Bayed A. & Ater M. (éditeurs). Du bassin versant vers la mer : Analyse multidisciplinaire pour une gestion durable.
Travaux de l'Institut Scientifique, Rabat, série générale, 2008, n°5, 81-91

An assessment of sandy beach macroinvertebrates inhabiting the coastal fringe of the Oued Laou river catchment area (Northern Morocco)

Isabella COLOMBINI [1], Abdellatif CHAOUTI [2], Mario FALLACI [1], Elena GAGNARLI [1], Abdellatif BAYED [2] & Lorenzo CHELAZZI [1]

[(1)] *Istituto per lo Studio degli Ecosistemi (ISE) del C.N.R. Via Madonna del Piano – 50019 Sesto Fiorentino, Firenze, Italia;* e-mail: chelazzi@ise.cnr.it
[(2)] *Université Mohammed V- Agdal, Institut Scientifique, Unité de Recherche OCEMAR BP 703, 10090 Rabat, Morocco;* e-mail:bayed@israbat.ac.ma

Abstract. This study analyses how changes in the chemical and physical characteristics of coastal environments due to river inputs affect the community structure of terrestrial arthropod populations. To this aim a stretch of coast in correspondence to the Oued Laou river mouth was chosen. Four sampling stations, two to the right and two to the left hand side of the river, were studied in spring and autumn. For each station two transects with pitfall traps set across shore were placed to capture active arthropods. The environmental parameters were also recorded and compared. Abundance, species richness and diversity indices were assessed and multiple regression analysis between biotic descriptors and most abundant species was performed with beach features. The results indicate that the Oued Laou river has an importance in structuring the habitat as differences in the biotic and abiotic components of the system were found at stations on the left side of the river compared to the right and between stations near and far. However, human impacts, higher on the left side, seem to affect population abundance. Alpha diversity index showed seasonal differences with relatively high values in spring and lower ones in autumn indicating a good beach quality that undergoes several disturbance factors with the change of the season.

Key words: terrestrial macroinvertebrates, spatial patterns, biotic descriptors, sandy beach, river inputs, Mediterranean Sea.

Evaluation des macroinvertébrés d'une plage sableuse sur la frange côtière du bassin versant de Oued Laou (Nord du Maroc)

Résumé. Cette étude analyse comment les changements dans les paramètres chimiques et physiques des environnements liés aux décharges d'un cours d'eau affectent la structure des populations d'arthropodes terrestres. Pour atteindre cet objectif, une zone de la côte proche de l'embouchure de l'Oued Laou a été choisie. Quatre stations d'échantillonnage, deux sur la rive droite et deux sur la rive gauche, ont été étudiées au printemps et en automne. Pour chaque station, deux transects avec des pièges ont été placés à travers la plage pour la capture des arthropodes actifs. Les paramètres environnementaux ont été également mesurés et comparés entre eux. L'abondance, la richesse spécifique et les indices de diversité ont été évalués et une analyse de régression multiple entre des descripteurs biotiques et les espèces les plus abondantes a été exécutée en considérant les caractéristiques de la plage. Les résultats montrent que l'Oued Laou a une importance dans la structuration de l'habitat, et que des différences dans les composantes biotiques et abiotiques du système ont été trouvées aux stations situées sur la rive gauche de l'Oued comparée à celles de la rive droite, et entre des stations proches et celles éloignées de l'embouchure. Cependant, l'impact humain, plus élevé sur la rive gauche, semble affecter l'abondance de la population. L'indice de diversité alpha a montré des différences saisonnières, avec des valeurs relativement élevées au printemps et valeurs faibles en automne indiquant une bonne qualité de plage qui subit plusieurs facteurs de perturbation avec le changement de la saison.

Mots clés : Macroinvertébrés terrestres, modèles spatiaux, descripteurs biotiques, plage sableuse, apports du cours d'eau, Mer Méditerranée

INTRODUCTION

Coastal stability largely depends on river sediment fluxes that are the main source of continental material exported to the sea. Probst & Amiot Suchet (1992) reviewed the data on suspended sediment transported by rivers for 130 drainage basins from the Maghreb region and analysed how several environmental factors (precipitation, mean annual runoff, drainage basin area and rock erodibility) influenced mechanical erosion and fluvial sediment transport. These authors estimated specific sediment yields of 400 $t.km^{-1}.year^{-1}$, on average, for river basins draining into the Mediterranean Sea. However, river inputs are highly influenced by natural and human induced changes in catchment areas. Construction of dams and other human activities such as changes in land use and vegetation clearance alter sediment fluxes. In Morocco, Snoussi *et al.* (2002) studied the impact of dam construction on the water and sediment discharges of the two largest rivers of the country, Moulouya and Sebou Rivers, and estimated that 93% and 95% of the sediment load was trapped by the reservoirs respectively. In addition, the water discharge was heavily reduced to 47 and 70% respectively after that damming activities had occurred. The reduction of river supply thus affected the coastline's morphological equilibrium and consequently changed the geomorphology of the two systems. These results confirm the findings of other authors that investigated interactions between watershed modifications and coastal evolution in other geographical areas (Simeoni & Bondesan 1997, Hay 1998, Barusseau *et al.*1998, Bonora *et al.* 2002).

Changes in the morphology of coastal environments due to modifications of river inputs consequently affect the community structure of macroinvertebrates. Recently Defeo & McLachlan (2005) reviewed the processes and regulatory mechanisms implicated in the distribution patterns of sandy beach macrofauna. A consistent amount of literature exists for macrobenthic communities. Alongshore patterns at the mesoscale were explained with gradients in physical factors including changes in sand particle size, exposure (from sheltered to exposed beach ends), salinity, morphodynamics and features associated with river mouths. Alongshore variations were also explained as result of the combination between biotic (intra and interspecific interactions) and abiotic factors. Degraer *et al.* 2003 showed that abundance and species composition along the shore decreased with increasing beach slope and grain size, and with decreasing beach width and relative tidal range. Lercari *et al.* (2002) and Lercari & Defeo (2003) studied the variation of the macrobenthic community in relation to freshwater river discharges. In this case, abundance, species richness, diversity, evenness decreased from undisturbed to disturbed sites affected by a freshwater discharge.

Contrarily not much work has been achieved on the interactions between geomorphological changes in sandy beaches due to the proximity of rivers and the community structure of terrestrial macro-invertebrates. Alongshore patchiness was demonstrated in terrestrial invertebrates of Mediterranean sandy beaches (Colombini *et al.* 2002) but in this case the influence of the nearby river was not analysed. A first approach was carried out within the framework of an International research project of the European community (Med-Core Project ICA3-CT2002-10003) in which biotic descriptors, such as abundance, species richness, evenness and diversity of terrestrial sandy beach macroinvertebrates were analysed at increasing distance from the Ombrone river mouth (Grosseto, Italy). The study showed an increase in species abundance and diversity at increasing distances from the river delta in relation to an increase of habitat diversity due to an amelioration of the beach dune characteristics (e.g. a greater development of the supralittoral and of the dune associated to an increase of psammophylous plant species) and to the reduction of human impacts (summer tourists, trampling). Habitat instability, due to an erosion process taking place at the river mouth and to an accretion process at the beach end, produced physical gradients that influenced the community structure of the macrofauna (Colombini *et al.* 2006).

