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Seasonal patterns of the macrozoobenthic community structure according to environmental conditions in a western Mediterranean lagoon close to the Gibraltar Strait

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- ✓ Structuring factors

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Abstract

The seasonal variability of the macrozoobenthic community was investigated in a North African lagoon (the Smir lagoon) of the Mediterranean. The total abundance and species number showed a seasonal pattern, with higher values in winter and lower ones in summer. The variability in physico-chemical (salinity, temperature, dissolved oxygen and pH) and biological (seaweed-seagrass cover) factors provided diverse habitats, and species-specific habitat association of organisms in response to environmental variability. The community structure had two major season groups related to the species composition and was mainly due to the abundance of *Cyathura carinata* and *Melita palmata*. The first discrimination group represented the summer community was explained by the high water temperature and salinity values and by the strong reduction of the vegetation cover, whereas the second one characterized the spring, autumn and winter community. Sediment was not considered as a temporal structuring factor of the macrofauna community due to lower sediment inputs into the lagoon and the absence of any significant changes in sediment habitats. The significant correlations between water variables and the benthic structure, particularly in summer, support that salinity and temperature should be considered among factors structuring the temporal pattern of composition and abundance of the community. In the outermost part of the lagoon connected with the Mediterranean Sea, pH, dissolved oxygen, macrophyte beds and hydrodynamics could be considered as contributing parameters of the seasonal community structure of this lagoon area. Thus seasonal dynamics of the faunal assemblages seemed to be also driven by biotic effects as recruitment trends, food availability and inter-specific competition.

1. Introduction

Coastal lagoons are transitional environments between riverine-terrestrial and marine ecosystems, and are commonly found along the Atlantic and Mediterranean coasts of North African countries. They play a key role as spawning grounds for fish and shellfish and are extensively exploited for aquaculture. They are considered as important centers for economic, social and cultural development and were early sites for human settlement [1,2]. Coastal lagoons are originally productive ecosystems characterized by extensive macrophyte (algae and seagrasses) meadows and are often rich in nutrients (high levels of primary production) [3]. This results from the inorganic and organic nutrient inputs from continental waters, and from the recycling processes between sediment and water [4].

Lagoons are highly dynamic environments controlled by physical processes, subjected to marine and continental influences [5]. These shallow coastal systems are often characterized by unpredictable hydrological, geomorphological and chemical conditions [6-8], which widely vary on a seasonal or even on a daily basis, and cause changes in the structure and the distribution patterns of inhabiting organisms [9-11]. In this sense coastal lagoons can be considered as harsh and naturally stressed habitats [5,12]. However, the specific set of factors structuring each lagoon and their scattered distribution make each system very unique [5]. Furthermore, lagoons are highly valuable habitats not only on account of their aesthetic features and of the varied and typical species they support, but also because since long time there is an expanding recognition of their economic value [13].

Lagoon community structure generally reflects the physical, geochemical and hydrodynamical features of the environment, and species' distribution appears to be largely consistent with the degree of marine influence on lagoon ecosystems [14]. From an ecological view point, the macrobenthic fauna is an important component in lagoon systems. In fact it plays a vital role in burial and dispersion [15] and in ecosystem processes such as nutrient cycling, detrital decomposition, pollutant metabolism, secondary production and food webs.

Understanding spatial and temporal distribution and abundance has become a fundamental part of ecological research on benthic communities [16]. Environmental variability is believed to play a major role in the change of structure expressed by variation in species richness, abundance, and biomass [17]. The relationship between temporal and spatial variability of environmental variables and biological patterns and processes in macrobenthic assemblages are still poorly understood [17]. The quantitative description of the distribution patterns across different spatial and/or temporal scales allows the understanding of processes that structure macrobenthic assemblages [18]. This approach is suitable to predict environmental changes due to anthropogenic impacts [19]. This is especially true for lagoon ecosystems which are characterized by a high degree of variability, are habitats of conservation importance and which support communities unique in structure and diversity [13]. Investigating the structure, functioning and dynamics of lagoonal macrozoobenthic communities seems to be a useful tool for the development of an integrated economic, social, and environmental management policy consistent with the conservation of these ecosystems [9].

The temporal variability of macro-invertebrates in lagoon systems and the influence of environmental factors in such variability are scarcely investigated in the southwestern Mediterranean region. The interest of this study is to improve our understanding especially on the seasonal dynamics of macrobenthic communities in southwestern Mediterranean coastal brackish habitats so as to establish baseline data and also to increase our knowledge on the biodiversity of the most northwestern part of continental Africa. With this aim, our study was undertaken at the Smir lagoon, which is located on the western Moroccan Mediterranean coast and is characterized by a high diversity of habitats within a complex of natural and artificial wetlands (marshes, merjas, drainage channels, beach, wadi, channels, dam, etc) [20]. Because of its geographical position on the northwestern coast of Morocco close to the Gibraltar strait, the Smir lagoon undergoes the influence of both the Mediterranean Sea and the Atlantic Ocean [21,22] generating particular environmental conditions which make the lagoon an interesting study case.

The main goal of this research was to conduct a short-term study where seasonal trends could be evaluated and to obtain a better understanding of the macrobenthic structure and functioning of the Smir lagoon just before the heavy interventions of landfill and urbanization undertaken there. The specific objectives were to measure environmental parameters (physico-chemical variables and sediment characteristics) and to determine their spatial/temporal trends; to describe the distribution patterns of the macrobenthic fauna and of the seasonal variability in the community structure, and finally, to analyze possible relationships between macroinfaunal and environmental variables in order to pinpoint key variables structuring seasonal community patterns.

2. Material and methods

2.1. *Study area*

The lagoon of Smir is a microtidal coastal brackish shallow soft-bottom system located in the northwest of Morocco approximately 25 km to the south of Gibraltar strait and at about 15 km to the north of the city of Tetouan (Figure 1). It represents the most western lagoon along the Mediterranean coast with a geographical position of 35°43' N and 5°20' W. The typical Mediterranean climate ("Csa" climate type according to the Köppen-Geiger climate classification) with hot and dry summers, and mild wet winters prevail in this area. The mean annual rainfall exceeds 600 mm (distributed between October and April) with an annual mean temperature lower than 16°C.

