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Study of the community structure of terrestrial arthropods of a Mediterranean sandy beach ecosystem of Morocco

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Abstract. Along the northern coast of Morocco an ecological study was conducted on the beach dune system of Restinga Smir (Province of Tétouan). Diversity monitoring, achieved through the study of the community structure of terrestrial arthropods, was carried out to assess the present state of the beach. Surveys were conducted in two different seasons (spring, autumn) using standard trapping techniques with pitfall cross traps along transects perpendicular to the shoreline. The fauna associated with the vegetation was assessed using mobile cages of 1 m^3. Only Isopoda and Coleoptera were chosen to be further analysed. Species were studied both quantitatively and qualitatively in the different zones and seasons using ecological coefficients (relative abundance) and Fisher's diversity index. The evenness of the community through Pielou-Brillouin method was calculated together with Simpson's dominance index. The results indicate that the arthropod communities of the beach dune system of Restinga Smir present general trends similar to those found on other beaches over the Mediterranean, which were studied with the same methods. However, the beach is suffering from several human impacts that have caused losses in habitats and thus in species richness. The study stresses the needs for correct management strategies to enhance the protection of this area.

Key words: Mediterranean beach-dune system, arthropods, species richness, diversity indices.

Etude de la structure du peuplement des arthropodes terrestres de l'écosystème d'une plage méditerranéenne du Maroc.

Résumé. Sur la côte nord du Maroc, une étude écologique a été menée sur le système plage-dune de la région de Restinga Smir (Province de Tétouan). Le suivi de la diversité à travers l'étude de la structure du peuplement d'arthropodes terrestres a été réalisé pour établir un état de référence de la plage. Les recherches ont été effectuées au printemps et en automne en utilisant des techniques de piégeage standards disposés en croix le long de transects perpendiculaires au rivage. La faune associée à la végétation a été étudiée en utilisant des cages mobiles de 1 m^3. Seuls les Isopodes et les Coléoptères ont fait l'objet d'analyses poussées. Les espèces ont été étudiées quantitativement et qualitativement dans les différentes zones et selon les saisons en utilisant des coefficients écologiques (abondance relative) et l'indice de diversité de Fisher. L'équitabilité du peuplement, évaluée par la méthode de Pielou-Brillouin et l'indice de dominance de Simpson ont été calculés. Les résultats indiquent que le peuplement d'arthropodes du système de plage-dune de Restinga Smir présente des tendances générales similaires à celles trouvées sur d'autres plages autour de la Méditerranée et qui ont été étudiées avec les mêmes méthodes. Cependant, la plage souffre de plusieurs impacts humains qui ont causé des pertes dans les habitats et donc dans la richesse spécifique. L'étude insiste sur les besoins en stratégies d'une gestion correcte pour rehausser le niveau de protection de cette région.

Mots clés : sytème plage-dune méditerranéen, arthropodes, richesse spécifique, indices de diversité.

INTRODUCTION

Within the framework of an integrated study carried out on several Mediterranean beach-dune systems by an international research project ("Bases for an Integrated Sustainable Management of Mediterranean Sensitive Coastal Ecosystems", MECO Project, EU Contract N° ERB IC 18-CT98-0270, 1999-2001) a baseline study was conducted on the beach of Restinga Smir along the northwest coast of Morocco near Tétouan. The aim of the research was to provide information on the present state of the beach through the study of species assemblages and, in particular, of significant terrestrial arthropod communities of the beach ecosystem. The urge to study the present state of beach environments was based on the fact that recently over the entire Mediterranean basin, an increasing number of beach ecosystems had rapidly become degraded and impoverished in species. The main impacts were all associated with human exploitation consisting in urbanisation, industrial and agricultural encroachments, tourist settlements (hotels, villages) and uses for recreational purposes. However, losses in species diversity had also been caused by another phenomenon, common to many beaches, consisting in the homogenisation of the habitat (Niemelä 2000). This generally occurred when certain management strategies, such as forestation of the dunes, were chosen to solve other more urgent problems (sand transportation, dune mobility, salinisation of valuable agricultural areas of the back-dune) or simply for economical reasons (high income from timber). Thus an assessment of the state of the beach of Smir through the study of the community structure of terrestrial arthropods, together with other multidisciplinary studies achieved at the same site by different teams of the project, seemed important. In fact, monitoring should not be an end to itself but a means to an end, and its aim should be to provide baseline data for decision makers for a sustainable management of this particular beach ecosystem.