The present study represents a further step in the knowledge of how terrestrial beach arthropod communities change in relation to their position occupied in space with respects to a river mouth. The aim of the study was to assess species richness, abundance and diversity along sandy beach ecosystems on both sides of a river mouth so as to understand how freshwater runoffs influence distribution patterns. For this purpose, a beach on the Mediterranean coast of Morocco was chosen. The physical characteristics of the environment (beach slope) were studied together with the substrate features (conductivity, sand size, organic matter, pH) in order to find relationships with the biotic components of the system. Seasonal comparisons were also assessed.

MATERIAL AND METHODS

Study site

The site chosen for the study was a 9 km stretch of coast in correspondence to Oued Laou river mouth, a locality along the north-western Mediterranean coast of Morocco. The river basin of Oued Laou represents the geographical limit between the Tétouan and Chefchaouen provinces. The main course of the oued originates from the calcareous chain of Jbel Tissouka at 1600 m of altitude and runs for 70 km before flowing into the Mediterranean. Its major affluents are Oued Tassikesté, Oued Farda, Oued Kalaa, Oued Essarem, Oued Talambote, Oued Moulay Bouchta, Oued Ouara and Oued Majjo. The geology of the limestone chain plays an important role in the hydrological regime of Oued Laou as it stores large quantities of water permitting a perennial summer supply in the upper part of its course whereas in its middle and lower part the supply is generally guaranteed by rainfall. The hydrological regime is thus characterised by strong seasonal contrasts with a torrential flow during winter and a severe deficit during summer, which is worsened by the water extraction of the population for agricultural needs (1300 ha out of 1800 ha are cultivated areas). Furthermore, Oued Laou is also exploited for hydroelectric power and presents two dams, one at Ali Thelat at the confluence of the Oued Laou and Oued Talambote and another at Akchour. The construction of the two dams was aimed at a better management of the water resources to contrast recurrent droughts caused by rainfall deficits but they have caused a decrease in sediment fluxes to the littoral plain. As the river reaches the plain it presents a meander course and in its final section it turns to the left running parallel to the shoreline. During rainy years, sediments are transported by the river directly to the sea whereas during drier years the mouth of the oued can be obstructed by a sand barrier.

The littoral plain of the Oued Laou river basin is of alluvial origins and presents a relatively wide beach with low relict dunes on the eastern side of the river mouth and on the western end of the bay (about 500 m SE of Cap Makkedh). In this section of the beach, eolian sand transport has built up slightly higher dunes that however reach only 2 m in height.

This plain in the past has undergone several changes, first during the Spanish Protectorate with landscape transformations for agricultural ameliorations and now with a rapid urbanisation caused by a growing local tourism. At present, the local economy of the area depends on summer tourism, agriculture and on traditional fishing. The rapid development of the area is thus severely threatening the coastal ecosystem of the plain. Particularly under threat are the sand beaches and the relict dunes. On the western end of the bay, a summer settlement of houses has been constructed directly on the beach-dune system. This barrier of houses compromise sediment exchanges between sea and land and consequently increase land erosion and risks of floods.

Field sampling

Field sampling was conducted at Oued Laou in two different seasons: in spring (26/04/04 - 03/05/04) and in autumn (27/09/05 - 02/10/05). Four sampling stations, two on the left bank (station 1: N 35° 27' 14.4", W 05°05' 33.0"; station 2: N 35° 26' 21.4", W 05° 05' 0.6") and two on the right (station 3: N 35° 25' 51.6", W 05° 04' 41.4"; station 4: N 35° 25' 19.0", W 05° 04' 21.5") were chosen. The stations at the two extremes (station 1 and station 4) were set each at a distance of 2 km from the river mouth, while station 2 and 3 were at 170 m and 870 m respectively from the river mouth. Station 3 was placed at this distance because in the symmetrical point of station 2 there had been several works of sand excavation and the area was severely damaged. Furthermore, the chosen spot corresponded to the first place where pioneer vegetation could be found in the high eulittoral. Furthermore, the retrodunal area presented the river running parallel to the shoreline. In autumn 2005 a sand barrier obstructed the river mouth because of the scarce amount of water in the river catchment area**.**

At each station two transects at a distance of 10 m from each other were set to capture arthropods of the eulittoral. Transects were composed by a set of pitfall traps at 4 m intervals, placed on the eulittoral starting from the mean high tide level up to the first pioneer plants. Traps were kept active for 72 consequent hours and individuals were collected once a day and preserved in 75% alcohol.

Sampling of environmental parameters was carried out by collecting sand samples at the sand surface with standard methods. For sand size analysis samples were collected in correspondence to each pitfall trap of the two transects for each day separately. To evaluate percentage of pebbles with a diameter greater than 4 mm a given volume of sand (1.5 litres) was collected and weighed. Then the sand was sieved through a 4 mm mesh size and the remaining pebbles were collected and weighed. Sand penetrability was also measured along transects using a graduated iron rod of 27.33 g weight (8 mm in diameter) dropped through a plastic tube of 1 m height (Bally 1983). For each pitfall trap three replicate measurements were taken. Beach slope were recorded at the two transects of each station. Beach slope was measured calculating the ratio (in percentage) between the difference in height and horizontal distance between two points.

Laboratory analysis

In the laboratory, faunal samples were sorted under binocular microscopes and where possible species were identified to species level. Counts were made for each transect and trap. The coleopterans alone were then chosen to be sorted further. When species were not recognisable they were subdivided into morphologically recognisable taxonomic units (RTUs) (Krüger& McGavin 1997). This method consists in subdividing each order at family level and then in grouping the different species of each family with conventional names (sp. 1, sp. 2 sp. 3 etc.).

From each transect the following sand parameters were determined: sand conductivity (salinity), pH, total organic matter, grain size (Folk & Ward 1957). These factors were determined according to standard methods (Black, 1965) respectively conductivity and pH of 10 g of sand in 50 cm³ demineralised water and for the organic matter weights of sand samples previously oven dried at 105°C for 24 hours and then burned for 3 hours in a muffle furnace at 600°C. Granulometric analysis was carried out using an automatic sieve shaker with meshes of different sizes (from 4 mm to 45 μm). The following granulometric parameters were considered: M_Z (mean grain size), σ_I (Inclusive graphic standard deviation), Sk_I (Inclusive graphic skewness) and K_G (Graphic kurtosis). Sand parameters of both sides of the river were then compared.

Data analysis

In spring 2004 and autumn 2005 faunal and environmental data were analysed separately at the four sampling stations. For the environmental parameters (total organic matter, pH, sand conductivity, mean grain size, grain size>4 mm and penetrability) at each station the data of the two transects (a, b) in the three days of sampling were used to calculate means with 95% confidence limits. Then data of the stations on the left side of the river mouth were cumulated and compared with those on the right side to verify if there were significant differences between the two sides. Comparisons were also made cumulating stations near the river mouth (stations 2 and 3) and comparing them with those farther away (stations 1 and 4). Seasonal differences of total means of each parameter were tested with T-Test. Total abundance (capture frequency) and species richness of coleopterans alone were correlated with the distance in meters from the river mouth proceeding from left to right using simple regression analysis. In this case, data were previously logarithmically transformed (ln). Multiple linear regression analysis (through backward elimination method) was performed in order to correlate the total Arthropoda, abundance, species richness and α diversity of coleopterans and most abundant species with the environmental parameters (total organic matter, pH, sand conductivity, mean grain size, grain size >4 mm, penetrability, beach slope).