The Smir lagoon occupies an area of about 3 km² and permanently receives seawater via the lagoon mouth during high tides. Its salinity fluctuates from nearly 18 to 40 on seasonal basis, in relation to the tidal movement and/or river discharge [23] and reaches a maximal depth of 2 m (especially in the lagoon channel) with an average of 0.5 m. The tide is semi-diurnal with an average tidal range of 0.5 m for neap tides and of 1.2 m for spring tides. Freshwater inflows are scarce [20] and are mainly assured by the Oued Smir River (Figure 1). Bottom sediments mainly consist of a soft muddy substrate and the few sandy areas are mainly concentrated as a sandbank close to the lagoon's entrance. Extensive meadows of seaweeds (e.g. Gracillaria verrucosa (Hudson) Papenfuss, 1950; *Enteromorpha linza* (Linnaeus) J.Agardh, 1883; *Ulva lactuca* Linnaeus, 1753; *Ulva rigida* C.Agardh, 1823; *Potamogeton pectinatus* L. (accepted name *Stuckenia pectinata* (L.) Börner, 1912)), and seagrasses (*Nanozostera noltii* (Hornemann) Tomlinson & Posluszny (accepted name *Zostera noltei* Hornemann, 1832) and *Ruppia cirrhosa* (Petagna) Grande, 1918) [24] cover almost completely the bottom of the area close to the entrance.

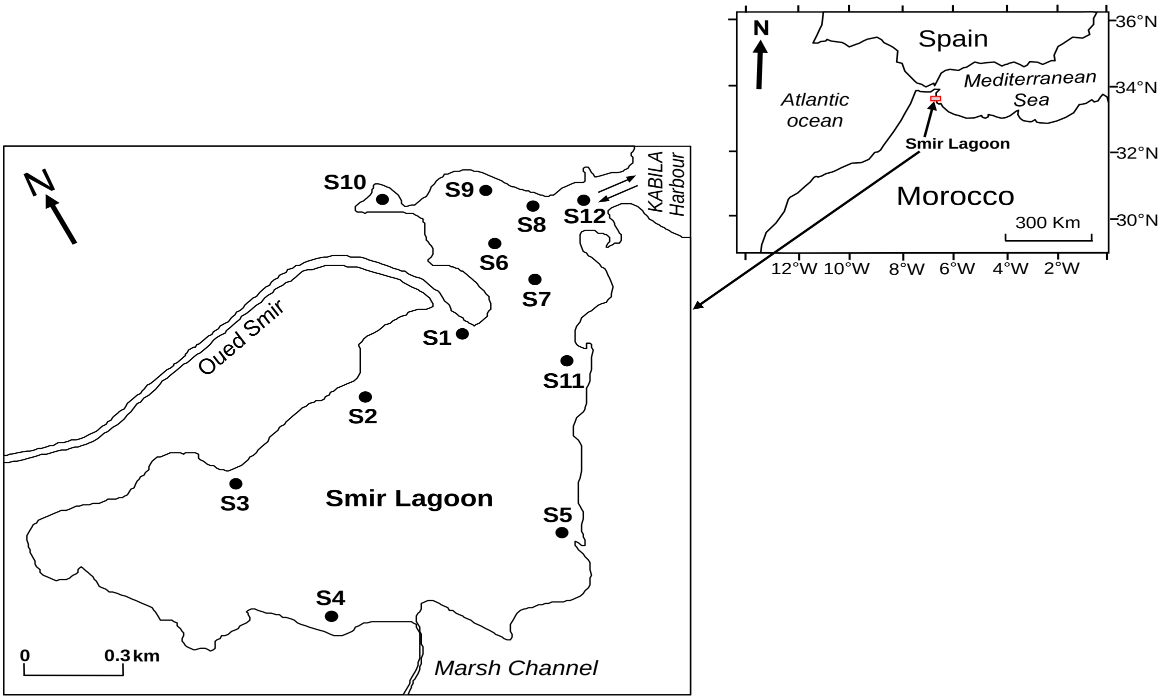

Figure 1: Geographical position of the Smir lagoon and location of the sampling stations.

2.2. *Sampling procedure and laboratory analyses*

Seasonal sampling in January (winter), March (spring), July (summer) and November (autumn) 2007 was carried out at twelve intertidal stations (Figure 1). Each time and at each sampling station, four random sampling units for the macrofauna were collected with a corer covering a surface of 625 cm^2 (0.25 m^2 as total surface) and penetrating to a depth of 30 cm. Samples were immediately sieved through a 1 mm^2 mesh size and fixed in 8% buffered formalin-seawater solution. All macro-invertebrates were identified to the lowest possible taxonomic level (usually species level) and counted.

Sediment samples were taken with a small PVC corer (5 cm inner diameter, 30 cm long) for particle size analysis and estimation of the sediment organic matter content (OMC). The OMC was determined by "loss on ignition" of dried sediment, at 500°C for 6 hours in a furnace. Sediment particle size analysis was performed using 63 to 2000 µm mesh sieves to separate the silt from the sand's fine particles and the latter from the coarse sand-gravel fractions. Each dried fraction was weighed and percentages were determined. Sediments were characterized by the percentages of each of the three above mentioned sedimentary fractions and by the median grain size. Sedimentary types were identified according to Chassé and Glémarec [25].

The abundance of the vegetation cover was qualitatively estimated in percentage according to the sampling 1 m^2-area. During spring low tides some variables of the water close to the bottom as well as temperature within the top 5 cm depth layer of the sediment, were measured *in situ* at each station and during each sampling date with appropriate instruments: salinity and water temperature were measured using a thermo-salinometer (WTW LF340), pH by a portable pH-meter (pHScan WP 1/2) and dissolved oxygen by a portable oxymeter (HANA HI 9142). Dissolved oxygen was measured in mg O2 per liter of water (mg l^{-1}), whilst salinity measurements are expressed as dimensionless practical salinity units [26].

