt/clay. The remaining stations were represented by the sedimentary fraction of fine sands. Other important abiotic factors were fine sands, gravels and organic matter, more heterogeneous in sandy bare bottoms (0.05-1.3%) compared to seagrass meadows stations (0.5-0.6%) (Table 3).

The tanaid *Apseudes talpa* was negatively correlated with fine sands, being the most abundant species in stations characterized by coarser sediments. To the contrary, the amphipod *Corophium acutum* was negatively correlated with fine sands, but positively correlated with very fine sands and silt/clay content, reaching highest densities in these sediments (Table 4).

Table 3. Correlation table of abiotic factors.

Variables	**Correl.(ρ)**
Very fine sands, Silt/Clay	0,285
Fine sands, Very fine sands	0,27
Gravels, Fine sands, Very fine sands	0,261
Gravels, Very fine sands, Silt/Clay	0,254
Organic matter, Fine sands, Very fine sands	0,244

Table 4. Correlations between abiotic variables and the most abundant species (p < 0,01**).

	Apseudes talpa	***Corophium acutum***
Fine sands	-0,573**	-0,547**
Very fine sands		0.547**
Silt/Clay		0.547**

DISCUSSION

The effects of sediment accumulation have been studied in different habitats (e.g. algal turfs in rocky bottoms (Phrathep et al. 2003), coral reefs (Richmond 1993), mangroves (Ellison 1998), seagrasses (Vermaat et al. 1997), freshwater systems (Henley et al. 2000) and estuaries (Ryan 1991). Special emphasis has been placed in the effects of sedimentation in commercial harbours since the process of sedimentation reduces the navigational or approach channel depth of a harbour, or tends as secondary effect to shift channel locations. Several authors have estimated the sedimentation rate (3-5 mm/year) in commercial harbours (Dominik et al. 1991), because of the importance of this problem in high costs of maintenance dredging. Goff et al. (1998) observed in Wellington harbour (New Zealand) seasonal patterns of sediment accumulation (low rates in summer and high rates in winter), although they found individual peaks related to flood events that occurred along the study period. Harbours usually show high organic matter inputs due to the increasing sedimentation caused by port structures (McCready et al. 2006), although no differences were found between inner and outer stations of Los Cristianos harbour.

Unfortunately, the sedimentation rate is unknown in Los Cristianos harbour, however, the increase of sedimentation level is clearly discerned during the last ten years (beach width 80 m), with a significant rise (> 3 m) (R. Riera *pers. obs.*).

Los Cristianos Bay harboured a diverse macrofaunathat sometimes reach high abundances (> 1000 ind/m^2). This bay is characterized by a high sedimentary stability, with a clear dominance of fine sands and low organic matter content, especially in *Cymodocea nodosa* meadows. The most abundant species were the tanaid *Apseudes talpa*, the amphipod *Ampelisca brevicornis* and the polychaete *Aponuphis bilineata*. The autoecology of the former species are different, with no interference among their habitats *Apseudes talpa* is a digger species that inhabits the upper 1-2 cm of the sediment. The amphipod *Ampelisca brevicornis* is a superficial detritivorous that inhabits the first millimeters of the sediment and the infaunal polychaete *Aponuphis bilineata* builds sandy tubes (Desroy & Retière 2001).

The presence of very fine sands and silt and clay was observed in inner stations of Los Cristianos harbour. These stations are characterized by a more diverse and abundant macrofauna, due to the presence of the amphipods *Cheirocratus assimilis* and *Corophium acutum* and the polychaete *Nainereis laevigata*, very abundant species in muddy-sand bottoms in other geographical regions. The former species are commonly found in constantly disturbed environments such as harbours probably well accustomed to turbulence caused by the transit of big boats and ferries (> 30m long).

The species *Cheirocratus sundevalli* has been collected in superficial layers of the sediment (0-5 cm) inside commercial harbours, with high levels of organic matter (> 5%) and total phosphorus (> 500 ppm) (Guerra-García et al. 2003). Several species of the genus *Corophium* (*C. runcicorne* and *C. sextonae*) have been found in deeper levels of the sediment (> 10 cm) since they build U-shaped galleries that allow them to escape from the top layers of the seabed (Guerra-García et al. 2003). The polychaete orbiniid *Nainereis laevigata*, has been recorded in muddy bottoms, as well as, fluctuating environments (Giangrande & Fraschetti 1995).