Diversity indices calculated only for Coleoptera were used to assess changes in the community and were analysed for the different stations separately or cumulating stations. Fisher et al.'s (1943) α diversity index was used and confidence limits were calculated using the standard error given in William (1947). To analyse the evenness of the community Pielou's (1978) evenness index through Brillouin (1962) index was used instead of the Shannon–Weaver index (1949). To express the abundance of the commonest species as a fraction of the total number of individuals Simpson's (1949) dominance index was calculated.

RESULTATS

Beach slopes at the different sampling stations

Beach slopes recorded in spring at the different stations showed steeper mean slopes compared to those registered in autumn of the following year. In both seasons, the steepest beach slope occurred at station 4 on the right side of the river mouth with 5.7% and 3.9% in spring and autumn respectively. Station 3, instead, was the flattest and presented a mean slope of 2.3% and 0.7% in the two seasons respectively. This station reached its greatest height on a.s.l. at a distance from the sea of 26 m (in spring) and of 21 m (in autumn). In this seaward part of the beach, mean slope was similar to the other stations whereas the major differences occurred landwards where station 3 greatly decreased its slope.

Environmental parameters

In spring, *total organic matter* (Fig. 1a) was evenly distributed in all stations with very similar values at the stations close to the river mouth. No differences were recorded when stations were cumulated (see confidence limits). Higher mean values of *pH* (Fig. 1b) were found at the stations on the left side of the river mouth and these became significantly higher from those of the right side when stations were cumulated. Instead, no differences appeared when stations closer to the river mouth were compared with those farther away. For this parameter the same trends were observed in autumn (Fig. 1h) with no significant differences with the previous sampling period ($p=0.868$). A significant higher mean was instead found for organic matter in autumn ($p<0.008$).

Regarding *mean grain size,* in spring (Fig. 1c), finer sands (higher values of Φ) were found at station 4 whereas around the mouth of the river coarser sands occurred and this became particularly evident when station 2 and 3 were summed and compared to stations 1 and 4 (cumulated). At increasing distance from the mouth, there was an increase in the percentage of large pebbles on the beach surface that was confirmed comparing cumulated stations nearer and farther away from the river mouth (Fig. 1d). In autumn finer sands were again found at the stations farther away from the river mouth and the same trends of the previous period were observed when stations were cumulated (Fig. 1i). Again a higher percentage of pebbles occurred in stations farther away from the river mouth however, generally, a lower percentage of pebbles was recorded in autumn compared to spring ($p<0.0001$) (Fig. 1j). In spring s*ubstrate conductivity* (Fig. 1e) never showed significant differences among stations considered individually or cumulated with mean values ranging from 217.2 to 322.5 μScm^{-1}. In autumn (Fig. 1k) station 2 presented a significantly lower mean value compared to the other stations but when the data of the different stations were cumulated no differences occurred ($p=0.395$). In spring (Fig. 1f) the highest values of *penetrability* were found at the first and second stations with a mean value of 44.9 mm when data were cumulated, showing that looser sands occurred on the left side of the river mouth. However, sands became more compact at increasing distances from the river mouth. In autumn (Fig. 1l) the situation substantially changed and no significant differences were ever found between stations.

Species abundance and richness

In spring a total of 6627 arthropods was caught during the three days of sampling. Of these 78.2% was composed by the amphipod *Talitrus saltator*, 4.3% by the isopod *Tylos europaeus*, and 13.1% by the Coleoptera order of which 11.6% was mainly represented by the adults and larvae of the genus *Phaleria.* Generally there was a linear increase in abundance proceeding from station 1 to 4 and this was particularly clear for the most abundant species (*T. saltator, T. europaeus, Phaleria acuminata* and *Phaleria bimaculata*) (Table Ia). This was confirmed by regression analysis in which a significant linear trend was obtained between the distance in metres and abundance of captured individuals ($y=0.6785x + 4.8019$ $R^2 = 0.6781$ $p<0.0001$). Only the Araneida order together with some Coleoptera species showed peaks of abundance around the river mouth but always in station 3. On the whole the total number of arthropods captured at the stations on the right side of the Oued Laou river mouth was six times the size of those captured on the left side (Table I n=902 at stations 1 and 2 versus n=5725 at stations 3 and 4).

Of the individuals captured on the two sides of the river mouth the crustacean species made up 70.6% and 84.7% of the total captures on the left and right side respectively, dominating the scenario. Also the adults of the two *Phaleria* species were mainly found at the stations at the right side of the river mouth even though its larvae were more or less evenly distributed at the two sides. The dermapteran *Labidura riparia* was mainly found at station 4 with 70.1% of captures.

In autumn (Table Ib) a lower number of arthropods (n=3680) were recorded during the three days of sampling. Again the amphipod *T. saltator* was the most abundant species with 46.4% of captures, followed by the tenebrionid beetles *P. acuminata* and *P. provincialis* with 40.8% (considering both adults and larvae) and by the isopod *T. europaeus* with 7.9% of captures.

In this case station 3 presented highest abundance and in particular for *T. saltator, T. europaeus, L. riparia* and the two *Phaleria* species whereas station 4 for the Formicidae and the Thysanura. Again the stations on the right side of the Oued Laou river mouth presented higher capture numbers compared to those on the left side (n=866 at stations 1 and 2, n=2814 at stations 3 and 4) confirming the distribution patterns previously observed. Also in this case a significant linear trend was obtained between distance in metres (starting from station 1) and abundance of captured individuals ($y=0.2669x + 4.7397$ $R^2 = 0.3299$ $p<0.005$).

Regarding total species richness in spring (Table Ia) the highest number of species was found at station 3 where 31 different species were collected. Of these 16 were coleopteran species (Table IIa). Species richness calculated for the coleopterans alone showed a significant linear trend with the distance increasing from station 1 to 4 ($y=0.2585x + 1.3567$ $R^2 = 0.5488$ $p<0.0001$). At Oued Laou the highest values of α diversity calculated for the Coleoptera occurred around the river mouth with station 2 presenting the highest values and this was confirmed when stations 2 and 3 were cumulated and compared to stations 1 and 4. The composition of the Coleoptera community presented the highest values of evenness at station 2 and these