2.3. *Data processing*

The data were analyzed using a combination of multivariate and univariate methods. The macrobenthic community structure was analyzed taking into account macrofauna abundance (=number of individuals/0.25 m^2, N), number of species (S), Shannon-Wiener's species diversity index (H′; as log2), Pielou's evenness index (J′) and Simpson's dominance index (λ). All of these biological parameters were calculated for each station and season using the DIVERSE routine of the PRIMER statistical package (Plymouth Marine Laboratory, PRIMER v5) [27]. The seasonal difference of indices was tested through one-way ANOVA, performing a post-hoc HSD test when significant differences were found (by SPSS 11.5 software), whereas relationships between variables were investigated using Spearman's non parametrical correlation analysis (by STATISTICA 6.0 software).

The seasonal macrofaunal pattern was tested using the multivariate data analyses. To detect temporal changes in the community structure of macrobenthos non-metric multidimensional scaling, nMDS (ordination) based on log-transformed abundance data (to fulfill statistical assumptions) was performed. Similarities between stations were calculated using the Bray-Curtis similarity coefficient. The group-average linkage method (sorting algorithm) was applied in clustering [27].

The significant differences in community structure and composition between sample groups were assessed by the pairwise analysis of similarities (one-way ANOSIM routine in PRIMER v5, [28-30]. Species responsible for the observed differences and that majorly contributed to the differentiation and dissimilarity among sample groups determined by ordination analysis were then identified by means of the SIMPER program (Similarity Percentages - species contributions). Environmental variables which best correlated with the multivariate pattern of the macrobenthic community were identified by means of BIO-ENV procedure (PRIMER package) [31].

3. Results

3.1. Environmental data

The seasonal variability of the water column and sediment parameters in the Smir lagoon is shown throughout the sampling periods (Table 1). Silt was predominant in the lagoon sediments. Three sedimentary types were identified; sandy mud (SM), mud (M) and muddy sand (MS). Two groups of stations were determined according to seasonal changes. The first group contained stations with unchanged sedimentary textures (stations 1, 2 and 5 on SM; stations 4 and 12 on M and station 11 on MS) whereas the second one was characterized by stations, which changed between SM and MS (stations 3, 6 and 7), between SM and M (stations 8 and 9) and, from MS to SM and to M (station 10). The median grain size didn't exceed 240 µm (all seasons) with silt content ranging between 17% in summer and 86% in winter.

Table 1: Seasonal variability of water parameters (mean values ± standard deviation) and sediment characteristics (min-max) recorded in the Smir lagoon.

Seasons	Winter	Spring	Summer	Autumn
Salinity	33.3±4.2	36.6±1.0	37.0±2.3	29.4±7.7
Tw (°C)	18.9±0.5	17.7±0.7	28.2±2.9	16.8±1.3
pH	8.2±0.1	8.4±0.2	8.5±0.3	8.3±0.2
DO (mg/l)	11.9±1.0	--	12.6±5.0	--
Ts (°C)	--	--	24.8±1.2	17.4±0.4
Md (µm)	<63-236	<63-235	<63-224	<63-222
Silt (%)	18.8-85.9	20.8-84.3	17.5-77.1	22.4-65.4
FS (%)	10.3-59.3	11.9-65.2	17.4-69.4	28.0-61.4
CSG (%)	3.7-21.9	3.8-23.5	4.3-13.2	5.8-16.2
OMC (%)	4.7-13.3	3.3-14.7	2.9-14.8	4.6-11.7
VC (%)	1-2	0-2	0-1	0

Tw: water temperature; DO: dissolved oxygen; Ts: temperature of sediment; Md: median grain size; FS: fine sand; CSG: coarse sand-gravel; OMC: organic matter content; VC: vegetation cover. Original data codes for vegetation cover are 0 = for no vegetation to scarce (0-25% of sampling 1 m²-area); 1 = low to medium coverage (25-75%), 2 = fully covered with vegetation (>75%); --: Values not available.

Sediment organic matter content (Table 1) ranged from moderate to high. The highest mean values of the OMC were recorded in winter (9.5 ± 2.7%) and generally characterized the muddy sediments. Significant relationships between median grain size, silt content and fine sand with OMC were pointed out (Table 2).

The water characteristics were not constant over the entire period of study. Water temperature (Tw) near the bottom showed a similar seasonal pattern at all stations (except S10 and S12) with minimum values in autumn and in spring and maximum ones in summer (Table 1). The highest values of sediment temperature (Ts) were registered in summer (Table 1) but no significant relations were found between these variables during autumn and summer seasons. Salinity exhibited quite similar trends than Tw with lower values in autumn and higher ones in summer (Table 1). Winter showed the lower pH values and the higher dissolved oxygen values on average compared to those of the other seasons. These two variables were significantly correlated in winter and summer (Table 2). The vegetation cover was well developed in winter and spring especially in the outermost part of the lagoon where *Enteromorpha linza* and *Nanozostera noltii* dominated and covered more than 75% of the 1 m² - sampling area during both seasons (Table 1).

Table 2: Non-parametric correlation analysis between environmental variables during each season. Spearman's rank correlation coefficient and pairwise p-value are shown only when correlations are significant.