Generally, diversity monitoring may be conducted on a vast range of ecological scales using a variety of techniques (surveying, cataloguing, quantifying) and mapping entities (Stork & Samways 1995, Niemelä 2000). Here, relevant arthropod communities were used to assess levels of diversity as they represented a major fauna component of the beach ecosystem. To determine the status of the beach of Smir or its changes in diversity over time and space the distribution and abundance of organisms and their associations with the physical environment was assessed across the beach from the shoreline to the dune in two different seasons. In Mediterranean areas not much work has been accomplished on terrestrial macrofauna of sandy beaches, (Angelier 1950, Binaghi 1964, Bigot *et al*. 1982, Ponel 1983, Fallaci *et al*. 1994, Giménez Casalduero & Esteve Selma 1994). Recently a comparative diversity study of five beach localities along the Mediterranean coasts has been carried out (Colombini *et al.* 2003). On the Moroccan Atlantic coast an ecological study was accomplished on the vegetation of the Mehdia reserve (Atbib 1983) whereas the Coleoptera community of the beach dune system of Sidi Boughaba had been analysed by Idrissi (1982). The present work adds important information on how species richness and abundance change over space and time on the beach dune system of Smir.

MATERIALS AND METHODS

Study site

The study area of Smir lies on the northern Moroccan coast, north of the town of M'Diq and consists in a beach dune system. Inland, the recent construction of a dam that conveys the waters of Oued Smir, has entrapped vital terrigenous sediments important for the nourishment of the beach-dune system and consequently has severely damaged the entire system. Furthermore, tourism development has increased the urban settlement of M'Diq and has led to heavy land-cover changes of the sandy coast between Cabo Negro and Fnideq (about 20 km). The only area that still conserved the original beach-dune features was located on the right hand side of the Kabila port. This area (35°42'55"N; 05°20'05"W), chosen as study site, presented a beach 55 m in width with a supralittoral (about 30 m) provided of abundant pioneer plants. The beach presented a mean slope of 9% and an orientation axis of 170°-350°. Mean tidal excursions were from 30 to 70 cm at neap and spring tide respectively. Mean grain size value was of 1.413 ϕ, mean value of inclusive graphic standard deviation, of inclusive graphic skewness and of graphic kurtosis was 0.859 ϕ, -0.276, and 1.346 respectively. According to McLachlan's (1980) rating scheme for assessing the degrees of exposure, this beach scored 12.5 and thus must be considered exposed. The dune, 7 m in height, was characterised by typical vegetation. The vegetation of the foredune consisted of *Ammophila littoralis, Pancratium maritimum, Elytrigia juncea, Calystegia soldanella, Eryngium maritimum, Cakile maritima, Mesembryanthemum* sp., whereas the summit of the dune and the backdune were characterised by *Juniperus phoenicea*, *Helichrysum stoechas, Pistacea lentiscus, Pancratium maritimum, Elytrigia juncea, Smilax aspera.* Landwards, *Eucalyptus* sp. was recently planted on the backdune (zone near the main road).

Sampling procedures

In May and October 2000 a survey was conducted on the Smir beach. A standard trapping system using pitfall traps along two transects (A, B) was used (Fig. 1). For each transect, 7 pitfall cross traps, which caught animals coming from the shoreline, the dune and the two longshore directions, were placed from sea towards land every ten meters on the eulittoral and every 20 m on the supralittoral and dune. These consisted of pitfall traps made by plastic cups (20 cm high and 10 cm in diameter) pushed in the sand to their rim and connected to one another by fibreglass bands (10 cm in height and 5 m long). According to the morphology of the beach, the transects were subdivided in four zones: eulittoral (traps 1-2), supralittoral (traps 3-4) seaward face of the dune (traps 5-6), and landward face of the dune (trap 7). Transects were kept active 72 consecutive hours, during which recognisable taxa were counted and registered. These animals were then released at the end of the sampling period.