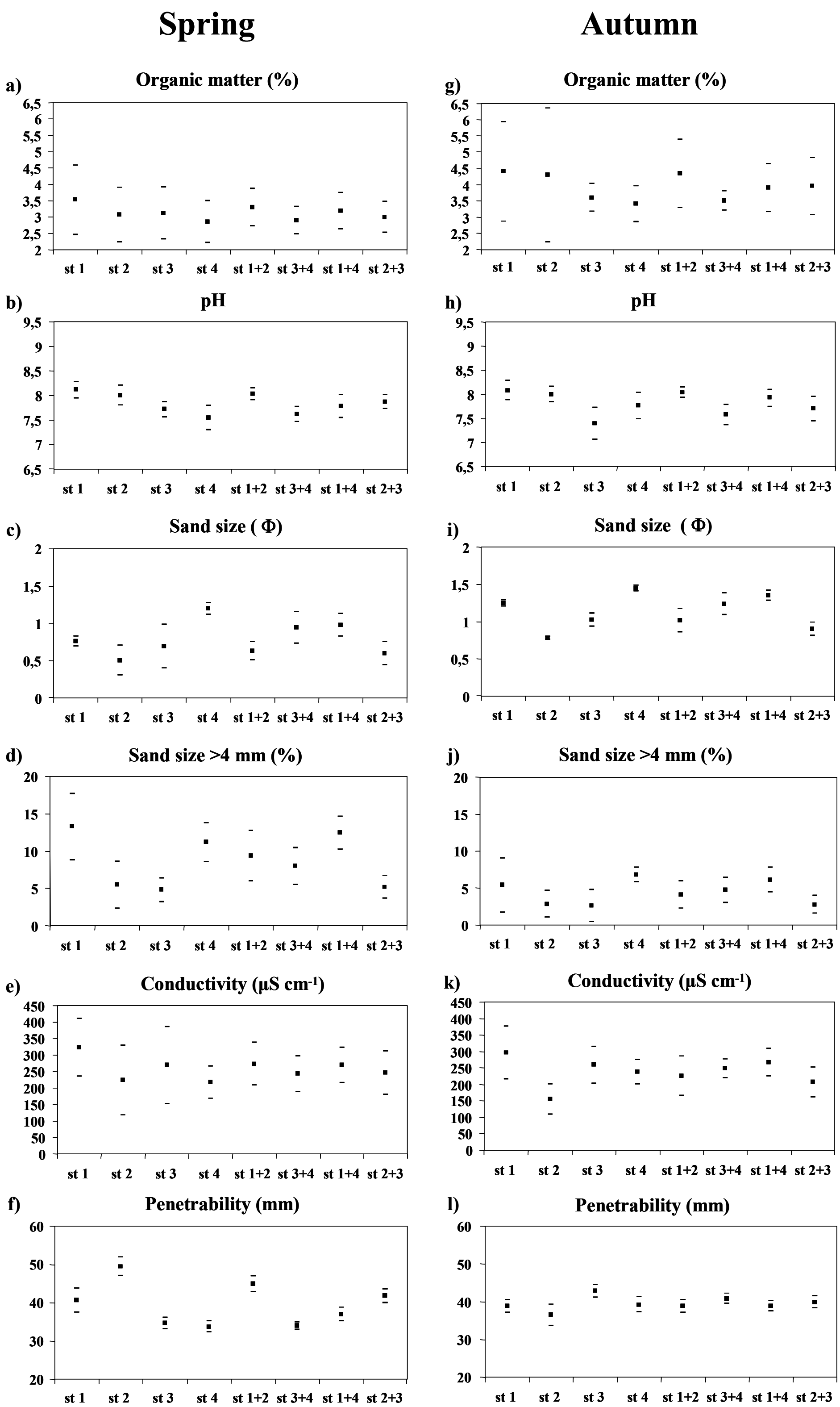

Figure 1: Mean sand parameters (with 95% confidence limits) are shown in the two seasons (spring a-f; autumn g-l) for each station separately and for cumulated stations (stations 1+2, right side of the river mouth, stations 3+4, left side of the river mouth, stations 1+4, far from the river mouth, stations 2+3 near the river mouth).

corresponded to the lowest values of the dominance index. Considering cumulated stations higher values of evenness occurred on the left side compared to the right and in stations closer to the river mouth. Dominance index was instead higher on the right side compare to the left and in stations farther away from the river mouth. In autumn species richness (Table Ib) was highest at station 4 in which a total of 18 species were found. Of these 9 belonged to the Coleoptera (Table IIb) with an increasing gradient proceeding from station 1 to 4 (y=0.1009x + 0.971 R^2 = 0.222 $p<0.05$). In general, during autumn, lower values of α diversity were found when compared to

Table I: Oued Laou: spring 2004 (a) and autumn 2005 (b), species richness and abundance of the most representative species at the different stations and on the total.

a)	left side		right side		
	station 1	station 2	station 3	station 4	Total
n total	184	718	2149	3576	6627
n species	15	28	31	28	60
Talitrus saltator	27	556	1736	2867	5186
Talorchestia deshayesii		7			7
Orchestia sp.		2			2
Tylos europaeus	20	23	86	157	286
Armadillidium album			1		1
Armadillidium vulgare			1		1
Agabiformius obtusus				3	3
Leptotrichus panzerii	1				1
Lycosidae	1	9	80	7	97
Other Araneida	2	3	5	1	11
Labidura riparia	4	14	8	61	87
Eurynebria complanata		1	1	1	3
Harpalus hitipes			1		1
Parallelomorphus laevigatus	1	1	4	14	20
Phaleria acuminata	33	25	105	270	433
Phaleria bimaculata	9	10	35	97	151
Phaleria larvae	76	15	46	48	185
Opatrum sabulosum	1	7	13	5	26
Other Tenebrionidae	1		9	2	12
Staphylinidae	1	7		3	11
Anthicidae		2	5	2	9
Other Coleoptera		3	3	11	17
Other Arthropods	7	33	10	27	77

b)	left side		right side		
	station 1	station 2	station 3	station 4	Total
n total	436	430	1862	952	3680
n species	13	13	12	18	30
Talitrus saltator	4	30	1158	513	1705
Tylos europaeus	3	22	253	18	296
Agabiformius obtusus	1				1
Leptotrichus panzerii	1	1			2
Stenophiloscia glarearum		2			2
Lycosidae	1	3	7		11
Other Araneida	1			1	2
Labidura riparia		12	26	1	39
Eurynebria complanata			1		1
Parallelomorphus laevigatus		1	1	5	7
Scarites buparius				1	1
Phaleria acuminata	133	170	223	152	678
Phaleria bimaculata	157	141	180	149	627
Phaleria larvae	104	15	5	48	172
Opatrum sabulosum			4	3	7
Ammobius sabulosus	4				4
Other Coleoptera			1	5	6
Formicidae	21	30	1	40	92
Thysanura		3		15	18
Other Arthropods	6		2	1	9

those of the previous season. The highest values of α diversity occurred at station 4 and on the right side compared to the left. However, the stations farther away from the river mouth presented higher values of α diversity showing an opposite trend compared to spring.

Diversity indices, Brillouin (H), Brillouin max (Hmax = ln(species richness)), and evenness (J'), were plotted in a bidimensional graph (modified from Qinghong 1995), for each station (Fig. 2a) and for cumulated stations (Fig. 2b) in the two seasons. From spring to autumn season there was a decrease both in H and Hmax with J' that remained more or less the same for each station showing a "evenness-type" dynamic. Only station 1 was the exception where H remained constant and J' increased showing a "richness-type" dynamic. Considering the cumulated stations (Fig. 2b) from spring to autumn H values decreased in relation to H max with J' remaining constant with again an evenness-type dynamic. Simpson index was always around 0.50 in both seasons and in all stations except for station 2 in spring where this value decreased to one half.