	Seasons	Salinity	Tw	pH	DO	Md	Silt	FS	CSG	VC
Ts	Summer	0.836**								
pH	Spring	0.692*			--					
	Summer		0.665*							0.767**
	Autumn		0.894**							0.700*
DO	Winter			0.786**						
	Summer		0.725**	0.889**						0.738**
Silt	Winter					-0.961**				0.606*
	Spring				--	-0.960**				
	Summer					-0.964**				
	Autumn					-0.985**				
FS	Winter					0.936**	-0.972**			-0.613*
	Spring				--	0.899**	-0.951**			
	Summer					0.960**	-0.972**			
	Autumn					0.958**	-0.983**			
CSG	Winter					0.783**	-0.804**	0.700*		
	Spring				--	0.673*	-0.650*			
	Autumn					0.740**	-0.712**			
OMC	Winter					-0.682*	0.790**	-0.783**	-0.741**	0.786**
	Spring				--	-0.935**	0.947**	-0.860**	-0.692*	
	Summer		0.831**	0.640*	0.600*		0.620*	-0.630*		
	Autumn					-0.861**	0.857**	-0.876**		

N=12 for all correlations. ** = p<0.01, * = p<0.05. Only parameters with significant correlations are shown in the table. For the abbreviations see Table 1.

One-way ANOVA analysis performed on environmental data (Table 3) showed significant differences between the four seasons for salinity, pH, water and sediment temperatures and vegetation cover. No significant relationships were obtained in the summer season for coarse sand-gravel content and only one statistically significant correlation between salinity and sediment temperature was detected during this season (Table 2). The correlations recorded between dissolved oxygen and environmental variables such as water temperature (rs = 0.725; p<0.01), pH (rs = 0.889; p<0.01) and vegetation cover (rs = 0.740; p<0.01) remained the most important ones during the summer. The vegetation cover was significantly related to pH in both summer (rs = 0.767; p<0.01) and autumn ((rs = 0.700; p<0.05) and to some sediment parameters (fine sand, silt and OMC) in winter. In spring and in autumn no significant relationships were found between the vegetation cover and environmental variables (except pH in autumn) (Table 2). The OMC in the sediments was negatively correlated with CSG, SF and Md (p<0.01) and positively with the silt content especially during winter and spring (Table 2).

3.2. Macrofaunal community

Throughout the sampling periods a total of 19,712 specimens belonging to 42 species of eight zoological groups were collected in the Smir lagoon. These were composed by 13 Crustacea (five Amphipoda, four Isopoda, two Decapoda, one Mysidacea and one Leptostracea), 12 Annelida Polychaeta, nine Mollusca, two Insect larvae; two Echinodermata, two Teleosteans, one Cnidaria and one Nemertea (see the complete list of species in [23]. Crustaceans were the dominant infaunal taxon, accounting generally for 71% of the total abundance and could exceed 90% (in winter and autumn). Species composition was almost the same in all stations. A pool of dominant species was common to all stations and seasons; *Melita palmata* (Montagu, 1804), *Corophium acherusicum* Costa, 1853, *Cyathura carinata* (Krøyer, 1847), *Lekanesphaera hooker*i (Leach, 1814) and *Hediste diversicolor* (O.F. Müller, 1776). The latter species made up 98% of all polychaetes and 27% of the total macrofaunal abundance especially in summer and, contrarily to the other four species, it didn't show any significant differences between seasons (Table 3). These taxa were also the leader species of the identified communities of the Smir lagoon (see Chaouti and Bayed [22]).

Table 3: One-way ANOVA analysis and post-hoc HSD test performed on environmental and biotic data between seasons.

Environmental data	F	p	D-M	D-J	D-A	M-J	M-A	J-A
Salinity	7.165	**0.001**	ns	0.000	0.043	0.000	ns	0.001
Water temperature	121.085	**0.000**	0.010	0.000	ns	0.006	ns	0.000
Dissolved oxygen	0.201	ns						
pH	3.101	**0.036**	ns	ns	ns	ns	ns	0.026
Sediment temperature	400.285	**0.000**	ns	0.027	ns	0.001	ns	0.000
Median grain size	0.389	ns						
Silt	0.237	ns						
Fine sand	0.215	ns						
Coarse sand-gravel	0.562	ns						
Organic matter content	0.588	ns						
Vegetation cover	4.257	**0.027**	ns	0.001	ns	ns	ns	0.016
Biotic data								
Biological indices								
Number of species	10.895	**0.000**	ns	0.000	0.001	0.000	0.000	0.000
Number of individuals	8.994	**0.000**	0.000	0.044	ns	0.029	0.000	0.000
Shannon-Wiener's index	1.512	0.225						
Pielou's index	10.026	**0.000**	0.008	0.003	0.005	0.000	ns	ns
Simpson's dominance index	1.263	0.299						
Dominant species								
H. diversicolor	2.355	0.085						
M. palmata	6.240	**0.001**	0.050	0.032	ns	0.000	ns	0.001
C. acherusicum	3.708	**0.018**	ns	ns	ns	0.011	ns	0.018
C. carinata	9.034	**0.000**	0.029	ns	ns	0.000	0.009	ns
L. hookeri	12.666	**0.000**	ns	0.011	0.002	ns	ns	0.000

The global F-ratios and pairwise p-values are shown. Degree of freedom = 3. Only significant values are indicated in the table. D = winter, M = spring, J = summer, A = autumn.

3.3. Structural analyses: univariate and multivariate analyses

Seasonal trends in the ecological descriptors S, N, H', J' and λ are shown in Table 4. At each station the number of species (S) decreased during summer and was highest during winter and spring reaching a maximum of 11 species during this study.

Table 4: Seasonal variability of mean values (±standard deviation) and of minimal and maximal values of community descriptors in the Smir lagoon.

Seasons	S	N	H'	J'	λ
Winter	11.0±3.3 (7-17)	862.3±697.3 (153-2132)	1.6±0.2 (1.4-1.9)	0.5±0.1 (0.4-0.7)	0.5±0.1 (0.3-0.6)
Spring	8.5±1.8 (5-10)	428.4±335.9 (70-1266)	1.7±0.3 (1.2-2.2)	0.6±0.1 (0.4-6.4)	0.4±0.1 (0.3-0.6)
Summer	4.5±1.6 (2-7)	47.5±18.0 (23-85)	1.5±0.4 (1.0-2.3)	0.7±0.2 (0.6-1.0)	0.4±0.1 (0.2-0.6)
Autumn	8.2±3.9 (5-14)	304.5±136.4 (62-497)	1.5±0.4 (1.1-2.4)	0.5±0.1 (0.4-0.8)	0.5±0.1 (0.3-0.6)

S: number of species; N: number of individuals (ind./0.25 m^2); H': Shannon-Wiener's diversity; J': Pielou's evenness; λ: Simpson's dominance.