To evaluate the macrofauna/plant biomass ratio, mobile cages of unitary units (1 m^3) were used (Lamotte & Bourlière 1969). The fauna present in 1 m^3 of vegetation was caught and the corresponding vegetation was weighed (fresh weights).

All samples which needed further analysis for identification were fixed in 75% alcohol and stored in the laboratory. In the laboratory, material was sorted under binocular microscopes and species were identified to order level. The Isopoda and Coleoptera alone were chosen to be sorted further. The choice of these two orders was based on the fact that Isopoda presented a greater number of species if compared for example to Amphipoda and Coleoptera were the most representative of the beach-dune system. Individuals were sorted with the criteria of the morphologically recognisable taxonomic units (RTUs) (Krüger & McGavin 1997). Since determination at species level is extremely time consuming because often samples must be sent to specialists, this method permits to have an idea of the number of species present in a sample, even if species names are not given. This method consisted in subdividing each order at family level and then in grouping the different species of each family with conventional names (family name 1, 2, 3 etc.).

The positions of transects were calculated with a GPS. Beach profiles and orientation were registered in correspondence to transects. Sand samples were taken in correspondence to each trap to evaluate grain size. Mean tidal excursions were calculated through Admiralty Tide Tables.

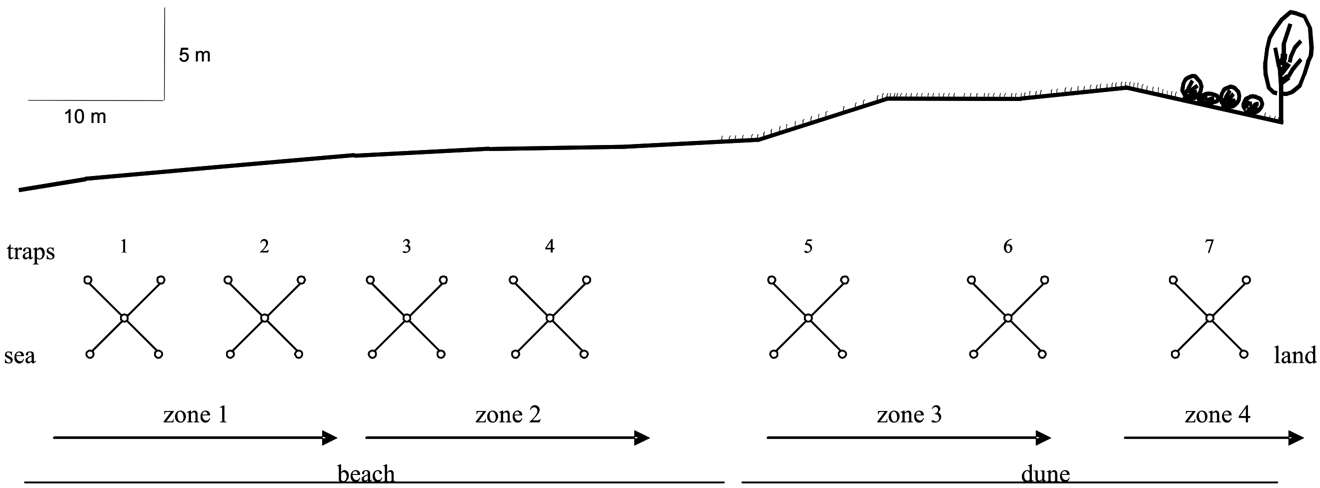

Figure 1. Schematic representation of the pitfall cross traps on the beach dune system of Smir.

Data analysis

Ecological coefficients such as relative abundance may be used to provide an estimate of how the community is structured (Van Heerdt & Mörzer-Bruyns 1960, Bigot & Bodot 1973, Ponel 1983). These were calculated for the Coleoptera and the Isopoda during the two seasons, on the total and for each zone. These involved estimating the abundance of individual species, as a function of the total number of individuals gathered in a particular zone or season. Species were then grouped as Abundant (A≥5%), Influent (2%≤A<5%) and Recedent (A< 2%).