Table II: Oued Laou: spring 2004 (a) and autumn 2005 (b) diversity indices of the Coleoptera species at the four stations analysed separately and at cumulated stations. For further explanations see figure 1 legend.

a)	left side		right side			left side	right side	far	near
	station 1	station 2	station 3	station 4	Total	station 1+2	station 3+4	station 1+4	station 2+3
n total	46	56	176	405	683	102	581	451	232
n species	6	16	16	14	33	17	22	16	26
α sup. lim.	2.88	10.91	5.55	3.58	8.53	7.53	5.51	4.15	9.43
α diversity	1.84	7.48	4.28	2.81	7.24	5.83	4.52	3.24	7.51
α inf. lim	0.80	4.06	3.00	2.04	5.95	4.12	3.54	2.32	5.59
Brillouin	0.76	1.61	1.27	0.98	1.23	1.37	1.14	0.98	1.48
Pielou evenness	0.48	0.68	0.49	0.38	0.36	0.54	0.38	0.37	0.48
Simpson Index	0.54	0.24	0.40	0.50	0.45	0.36	0.47	0.51	0.36

b)	left side		right side			left side	right side	far	near
	station 1	station 2	station 3	station 4	Total	station 1+2	station 3+4	station 1+4	station 2+3
n total	294	312	410	315	1331	606	725	609	722
n species	3	3	6	9	12	4	11	10	6
α sup. lim.	0.65	0.64	1.36	2.24	2.27	0.78	2.37	2.21	1.17
α diversity	0.47	0.46	1.00	1.73	1.82	0.57	1.84	1.70	0.90
α inf. lim	0.28	0.28	0.63	1.21	1.36	0.37	1.31	1.19	0.62
Brillouin	0.74	0.70	0.76	0.88	0.80	0.73	0.83	0.84	0.74
Pielou evenness	0.68	0.64	0.43	0.41	0.33	0.53	0.35	0.37	0.42
Simpson Index	0.49	0.50	0.49	0.46	0.48	0.49	0.47	0.47	0.49

Table III: Spring 2004. Multiple regression analysis (with backward elimination method) of different environmental parameters with the most abundant species and total abundance. Abundance, species richness, and α diversity of the Coleoptera community were also correlated with the chosen parameters. Only significant correlations are shown (* = p<0.05; **= p<0.01).

	Constant	Cond. (mS/cm)	pH	Org. mat (%)	Pen. (cm)	Slope (%)	M_z (Φ)	>4mm (%)	R^2
Total Arthropoda									
Tylos europaeus ad							16.468 *		0.491
Tylos europaeus j									
Talitrus saltator ad									
Talitrus saltator j									
Labidura riparia		-102.789 *					40.075 **		0.812
Phaleria acuminata		-404.063 *					177.576 **		0.860
Phaleria bimaculata		-156.211 *					65.159 **		0.729
Coleoptera (n)		-623. 773 *					257.531 **		0.839
Coleoptera species	485.756 *		-56.007 *	6.652 *	-5.249 *		-73.658 *	1.939 *	0.943
α diversity (Cole)	425. 366 *	13.378 *	-50.712 *	-6.747 *	-3.434 *		-70.781 *	2.021 *	0.999

In spring (Table III) multiple regression analysis preformed between total abundance and the tested parameters never showed significant correlations. For crustacean species, a positive correlation with mean grain size occurred only for adults of *T. europaeus*. In the other cases (*L. riparia*, *Phaleria* species, Coleoptera abundance) negative correlations occurred with conductivity and positive ones with mean grain size. In the case of Coleoptera species and α diversity of coleopterans negative correlations were found with pH, penetrability and mean grain size and positive ones with conductivity, organic matter and pebbles > 4mm. In autumn (Table IV) total abundance showed significant correlations with several parameters with negative correlations with pH, organic matter and mean grain size and positive ones with conductivity, penetrability and pebbles > 4mm. For *T. europaeus* (adults) correlations were found with a greater number of parameters compared to spring with negative correlations for conductivity, penetrability and beach slope and positive ones for mean grain size, pebbles > 4mm and organic matter. Juveniles were correlated negatively with pH and beach slope and positively with pebbles > 4mm. *T. saltator* (adults) presented negative and positive correlations with pH and mean grain size respectively. In this season juveniles increased with more looser sand. Coleopteran species never presented significant correlations with the analysed parameters whereas *α* diversity showed similar trends when compared to the previous season except for conductivity and mean grain size where negative and positive correlations were found respectively. *P. acuminata* was correlated negatively with a higher number of parameters (conductivity, pH, beach slope mean grain size) compared to spring whereas *P. bimaculata* only with pH.

DISCUSSION

At Oued Laou the environmental features registered at the different stations reflect the geomorphological characteristics of the area. The meander course of the river in its lower section and the terminal part that turns west running parallel to the shoreline for about one km, indicate that the river outflow was very irregular and quite limited depending on the season and the hydrological regimes of the dams (Rkiouak *et al.* 1997). This terminal section running from south-east to north-west was also under the direct influence of the local dominant marine currents from east (Haïda & Snoussi, 2002). This dynamic was also supported by the grain size analysis registered at the four stations. In fact the stations on the left hand side of the river presented coarser sands compared to those on the right and this was due to the alongshore marine currents that tended to shift the fluvial inputs on this side of the coast. However, the stations farther away from the river mouth registered the finest sand size in relation to the greater amount of time that fine sand remained suspended and consequently was transported farther away. The highest ratios between pebbles and sand occurred at stations 1 and 4 where the input of fluvial sediments had the tendency to decrease. Sand penetrability reflected sand size with looser sand at stations around the river mouth where sand was coarser and with more compact sand at stations farther away where finer sand occurred. A similar trend was found by the same authors on beaches of other Mediterranean areas (Colombini *et al.* in press a). In autumn, the relationship between sand size and penetrability was not so clear and this was probably related to the heavy human impact (trampling, vehicles and camping on the beach), that the area had undergone during summer months. Furthermore, no seasonal or spatial differences ever occurred in the conductivity of the sand indicating that during the two sampling periods the river did not influence this parameters. Comparing mean values of conductivity of Oued Laou with other localities (Colombini *et al.* in press a) lower values were obtained and this was in relation to the occurrence of relatively high beach slopes and coarse sand that prevented the formation of beach pools. Instead the significantly lower pH values that occurred on the right side of the river mouth compared to the left showed the direct influence of the river in particular where its course ran parallel to the shoreline (see station 3). In this case the continuous freshwater filtration through the sand barrier progressively induced a decrease in the pH values. Also the low level of beach slope that occurred at station 3 was due to the presence of the river flowing in the retrodunal area that continuously caused changes of the profile according to the hydrological regime of the river.