The total number of species was in general lower. Mean abundance (N) had a similar pattern and showed the highest value in winter. Total number of individuals showed the maximum value in winter reaching 2132 ind./0.25 m^2 at station S12. Shannon-Wiener's index (H') varied from 1.0 to 2.4 bit with a higher average in spring not exceeding 1.7 ± 0.3 bit (Table 4). Evenness index (J') ranged from 0.4 to 1.0 with a mean value (0.7 ± 0.2) higher in summer than in the other seasons. Simpson's dominance index (λ) displayed values from 0.2 to 0.6 with slight variations and comparable mean values (Table 4). Using a one-way ANOVA analysis (Table 3), significant between-season differences were found for all biological descriptors except for H' and λ indices. Analyzing the relationships between biotic and abiotic variables using Spearman's non-parametric test, significant correlations emerged mainly for winter (Table 5).In fact significant relations were found in this season between S, N and J' on the one hand and salinity, OMC, fine sand and vegetation cover on the other. Fewer ones were obtained in autumn between J' and fine sand and OMC. H' and λ indices were not significantly related to environmental variables (Table 5). During all sampling seasons, no significant correlations were found between biotic parameters, and Tw, pH, Md, Silt content and CSG (Table 5). *C. acherusicum* and *H. diversicolor* were significantly correlated only with one environmental factor; salinity and coarse sand-gravel respectively (Table 5). *M. palmata* was significantly and exclusively related to sediment parameters in winter (Table 5). This amphipod and the isopod *C. carinata* were the only species that showed significant relationships with the vegetation cover in winter.

Table 5: Spearman's rank correlation between dominant species, biological indices and environmental parameters during each season.

	Seasons	Salinity	Tw	pH	Md	Silt	FS	CSG	OMC	VC
S	Winter	0.742**							0.572*	0.683*
N	Winter	0.649*					-0.664*		0.692*	0.609*
J'	Winter	-0.658*								
	Autumn						-0.634*		0.603*	
H. div.	Winter							0.631*		
M. pal.	Winter				-0.710**	0.783**	-0.811**	-0.720**	0.909**	0.710**
	Autumn	-0.601*		0.580*						0.710**
C. ach.	Winter	0.575*								
C. car.	Winter									0.605*
	Summer		-0.707*						-0.657*	
L. hoo.	Spring							-0.684*		
	Summer							-0.722**		
	Autumn		-0.862**	-0.668*						

N=12 for all correlations. Only parameters with significant correlations are shown in the table. For abiotic and biotic parameters codes see Tables 1 and 4 respectively. ** = $p<0.01$, * = $p<0.05$. *H. div*. = *H. diversicolor*; *M. pal*. = *M. palmata*; *C. ach*. = *C. acherusicum*; *C. car*. = *C. carinata*; *L. hoo*. = *L. hookeri*.

The nMDS plot displayed a clear discrimination between the two major seasonal groups at a similarity level of 20%; one group included samples of winter, spring and autumn whereas the second one gathered those of summer (Figure 2). The community structure of macrobenthic infauna changed between seasons, with an acceptable stress value of 0.12. Although well separated on nMDS ordination (Figure 2B), these faunal groups did not display a high internal similarity (20%) as shown for cluster analysis (Figure 2A). In fact, clustering, based on Bray–Curtis similarities clearly showed similar results to those of the nMDS analysis and all summer samples were grouped into one cluster. Moreover a group of seasonal samples of station S10 (S10A, S10J and S10M) with S11J joined the first group at 76% similarity, while S10D was clustered with the second group at 60% similarity. On the nMDS plot all seasons' samples of this station joined the summer group (Figure 2). There were significant differences in the faunistic composition between seasonal groups (ANOSIM, global R = 0.770, number of used permutations = 999, significance level = 0.1%). The dissimilarity (82.45%) between the three-seasons' group and the summer group were mainly caused by *C. carinata* and *M. palmata* (Table 6). The SIMPER analysis showed that *C. carinata*, *M. palmata*, *L. hookeri* and *C. acherusicum* were the species that made the major contribution to similarity within the first group (Table 6). This group was the less similar with an average similarity 41.76%. On the other hand, *H. diversicolor*, *C. carinata* and *M. palmata* were the taxa that contributed most to similarity and defined the summer group according to the SIMPER analysis as the most similar group, (average similarity within the group was 52.64%), with high similarity within this group (Table 6).