Diversity indices were calculated and were used to identify species richness. The analysis was carried out on a seasonal basis both on the beach and on the dune. Fisher *et al.*'s (1943) α diversity index was used and confidence limits were calculated using the standard error given in Williams (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.

RESULTS

Pitfall cross traps captured a total of 13834 arthropods in May and 37807 in October. In May, the most abundant arthropods were the Isopoda (37.72%) followed by the Collembola (26.25%) the Hymenoptera (12.30%) and the Amphipoda (9.44%). The Coleoptera represented only 5.02% of total captures. In October the Collembola was the most abundant class with 72.35% of total captures. This was followed by the Amphipoda and Isopoda with 13.57% and 10.4% of total captures respectively. The Coleoptera represented only 0.84% whereas the other categories did not reach values over 1%.

Considering the captures with pitfall traps on the beach and dune separately (Figure 2a), it is clear that in May some categories such as Acarina, Amphipoda, Coleoptera and their larvae and Isopoda were mainly present on the beach whereas the remaining categories presented higher captures on the dune. In October (Fig. 2b) the arthropod categories were distributed with a similar pattern with the exception of the Collembola and Diptera that presented higher concentrations on the beach.

In May, mobile cages captured 636 arthropods (Fig. 2c) and the main categories tied to the vegetation of the dune were the Collembola (41.19%) and the Hymenoptera (12.73%) followed by Araneae (10.69%), Coleoptera (9.90%) and Hemiptera (9.11%). In October, total captures were lower (n=160) (Fig. 2d) and in this case the most represented categories were Araneae (24.37%), Coleoptera (16.25%) and Pseudoscorpiones (10.62%).

In May, the number of individuals found in 1 cube metre of vegetation was 212 ind./m^3. In this same volume an average of 4686.3 g of plant material was collected and this corresponded to 45.23 ind./kg of plant material. In October, 53.3 ind/m^3 were captured in 1 cube metre of vegetation containing 1018.3 g of plant material and this corresponded to 52.37 ind./kg of plant material.

Comparing the single categories captured with pitfall traps within each area (beach and dune) (Fig. 3), the most abundant categories (Amphipoda, Collembola and Isopoda) were considered separately. In this case, the Collembola were always the most abundant category except in May on the beach where the Isopoda were dominant (Fig. 3c). Comparing the other categories on the beach and in the two seasons, in May (Fig. 3a) the Hymenoptera was the most abundant category followed by Coleoptera, Acari and Araneae, whereas in October (Fig. 3e) the Diptera took the Hymenoptera's place in abundance and the other categories followed with a pattern similar as in May. On the dune, in May (Fig. 3b), again the Hymenoptera was the most abundant taxon followed by the Diptera and Coleoptera, whereas in October (Fig. 3f) the Araneae dominated the scenario followed by Coleoptera, Diplopoda and Hymenoptera. Of all captured arthropods only the Coleoptera and Isopoda were furthered analysed. In May, 695 Coleoptera, belonging to 17 families, were captured whereas in October capture numbers decreased to 319 and were represented by 13 families. For the Isopoda only four families represented the 5219 captured individuals of May whereas in October the 3933 sampled Isopoda belonged to three families.

The results of the abundance analysis at Smir calculated for the Coleoptera and the Isopoda during the two seasons, on the total and for each zone, are reported in tables I-II and III-IV respectively.

During the entire study period, 47 species were collected of which 36 species in May and 29 in October. In spring (Tab. I) three species, belonging to the Tenebrionidae family, were classified as abundant: Te 29 (*Phaleria acuminata*), Te 1 (*Erodius*) and Te 8 with 44.46%, 25.61% and 7.05% respectively. The influent species were represented by a Carabidae Ca 36 (*Scarites buparius*, 4.17%), a Staphylinidae St 5 (*Phytosus nigriventris*, 2.3%) and a Tenebrionidae Te 7 (2.3%). The remaining 30 species were all classified as recedent species. In October there was an increase of abundant species, with the Curculionidae (Cur 25) reaching 23.51%, *Phytosus nigriventris* increasing to 16.30%, the Cryptophagidae (Cr 1 *Cryptophagus* sp.) 13.16% followed by *Phaleria acuminata* (slightly decreased to 11.28%), the Carabidae (Ca 11) of the *Amara* genus