The quantitative and qualitative changes in the community structure registered from spring to autumn were mainly caused by the drastic decrease in abundance of *Talitrus saltator* and by the general decrease in species number in relation to their biological cycles. The low abundance of amphipods captured during autumn at Oued Laou contrasts with the general findings of other authors for beaches over the western Mediterranean (Scapini *et al.* 1992, Colombini *et al.* 2005, Fallaci *et al.* 2003, Marques *et al.* 2003) in which an increase in capture frequency always occurred from spring to autumn months. This higher abundance in autumn was mainly due to the birth of a new generation. In the case of Oued Laou the number of adults remained more or less constant between the two seasons, whereas the juveniles decreased about 10% indicating that the autumn sampling period occurred before the second annual breeding season (Marques *et al.* 2003). For the other crustacean species, *Tylos europaeus,* abundance remained constant between seasons and no differences were found between age classes, contrasting with other results in which changes in species abundance had always been recorded (Fallaci *et al.* 1996, Colombini *et al.* 2005). The decrease from spring to autumn in total species richness and species richness of coleopterans confirms a trend already found for other beaches over the Mediterranean and for Smir, a Moroccan locality at about 50 km north of Oued Laou (Colombini *et al.* 2005. However, in spring on the beach of Oued Laou species richness of coleopterans alone (n=33) showed values higher than those of Smir (n=19) and of other localities (Ir-Ramla tat-Torri, Malta n=17, Zouara, Tunisia n=24) but lower than those of Burano, Italy (n= 36) registered for the same season (Colombini *et al.* 2003). This indicates that Oued Laou presents a good habitat quality. Of the Coleoptera, the Tenebrionidae *Phaleria acuminata* and *Phaleria bimaculata* were the dominant species with the former presenting higher captures in spring compared to the latter. The presence of two sympatric species belonging to the same genus that occupy a similar ecological niche is a phenomenon quite common for the *Phaleria* genus (Aloia *et al.* 1999, Fallaci *et al.* 2002, Colombini *et al.* 2005). These species, that apparently present similar characteristics, actually show shifts in life cycles and different adaptations to the beach environment. Furthermore, the higher number of captures registered in autumn was due to the emergence of the new generation during summer-autumn months since these species are typically univoltine (Fallaci *et al.* 2002).

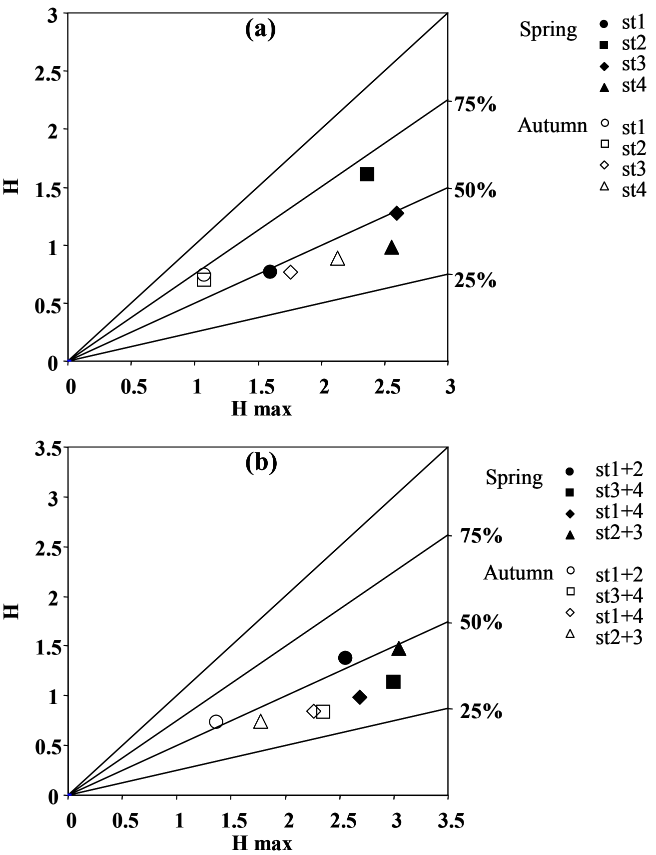

Figure 2: Brillouin (H), Brillouin max, and evenness (J'), plotted in a bidimensional graph (modified from Qinghong 1995), for each station (a) and for cumulated stations (b) in the two seasons. Lines represent evenness values at 100, 75, 50 and 25%.

Table IV: Autumn 2005. Multiple regression analysis (with backward elimination method) of different environmental parameters with the most abundant species and total abundance. Abundance, species richness, and α diversity of the Coleoptera community were also correlated with the chosen parameters. Only significant correlations are shown (*=p<0.05; **=p<0.01;*** =p<0.001).

	Constant	Cond. (mS/cm)	pH	Org. mat (%)	Pen.(cm)	Slope (%)	M_z (Φ)	>4mm (%)	R^2
Total Arthropoda	6161.76**	802.16**	-823.54**	-74.57**	274.56*		-310.50**	22.61*	1
Tylos europaeus ad	194.69***	-169.52***		9.44**	-56.61***	-21.86***	74.74**	2.14**	1
Tylos europaeus j	620.89**		-66.96**			-35.66***		6.38*	0.985
Talitrus saltator ad	4786.83***		-610.69***				134.79*		0.973
Talitrus saltator j	-1114.23**				293.95**				0.738
Labidura riparia	16.04*					-4.24*			0.568
Coleoptera (n)	777.10***		-78.19**						0.825
Coleoptera species									
Phaleria acuminata	400.38**	-91.19*	-32.18*			-14.19*	-39.00*	8.70*	0.989
Phaleria bimaculata	326.69*		-31.79*						0.418
α diversity (Cole)	21. 26*	-24. 62*		1.477 *	-7.00*	-2. 65*	11.34*	16.59*	0.996

Interesting was the significant linear increase that was registered in both seasons for species abundance and richness (of coleoptera) proceeding from the left to the right side of the river mouth. This was particularly evident for the crustaceans and the two species of the *Phaleria* genus. The presence of a lower abundance on the left side of the river compared to the right must be associated with a lower quality of the beach habitat and to a higher human impact. In fact the stretch of coast on the left hand side of the river presented the village of Oued Laou and a tourist settlement recently built directly on the beach that destroyed the natural characteristics of the environment and consequently had a heavy impact on the arthropod community. Evidence that the beach fauna was affected by human disturbance was also given by the higher captures that occurred at station 3 instead of station 4 during autumn sampling. At the latter station, due to the vicinity of the village of Kaa Asrasse, human pressure on the beach environment was higher than that at station 3 especially during summer months where camping and parking activities occurred directly on the beach (personal observations). Caffyn et al. (2002) demonstrated that the distribution of tourist on a sandy beach generally has a gaussian distribution with the mean corresponding to the assess to the beach. For talitrid species it was hypothesised the sandhoppers could move to less impacted areas, that serve as corridors, where they withstand spatially and temporally limited disturbance (Fanini et al. 2005, Weslawski 2000 a, b).

The overall results of Fisher's diversity index calculated for the coleopterans showed higher values for spring compared to autumn confirming the finding obtained for other beach localities (Colombini *et al.* 2006. When comparisons of values were made with these localities in spring the site of Oued Laou ranked relatively high in the list appearing second only after the Tyrrhenian site of Burano. In autumn, however, α diversity dropped to very low values ranking last. This means that Oued Laou still preserves a relatively rich beach community (at least in spring months) but also that disturbance factors become very important with the change of the season.