In short, the macrobenthos in Los Cristianos Harbour is characterized by two differentiated assemblages, one of which occupies seagrass meadows and medium-sand seabeds (outer stations) and the second one is associated with finer sediments, such as, silt and clay and very fine sands (inner stations). However, a multidisciplinary study is necessary to evaluate precisely the environmental effects of sedimentation inside Los Cristianos harbour.

ACKNOWLEDGEMENTS

This work was financed by Arona town council. We wish to thank Jesus Falcón and Gustavo González for their help during the sampling campaign, and a special mention to Prof. Alberto Brito (Dept. of Animal Biology of the University of La Laguna) for his encouragement and kind interest. To Dr. Óscar Pérez (CIMA SL) for map preparation.

REFERENCES

Alzieu, C. 2000. Impact of tributyltin on marine invertebrates. *Ecotoxicology* 9: 71-76.

Buchanan, J.B. 1984. Sediment analysis. Pp 41-65 in: Holme NA, McIntyre, AD (Eds). *Methods for the study of marine benthos*. Blackwell, Oxford, 241 pp.

Callier, M., R.L. Fletcher, C.H. Thorp & D. Fichet 2009. Macrofaunal community responses to marina-related pollution on the south coast of England and west coast of France. *Journal of the Marine Biological Association of the United Kingdom* 89(1): 19-29.

Chapman, P.M., R.N. Dexter & E.R. Long 1987. Synoptic measures of sediment contamination, toxicity and infaunal community composition (the Sediment Quality Triad) in San Francisco Bay. *Marine Ecology Progress Series* 37: 75-96.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117-143.

Clarke, K.R. & R.M. Warwick. 2001. Change in marine communities: an approach to statistical analyses and interpretation. 2nd edition, PRIMER-E, Plymouth. 91 pp.

Desroy, N. & C. Retière 2001. Long-term changes in muddy fine sand community of the Rance Basin: role of recruitment. *Journal of the Marine Biological Association of the United Kingdom* 81: 553-564.

Dominik, J., J.L. Loizeau, P.Y. Favarger, J.P. Vernet & R.L, Thomas 1991. History of mercury contamination reconstructed from high-resolution radio-isotopic dating of sediment cores in lake Geneva. Pp. 133-143 in: J. P. Vernet (Ed.) *Heavy Metals in the Environment* Elsevier. Amsterdam. 273 pp.

Ellison, J.C. 1998. Impacts of sediment burial on mangroves. *Marine Pollution Bulletin* 37: 420-426.

Estacio, F.J., E.M. García-Adiego, D.A. Fa, J.C. García-Gómez, J.L. Daza, F. Hortas & J.L. Gómez-Ariza 1997. Ecological studies in a polluted area of Algeciras Bay (Southern Spain): External versus Internal outfalls and environmental applications. *Marine Pollution Bulletin* 34(10): 780-793.

Giangrande A. & S. Fraschetti 1995. A population study of *Naineris laevigata* (Polychaeta, Orbiniidae) in a fluctuating environment (Mediterranean Sea). *Scientia Marina* 59(1): 39-48.

Goff, J.R., G.B. Dunbar & J.P. Barrett 1998. Monthly and decadal sediment accumulation rates in a semi-enclosed embayment. *Journal of Coastal Research* 14(2): 461-471.

Guerra-García, J.M., J.R. Corzo & J.C. García-Gómez 2003. Distribución vertical de la macrofauna en sedimentos contaminados del interior del puerto de Ceuta. *Boletín del Instituto Español de Oceanografía* 19(1-4): 105-121.

Guerra-García, J.M. & J.C. García-Gómez 2005. Oxygen levels versus chemical pollutants: do they have similar influence on macrofaunal assemblages? A case study in a harbour with two opposing entrances. *Environmental Pollution* 135: 281-291.