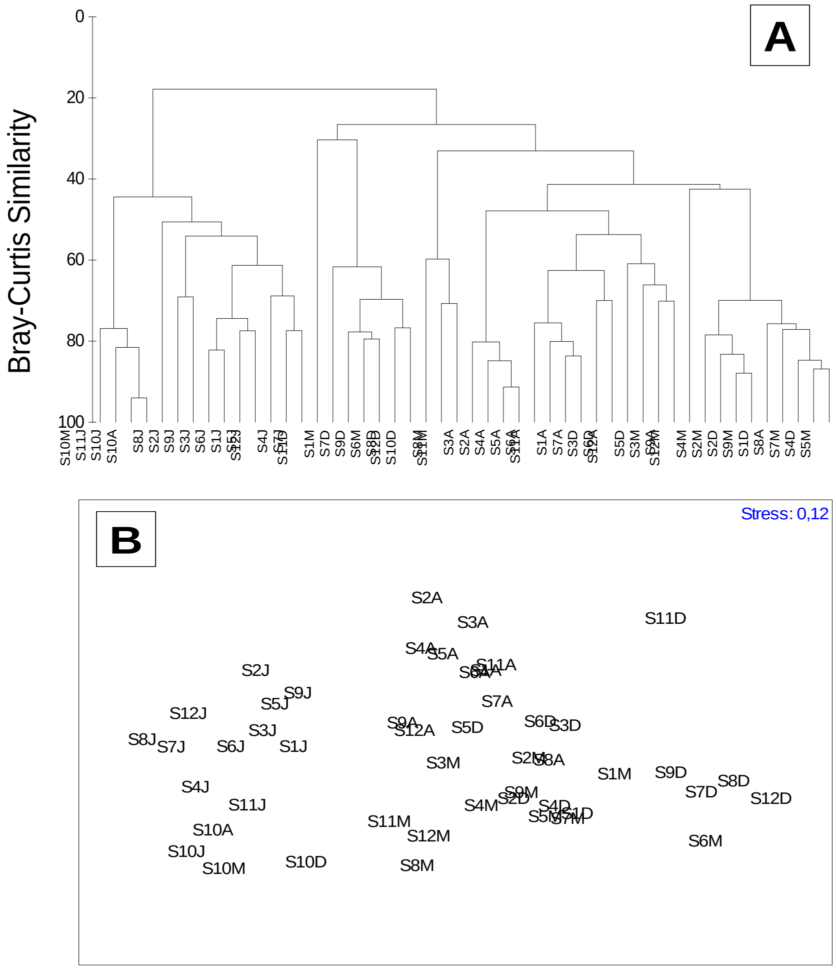

Figure 2: Dendrogram of hierarchical clustering (A) and multidimensional scaling (MDS) ordination plot (B) of log-transformed abundance data of the seasonal macrobenthic samples based on the similarity of the faunal composition at the sampling stations. A: autumn, D: winter, M: spring, J: summer

The BIO-ENV procedure showed lower correlation values among abundance data and any combination of the measured sedimentary variables (harmonic Spearman's rank correlation ρw <0.100). Correlations were higher for the combination of salinity, water temperature, pH, vegetation cover and organic matter content (ρw: 0.481) with faunistic data. The best correlations to explain multivariate pattern of macrofaunal distribution were obtained for the combination of water temperature and vegetation cover ((ρw >0.481). Water temperature was the variable that alone showed the highest correlation (ρw: 0.418), followed by organic matter content (ρw: 0.366) and salinity (ρw: 0.271).

4. Discussion

To obtain an overall picture of the macrofaunal communities of the Smir lagoon on a short-term temporal basis a sampling scheme, based on a grid of stations covering the whole lagoon was used during four seasons. The total number of benthic macrofauna species in the lagoon (11 as a maximum value throughout the seasons) was sufficiently low to consider these soft bottoms as particularly poor in macro-invertebrates: the amphipods *C. acherusicum* and *M. palmata*, the isopods *C. carinata* and *L. hookeri* and the polychaete *H. diversicolor* were the most common and abundant species. However this number of species was still relatively higher compared to other Mediterranean lagoons, which usually have muddier sediments and higher organic matter contents [12.32-34]. Logically, in an environment controlled by environmental stress factors, fewer species survive and consequently, species richness is lower [35]. Moreover, in undisturbed coastal environments low species richness, together with low diversity values, is related to the stressful conditions [36] and in particular, to those related to high seasonal and tidal salinity fluctuations. The low species diversity found in the

Smir lagoon may be related to the occurrence of only a few habitats or to the absence of a variety of habitats, differing in sediment, temperature, salinity and macrophyte-coverage and/or to environmental stresses.

Table 6: Result of SIMPER analysis between groups established after ordination analysis. SIMPER analysis Average similarity for the group; species that contribute most to similarity for each group (Cluster).

Cluster C1						
Average similarity: 41,76%						
Species	Av.Abund	Av.Sim	Sim/SD	Contrib.%	Cum.%	
C. carinata	146.45	22.01	1.91	52.72	52.72	
M. palmata	246.18	10.32	0.69	24.72	77.44	
L. hookeri	49.18	4.70	0.58	11.26	88.70	
C. acherusicum	80.12	2.23	0.59	5.34	94.04	
Cluster C2						
Average similarity: 52.64%						
Species	Av.Abund	Av.Sim	Sim/SD	Contrib.%	Cum.%	
C. carinata	21.60	31.46	2.49	59.78	59.78	
H. diversicolor	22.00	15.75	1.07	29.93	89.71	
M. palmata	3.40	2.49	0.83	4.74	94.44	
Clusters C1 & C2						
Average dissimilarity = 82.45%						
	Group C1	Group C2				
Species	Av. Abund	Av. Abund	Av. Diss	Diss/SD	Contrib.%	Cum.%
M. palmata	246.18	3.40	27.14	1.10	32.92	32.92
C. carinata	146.45	21.60	24.60	1.62	29.84	62.76
L. hookeri	49.18	7.00	11.44	0.71	13.88	76.63
C. acherusicum	80.12	0.47	8.45	0.61	10.24	86.88
H. diversicolor	21.09	22.00	6.21	0.71	7.53	94.41

Av.Abund = average abundance (abundance as ind./0.25 m²); Av.Sim = average similarity; Sim/SD = similarity/ standard deviation Contrib.% = contribution; Cum.% = cumulative contribution; Av. Diss = average dissimilarity; Diss/SD = dissimilarity/standard deviation.

Seasonal patterns were found for the species number and abundance, reaching higher values in winter and lower ones in summer. In fact, the total abundance showed a seasonal variation with a peak in winter and low abundance values in summer; with maximum values similar to those recorded in other Mediterranean lagoons [7.10.12.32.33.37-40]. Other coastal systems were instead characterized by an opposite pattern, where the macrofaunal community showed an abundance increasing in spring and autumn, and decreasing in winter [41-43]. This common seasonal pattern seems to reflect the recruitment patterns of species, which usually take place during spring and autumn. At the Smir lagoon the seasonal pattern was mainly related to the variability in the abundance of the main species, such as *M. palmata*. *C. carinata* and *C. acherusicum* whose abundances were related to their recruitment period reported in winter (presence of a high number of juveniles in samples). This statement was confirmed by the SIMPER analysis and the grouping of the seasonal samples was mainly due to this fact.