In spring higher values of α diversity occurred at stations around the river mouth. At station 2 a greater number of staphylinid species (7) were found. These species are generally tied to humid areas or to river banks and for this reason they occurred at this station in a greater number due to the vicinity of the river. Instead, at station 3 the community was mainly composed by tenebrionid, anthicid and carabid species typical of beach dune habitats. In fact this station was the only one that presented a vegetated dune. For autumn season α diversity was highest at station 4 where the number of species was the highest but here the abundance was lower than at station 3 showing that human disturbance affected abundance of species more than species richness.

When the evenness of the coleopteran community was compared between the two seasons at the different stations and at cumulated stations the values remained more or less constant except at station 1 where there was an increase in the value in autumn. This was due to the fact that the two *Phaleria* species were captured in this station with almost the same quantity increasing the uniformity of the community. The low dominance index found for station 2 at spring was mainly due to a high number of species (16) associated with low capture numbers.

The responses of crustacean species to the chemical and physical parameters along the shore were different according to the season and reflected their zonation patterns along the sea-land axis. In fact, in spring the absence of a response of these species to the beach parameters was in relation to the more homogeneous conditions of the beach along the shore due to rainfall that occurred in this period of the year. So species distribution, with increasing abundance on the right side compare to the left, was not so much related to the beach parameters but was based on the lower human impacts on this side of the river. Instead in autumn, after a dry period, there was a non homogeneous distribution of the conditions along the sea-land axis that imposed choices to the crustaceans. In fact the intensity of the response depends on the zonation patterns (Colombini *et al.* 2002) with the more seaward species, *T. saltator* and in particular its juveniles, responding less to the beach parameters compared to the two age classes of *T. europaeus* zoned more landwards. Talitrids generally inhabit areas where risks of dehydration were low and shifted their zonation according to substrate moisture both during the active (Fallaci *et al.* 1999) and resting phase (Fallaci *et al.* 2003). Consequently, amphipods were less conditioned by the other beach parameters. Contrarily, adults of *T. europaeus* preferred flatter beach areas with finer sand associated to a higher percentage of large pebbles and higher contents of organic matter. Previous data on micro-scale spatial distribution of *T. europaeus* showed similar correlations with the tested parameters indicating a good correspondence of the data (Colombini *et al.* 2005). The more landward species, the two *Phaleria* species and *Labidura riparia*, showed similar preferences to sand parameters also in spring. There was a tendency to occupy areas with finer sand and lower conductivity. This was probably related to the species needs of finding adequate areas where eggs could be deposited since this was the season when breeding occurred (Fallaci *et al.* 2002). In a previous study carried out on the French Atlantic coast (Colombini *et al.* 1996) it had been demonstrated that for *L. riparia* and *Phaleria cadaverina* substrate moisture was a limiting factor of minor importance when compared to *T. europaeus*. In autumn the difference in the responses found between the two *Phaleria* species indicate intrinsic differences as shown for other sympatric *Phaleria* species living on a Tyrrhenian sandy beach (Aloia *et al.* 1999, Fallaci *et al.* 2002, Colombini *et al.* 2005).

In addition, abundance, species richness and α diversity of Coleoptera varied according to the environmental parameters. Coleoptera abundance substantially was in accordance with the results of the two *Phaleria* species being total numbers mainly represented by these two species. For species richness the absence of significant correlations in autumn was mainly due to the low number of species found whereas in spring higher number of species occurred where trophic resources were more abundant and pH values were lower. In fact McLachlan (1991) states that in sandy beach environments proceeding from sea landwards species numbers increase with increasing organic matter and decreasing pH values. Thus, it can be hypothesised that also longshore distribution patterns of the species can be regulated by the same factors. The differences found in the two seasons in the correlations between α diversity and environmental parameters were mainly caused by seasonal changes in the community structure where not only species but also family numbers changed imposing different strategies.

As conclusion, this work indicates the importance of the Oued Laou River in structuring the environmental characteristics of the sandy beaches. Differences in beach parameters were found not only at stations on the left side of the river compared to those on the right but also between stations near and far. Seasonal and spatial differences occurred in species abundance and richness. Seasonal differences were certainly due to the species biological cycles but also to the heavy human disturbance that occurred during summer months that decreased population abundance. Also the difference in abundance that occurred between the two sides of the river was related to the different human impacts that occurred on the beaches and to the presence of a relict dune. Species responses to environmental parameters depended on the beach fascia occupied (insects) and on the physiological conditions (age, reproductive phase) with seaward species responding less than landward ones (crustaceans). The relatively high value of α diversity of spring indicated a good beach quality as compared to other localities. However, the great decrease of this value as the season changed showed that the beaches around the Oued Laou River were subjected to several disturbance factors indicating the needs of urgent management plans.

Acknowledgements
This research was funded by the Bilateral projects Italy-Morocco CNR-CNRST 2002-2003, 2004-2005, and the European Community (Med-Core Project ICA3-2002-10003). We would like to thank the local Authorities for their assistance.

References

Aloia A., Colombini I., Fallaci M. & Chelazzi L., 1999. Behavioural adaptations to zonal maintenance of five species of tenebrionids living along a Tyrrhenian sandy shore. *Mar. Biol.* 133, 473-487.

Bally R., 1983. Factors affecting the distribution of organisms in the intertidal zones of sandy beaches. *In*: McLachlan, A. & Erasmus, T. (eds) *Sandy beaches as Ecosystems* W. Junk, The Hague, 391-403.

Barusseau J.P., Bâ M., Descamps C., Diop E.S., Diuof B., Kane A., Saos J.L. & Soumaré A., 1998. Morphological and sedimentological changes in the Senegal River estuary after the construction of the Diama dam. *J. Afr. Earth Sci.* 26(2), 317-326.

Bonora N., Immordino F., Schiavi C., Simeoni U., & Valpreda E., 2002. Interaction between catchment basin management and coastal evolution (Southern Italy) *J. Coast. Res. -SI* 36, 81-88.

Black, C.A., 1965. Methods of soil analysis. Vol 2, *Am. Soc. Agr.* Madison, Wisconsin 1572 pp.

Brillouin L., 1962. *Science and Information Theory.* (2nd ed.). New York: Academic Press 351 pp.

Caffyn A., Prosser B. & Jobbins G., 2002 Socio-economic analysis of sites. In Scapini F. (ed.) Baseline research for the intergrated sustainable management of Mediterranean sensitive coastal ecosystems. A manual for coastal managers, scientists and all those studying coastal processes and management in the Mediterranean. IAO, Florence 167-184.

Colombini I., Aloia A., Bouslama M.F., El Gtari M., Fallaci M., Ronconi L., Scapini F. & Chelazzi L., 2002. Small-scale spatial and seasonal differences in the distribution of beach arthropods on the northern Tunisian coast. Are species evenly distributed along the shore? *Mar. Biol.* 140, 1001-1012.

Colombini I., Fallaci M., Milanesi F., Scapini F. & Chelazzi L., 2003. Comparative diversity analysis in sandy littoral ecosystems of the Western Mediterranean. *Estuar. Coast. Shelf Sci.*, 58S, 93-104.