Hall, L.W., M.A. Unger, M.C. Ziegenfuss, J.A. Sullivan & S.J. Nushong 1992. Butyltin and copper monitoring in a north Cheasepeake Bay marina and river system in 1989: an assessment of tritutyltin legislation. *Environmental Monitoring and Assessment* 22: 15-38.

Henley, W.F., M.A. Patterson, R.J. Neves & A.D. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs: a concise review for natural resource managers. *Reviews in Fisheries Science* 8: 125-139.

Jackson, M.L. 1960. *Soil chemical analysis*. Prentice Hall, New York, 498 pp.

Lehmann, E.L. 1975. *Nonparametrics: Statistical Methods Based on Ranks*. Holden Day, San Francisco, CA, 463 pp.

Lenihan, H.S., J.S. Oliver & M.A. Stephenson 1990. Changes in hard bottom communities related to boat mooring and tributyltin in San Diego Bay: a natural experiment. *Marine Ecology Progress Series* 60: 147-159.

McCready, S., G.R. Birch & E.R. Long. 2006. Metallic and organic contaminants in sediments of Sydney Harbour, Australia and vicinity-A chemical dataset for evaluating sediment quality guidelines. *Environmental International* 32: 455-465.

McGee, B.L., C.E. Schlekat, D.M. Boward & T.L. Wade 1995. Sediment contamination and biological effects in a Chesapeake Bay marina. *Ecotoxicology* 4: 39-59.

Pearson, T.H., R. Rosenberg 1978. Macrobenthic succesion in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology: an Annual Review* 16: 229-311.

Prathep, A., R. Marrs & T. Norton 2003. Spatial and temporal variations in sediment accumulation in an algal turf and their impact on associated fauna. *Marine Biology* 142 (2): 381-390.

Richmond, R.H. 1993. Coral reefs: present problems and future concerns resulting from anthropogenic disturbances. *American Zoologist* 33: 524-536.

Riera, R., J. Núñez & M.C. Brito (in press) Effects of a freshwater runoff on an intertidal meiofaunal assemblage in Tenerife, Canary Islands (NE Atlantic Ocean). Vie et Milieu.

Riera, R., O. Monterroso, M. Rodríguez & E. Ramos. 2011. Biotic indexes reveal the impact of harbour enlargement on benthic fauna. *Chemistry and Ecology* 27: 311-326.

Riera, R., J.D. Deldado, M. Rodríguez, O. Monterroso & E. Ramos. 2012. Macrofaunal communities of threatened subtidal maërl seabeds on Tenerife (Canary Islands, north-east Atlantic Ocean) in summer. *Acta Oceanologica Sinica* 31: 98-105.

Ryan, P.A. 1991. Environmental effects of sediment on New Zealand streams: a review. *New Zealand Journal of Marine and Freshwater Research* 25: 207-221.

Short, A.D. 1999. *Handbook of Beach and Shoreface. Morphodynamics*. Wiley (Ed.). 379 pp.

Thomas, K.V., M. McHugh & M. Waldock 2002. Antifouling paint booster biocides in UK coastal waters: inputs, occurrence and environmental fate. *Science of the Total Environment* 293: 117-127.

Traunspurger, W., & C. Drews 1996. Toxicity analysis of freshwater and marine sediments with meio- and macrobenthic organisms: a review. *Hydrobiologia* 328: 215-261.

Vermaat, J.E., N.S.R. Agawin, M.D. Fortes, J.S. Uri, C.M. Duarte, N. Marba, S. Enriqueza & W. van Vierssen. 1997. The capacity of seagrasses to survive increased turbidity and siltation: the significance of growth form and light use. *Ambio* 26: 499-504.

Walkey, A. 1947. A critical examination of a rapid method for determining organic carbon in soil. *Soil Science* 63:251–263

Weis, J.S. & P. Weis 1992. Construction materials in estuaries: reduction in epibiotic community on chromated copper arsenate (CCA) treated wood. *Marine Ecology Progress Series* 83: 45-53.

Received 27 Oct 2011. Accepted 26 Apr 2012,