Because of the lack of regular and sufficient sediment inputs into the lagoon no real changes occurred in the sediment habitats. This was assessed in most stations by the absence of significant between-seasons differences in the sediment characteristics. Additionally, the rank correlation values measured with the BIO-ENV approach indicated that the fluctuations in the sediment variables did not play a relevant role in structuring the macrofaunal community. In contrast, temperature, pH, vegetation coverage, organic matter content and salinity did correlate with the community pattern and permitted the seasonal group discrimination. Thus, the sediment doesn't seem to have a significant effect on the macroinfauna (according to the autoecology of species (eurytope) supporting a large specter of sedimentary habitats). Consequently, sediment did not play a significant role in the seasonal discrimination of faunal assemblages but the analysis suggested that other factors acted in controlling the biological community structure at the Smir lagoon.

The spatial distribution of Smir lagoon's infauna was affected by various environmental variables such as water temperature, pH, dissolved oxygen, sediment and vegetation cover as described by Chaouti and Bayed [22]. Moreover it was hypothesized that environmental variables acting as gradients in brackish waters affected the spatial distribution of macrobenthic animals and resulted in differences in the assemblage structure among habitats in brackish systems [8.11.12.41.44.45]. In the same way, many studies have suggested that variability in physical, chemical and biological factors provide diverse habitats, and species-specific habitat association of organisms in response to environmental variability [11.45.46]. The multivariate analyses showed a seasonal discrimination between summer samples, on the one hand, and the other seasonal samples on the other. This agrees with the HSD post-hoc test result, which showed significant differences between summer samples and others in most cases. This statement emerged also from the significant correlations found between water variables and the benthic structure in the whole lagoon. In particular, high values of temperature and salinity associated with a poor vegetation cover were recorded during the summer and were accompanied by a decrease in species number and in abundance of dominating species. This supports the idea that salinity and water temperature could be considered among the structuring factors of the composition and temporal pattern of the community.

In particular, in the outermost parts of the lagoon connected with the Mediterranean sea, temperature and salinity acted together with pH and dissolved oxygen due to the presence of alga-seagrass beds and to certain hydrodynamic features. These environmental variables could be considered as contributing factors of the composition and seasonal structure of the macrofauna.

At the Smir lagoon the seasonal dynamics of the macrobenthic fauna is not only driven by differences in the temporal fluctuations of the environmental parameters but also seems to be a result of synergistic effects of these factors together with several other natural processes such as recruitment trends, food availability, hydrodynamics and inter-specific competition. This fact has also been reported for other systems [47.48]. These authors found that the seasonal changes in the communities of southern German Bight (towards the north-eastern Dogger Bank on North Sea. Germany) were not a result of the change in the community structure but simply a return of the macrofaunal community structure to its previous status after the hot season (spring and summer). Indeed, many studies in coastal lagoons indicated that benthic assemblages undergo marked seasonal fluctuations that follow regression/recovery patterns. This includes a regression of the assemblage in summer/autumn and a subsequent recovery in winter/spring [9.12.37.49.50]. Furthermore, the source of pollutants, the degree of exposition to hydrodynamics, the water circulation and renewal, the habitat type and depth probably were factors all involved in the macrofauna variability of lagoon systems [51].

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References

1. Lasserre P., *Nat. Res.* (UNESCO) 15 (1979) 2-21.
2. Barraqué B., Vernazza-Licht N., Bley D., Boëtsch G., Fozzati L., Rabino-Massa L. L'homme et la lagune. Editions de Bergier. Châteauneuf de Grasse (1998).
3. Colombo G. Lagoons. The Coastline. Wiley J. Sons A.. Chichester (1977)
4. Nowicki B.L., Nixon S.W., *Mar. Ecol. Prog. Series*., 22 (1985) 21-30.
5. Barnes. R.S.K., Coastal lagoons. The natural history of a neglected habitat. Cambridge studies in modern biology. 1. Cambridge University Press. Cambridge (1980).
6. Magni P., Como S., Montani S., Tsutsumi H., *Mar. Biol*., 149 (2006) 1185-1197.
7. Magni P., Draredja B., Melouah K., Como S., *Mar. Environ. Res*., 109 (2015) 168-176.
8. Kanaya G., Nakamura Y., Koizumi T., Yamada K., *Mar. Environ. Res*.. 108 (2015) 14-23.
9. Koutsoubas D., Dounas C., Arvanitidis C., Kornilios S., Petihakis G., Triantafyllou G., Eleftheriou A., *ICES J. Mar. Sci.*, 57 (2000) 1472-1480.
10. Carvalho S., Moura A., Gaspar M.B., Pereira P., da Fonseca L.C., Falcão M., Drago T., Leitão F., Regala J., *Acta Oecol*., 27 (2005) 143-159.
11. Kanaya G., Suzuki T., Kikuchi E., *Estuar. Coast. Shelf Sci*., 92 (2011) 169-179.
12. Como S., Magni P., *Estuar. Coast. Shelf Sci*., 83 (2009) 638-646.
13. Barnes R.S.K., The coastal lagoons of Britain. An overview and conservation appraisal. *Biol. Conser.,* 49 (1989) 295-313.
14. Mariani S., *Estuar. Coast. Shelf Sci*., 52 (2001) 261-267.
15. Snelgrove P.V.R., *Biodiv. Conserv*., 7 (1998) 1123-1132.
16. Dauvin J.C., Thiebaut E., Gesteira J.L.G., Ghertsos K., Gentil F., Ropert M., Sylvand B., *J. Exp. Mar. Biol. Ecol*., 307 (2004) 217-235.
17. Ysebaert T., Herman P.M.J., *Mar. Ecol. Prog. Series*., 244 (2002) 105-124.
18. Constable A.J., *Aust. J Ecol*., 24 (1999) 452-476.