Colombini I, Fallaci M & Chelazzi L., 2005. Micro-scale distribution of some arthropods inhabiting a Mediterranean sandy beach in relation to environmental parameters. *Acta Oecol.* 28, 249-265.

Colombini I., Chaouti A., Fallaci M., Gagnargli E., Scapini F., Bayed A. & Chelazzi L., 2006. Effects of freshwater discharge on terrestrial arthropods in Atlantic and Mediterranean sandy shores. *In* Scapini F. (Ed.) – Proceedings of the MEDCORE International Conference Florence 10-14 November 2005, Firenze University Press, 237-265.

Colombini I., Bouslama M. F., El Gtari M., Fallaci M., Scapini F. & Chelazzi L., 2005. Study of the community structure of terrestrial arthropods of a Mediterranean sandy beach ecosystem of Morocco. *In* : Bayed A. & Scapini F. (Eds) – *Ecosystèmes côtiers sensibles de la Méditerrané : cas du littoral de Smir*. *Trav. Inst. Sci.* série générale, 4, 43-54.

Defeo O. & McLachlan A. 2005. Patterns, processes and regulatory mechanisms in sandy beach macrofauna: a multi-scale analysis. *Mar. Ecol. Prog. Ser*. 195, 1-20.

Degraer S., Volkaert A. & Vincx M. 2003. Macrobenthic zonation patterns along a morphodynamical continuum of macrotidal, low bar/rip and ultra-dissipative sandy beaches. *Estuar. Coast Shelf Sci.*, 56, 459-468.

Fallaci M., Colombini I., Taiti S., & Chelazzi L. 1996. Environmental factors influencing the surface activity and zonation of *Tylos europaeus* (Crustacea: Oniscidea) on a Tyrrhenian sandy beach. *Mar. Biol.* 125, 751-763.

Fallaci M., Aloia A., Audoglio M., Colombini I., Scapini F. & Chelazzi L. 1999. Differences in behavioural strategies between two sympatric talitrids (Amphipoda) inhabiting an exposed sandy beach of the French Atlantic coast. *Estuar. Coast. Shelf Sci*., 48: 469-482.

Fallaci M., Aloia A., Colombini I. & Chelazzi L. 2002. Population dynamics and life history of two *Phaleria* species (Coleoptera, Tenebrionidae) living on the Tyrrhenian sandy coast of central Italy. *Acta Oecol*. 23, 69-79.

Fallaci M., Colombini I., Lagar, M., Scapini F. & Chelazzi L. 2003. Distribution patterns of different age classes and sexes in a Tyrrhenian population of *Talitrus saltator* (Montagu). *Mar. Biol.* 142,101-110.

Fanini L., Martín Cantarino C. & Scapini F. 2005. Relationships between the dynamics of two *Talitrus saltator* populations and the impacts of activities linked to tourism. *Oceanol*., 47, 93-112.

Fisher R.A., Corbet A.S. & Williams C.B., 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. *J. Anim. Ecol.* 12**,** 42-58.

Folk R.L. & Ward W.C., 1957. Brazos river bar: a study in the significance of grain size parameters. *J. Sedim. Petrol*. 27, 3-26.

Haïda S. & Snoussi M. 2002. Problèmes d'érosion du littoral méditerranéen marocain et techniques de réhabilitation. *In*: CIESM, 2002. Erosion littorale en Méditerranée occidentale : dynamique, diagnostic et remèdes. *CIESM Workshop Series*, 18, 49-52.

Hay W.W. 1998. Detrital sediment fluxes from continents to oceans. *Chem. Geol.*145, 287-323.

Krüger O. & McGavin G.C. 1997. The insect fauna of *Acacia* species in Mkomazi game reserve, north-east Tanzania. *Ecol. Entomol.* 22, 440-444.

Lercari D. & Defeo O. 2003. Variation of a sandy beach macrobenthic community along a human -induced environmental gradient. *Estuar. Coast. Shelf Sci*., 58S, 17-24.

Lercari D., Defeo O. & Celentano E. 2002. Consequences of a freshwater canal discharge on the benthic community and its habitat on an exposed sandy beach. *Mar. Pollut. Bull.* 44, 1397-1404.

McLachlan A. 1991. Ecology of coastal dune fauna. *J. Arid Environ*. 21.229-243.

Marques J.C., Gonçalves S.C., Pardal M.A., Chelazzi L., Colombini I., Fallaci M., Bouslama M. F., El Gtari M., Charfi-Cheikhrouha F. & Scapini F. 2003. Comparison of *Talitrus saltator* (Amphipoda, Talitridae) biology, dynamics and secondary production in Atlantic (Portugal) and Mediterranean (Italy and Tunisia) populations. *Estuar. Coast. Shelf Sci*., 58S: 127-148.

Pielou E.C. 1978. *Population and community ecology: principles and methods.* Gordan and Breach Science Publishers, New York, 424 p.

Probst J.L. & Amiot Suchet P. 1992. Fluvial suspended sediment transport and mechanical erosion in the Maghreb (North Africa). *Hydrol. Sci.* 37, 621-637.

Qinghong L. 1995. A model for species diversity monitoring at community level and its application. *Environ. monit. assess.*, 34, 271-284.

Rkiouak S., Pulido-Bosch A. & Gaiz A. 1997. Potentialités hydrogéologiques d'une plaine littorale marocaine (Oued Laou, Tetouan-Chefchaouen). *Hydrolog. Sci. J*. 42, 101-118.

Scapini F., L. Chelazzi, I. Colombini & M. Fallaci 1992. Surface activity, zonation and migrations of *Talitrus saltator* (Montagu, 1808) on a Mediterranean beach. *Mar. Biol.* 112, 573-581.

Shannon C.E. & Weaver W., 1949. *The mathematical theory of communication*. University of Illinois Press, Urbana. 225 p

Simeoni U. & Bondesan M. 1997. The role and responsibility of man in the evolution of the Italian Adriatic coast. *In* Briand F. & Maldonado A (eds) Transformations and evolution of the Mediterranean coastline; CIESM Science Series *Bull. Inst. Océanogr. Spéc*. 18, 111-132.

Simpson E. H. 1949 Measurement of diversity. *Nature* 163, 688.

Snoussi M., Haïda H. & Imassi S. 2002. Effects of the construction of dams on the water and sediment fluxes of the Moulouya and Sebou rivers, Morocco. *Reg. Environ. Change*, 3, 5-12.

Wesławski J.M., Kupidura T. & Zabicki M. 2000a, Sandhoppers, *Talitrus saltator* (Montagu 1808) (Amphipoda, Gammaridea), at the Polish Baltic coast: seasonal and spatial distribution patterns, *Crustaceana*, 73 (8), 961–969.

Węsławski J.M., Stanek A., Siewert A. & Beer N. 2000b, The sandhopper *(Talitrus saltator*, Montagu 1808) on the Polish Baltic coast. Is it a victim of increased tourism? *Oceanol. Stud*., 24 (1), 77–87.

Williams C.B. 1947 The logarithmic series and its application to biological problems. *J. Anim. Ecol.* 34, 253-272.

Manuscrit reçu le 5 juin 2006