19. Ysebaert T., Meire P., Herman P.M.J., Verbeek H., *Mar. Ecol. Prog. Series*., 225 (2002) 79-95.
20. Bayed A., Chaouti A., Impact des aménagements hydrauliques. touristiques et urbains sur l'équilibre et le fonctionnement de la lagune et des marais de Smir. Ecosystèmes côtiers sensibles de la Méditerranée: cas du littoral de Smir. Bayed A., Scapini. F., *Trav. Inst. Sci*., série générale, 4 (2005) 75-85.
21. Chaouti A., Bayed A., Effets d'une perturbation anthropique sur les conditions hydrologiques de la lagune de Smir (Nord-Ouest. Maroc). *Rev. Sci. Eau, Numéro spécial: Perturbations environnementales et aménagement des écosystèmes d'eau douce*, 18 (2005a) 181-197.
22. Chaouti A., Bayed A., *Vie Milieu*, 58 (2008) 25-35.
23. Chaouti A., Bayed A., Diversité taxonomique et structure de la macrofaune benthique des substrats meubles de la lagune de Smir (Maroc). Ecosystèmes côtiers sensibles de la Méditerranée: cas du littoral de Smir. Bayed A., Scapini F., *Trav. Inst. Sci., Rabat*, série générale, 4 (2005b) 33-42.
24. Benhissoune S., Chaouti A., Bayed A. Distribution des macrophytes benthiques dans la lagune de Smir (nord-ouest du Maroc). Ecosystèmes côtiers sensibles de la Méditerranée: cas du littoral de Smir. Bayed A., Scapini F., *Trav. Inst. Sci.,* série générale, 4 (2005) 25-30.
25. Chassé C., Glémarec M., *J. Rech. Océanogr*., 1 (1976) 1-18.
26. UNESCO (United Nations Educational. Scientific and Cultural Organization) The International System of Units (SI) in Oceanography. Report of IAPSO working group on symbols. units and nomenclature in physical oceanography (SUN). UNESCO technical papers in marine science. N° 45 (1985).
27. Clarke K.R., Warwick R.M., Changes in marine communities: an approach to statistical analyses and interpretation. Natural Environmental Research Council. Plymouth. Plymouth Marine Laboratory UK (1994).
28. Clarke K.R., *Aust. J Ecol*., 18 (1993) 117-143.
29. Clarke K.R., Gorley R.N., PRIMER (Plymouth Routines in Multivariate Ecological Research) v5: User Manual/Tutorial. PRIMER-E Ltd. Plymouth. United Kingdom (2001).
30. Clarke K.R., Warwick R.M., Change in marine communities: an approach to statistical analysis and interpretation. second ed. PRIMER-E. Plymouth. United Kingdom (2001).
31. Clarke K.R., Ainsworth M., *Mar. Ecol. Prog. Series*, 92 (1993) 205-219.
32. Kevrekidis T., *Internat. Rev. Hydrobiol*., 89 (2004) 407-425.
33. Magni P., Micheletti S., Casu D., Floris A., De Falco G., Castelli A., *Chem. Ecol*.. 20 (2004) S397-S409.
34. Galuppo N., Maci S., Pinna M., Basset A., *Transit. Water Bull*., 4 (2007) 9-19.
35. Menge B.A., Sutherland J.P., Species diversity gradients: synthesis of the roles of predation. Competition, and temporal heterogeneity. *Amer. Nat*., 110 (1975) 351-369.
36. Muniz P., Venturini N., Pires-Vanin A.M.S., Tommasi L.R., Borja A., *Mar. Pollut Bull*., 50 (2005) 624-637.
37. Mistri M., Fano E.A., Rossi R.; *Mar. Ecol. Prog. Series*, 215 (2001a) 289-296.
38. Mistri M., Rossi R., Fano A., *Estuar. Coast. Shelf Sci*., 52 (2001b) 605-616.
39. Mistri M., Ghion F., Modugno S., Rossi R., *J. Mar. Biol. Ass. U.K.*, 82 (2002) 771-778.
40. Nonnis Marzano C., Scalera L., Fianchini A., Gravina F., Mercurio M., Corriero G., *Oceanol. Acta*, 26 (2003) 57-66.
41. Ysebaert T., Herman P.M.J., Meire P., Craeymeersch J., Verbeek H., Heip C.H.R., *Estuar. Coast. Shelf Sci*., 57 (2003) 335-355.
42. Chainho P., Costa J.L., Chaves M.L., Lane M.F., Dauer D.M., Costa M.J., *Hydrobiologia*, 555 (2006) 59-74.
43. França S., Vinagre C., Pardal M.A., Cabral H.N., *Sci. Mar*., 73 (2009) 307-318.
44. Bazaïri H., Bayed A., Glémarec M.. Hily C., *Oceanol. Acta*, 26 (2003) 457-471.
45. Nanami A., Saito H., Akita T., Motomatsu K., Kuwahara H., *Estuar. Coast. Shelf Sci*., 63 (2005) 167-176.
46. Kanaya G., Kikuchi E., *Estuar. Coast. Shelf Sci*., 78 (2008) 674-684.
47. Reiss H., Kröncke I., *J. Mar. Sci*., 61 (2004) 882-905.
48. Reiss H., Kröncke I., *Estuar. Coast. Shelf Sci.*, 65 (2005) 253-274.
49. Mistri M., *ICES J. Mar. Sci*., 59 (2002) 314-322.
50. Nicolaidou A., Petrou K., Kormas K.Ar., Reizopoulou S., *Hydrobiologia*, 555 (2006) 89-98.
51. Blanchet H., Lavesque N., Ruellet T., Dauvin J.C., Sauriau P.G., Desroy N., Desclaux C., Leconte M., Bachelet G., Janson A.L., Bessineton C., Duhamel S., Jourde J., Mayot S., Simon S., de Montaudouin X., *Ecol. Indicat*.. 8 (2008) 360-372.

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