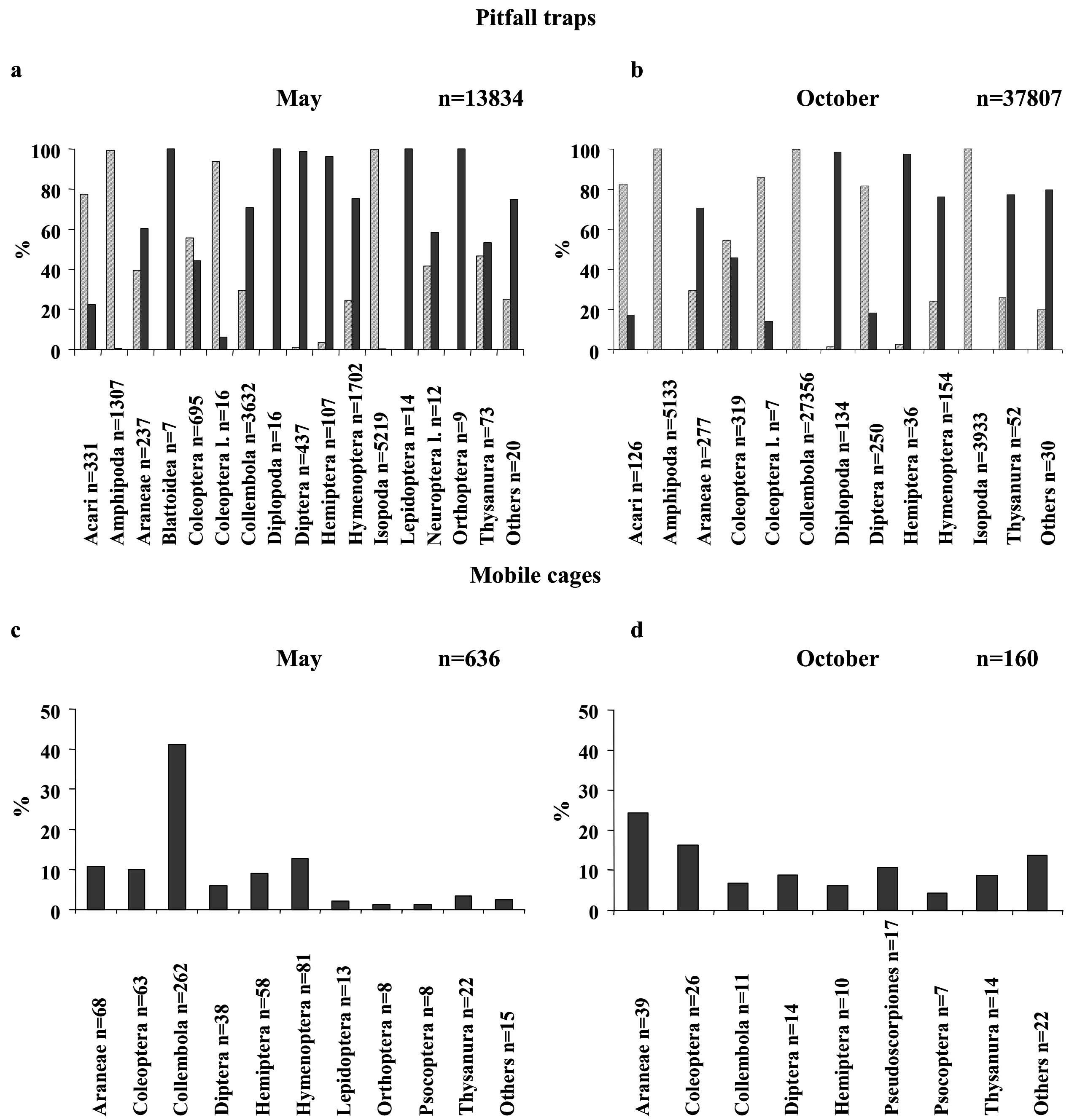

Figure 2. Percentage of captures of each taxon sampled at Smir within the beach (black areas) and dune (dashed areas) zones during the two seasons using pitfall cross traps (a, b) and mobile cages (c, d).

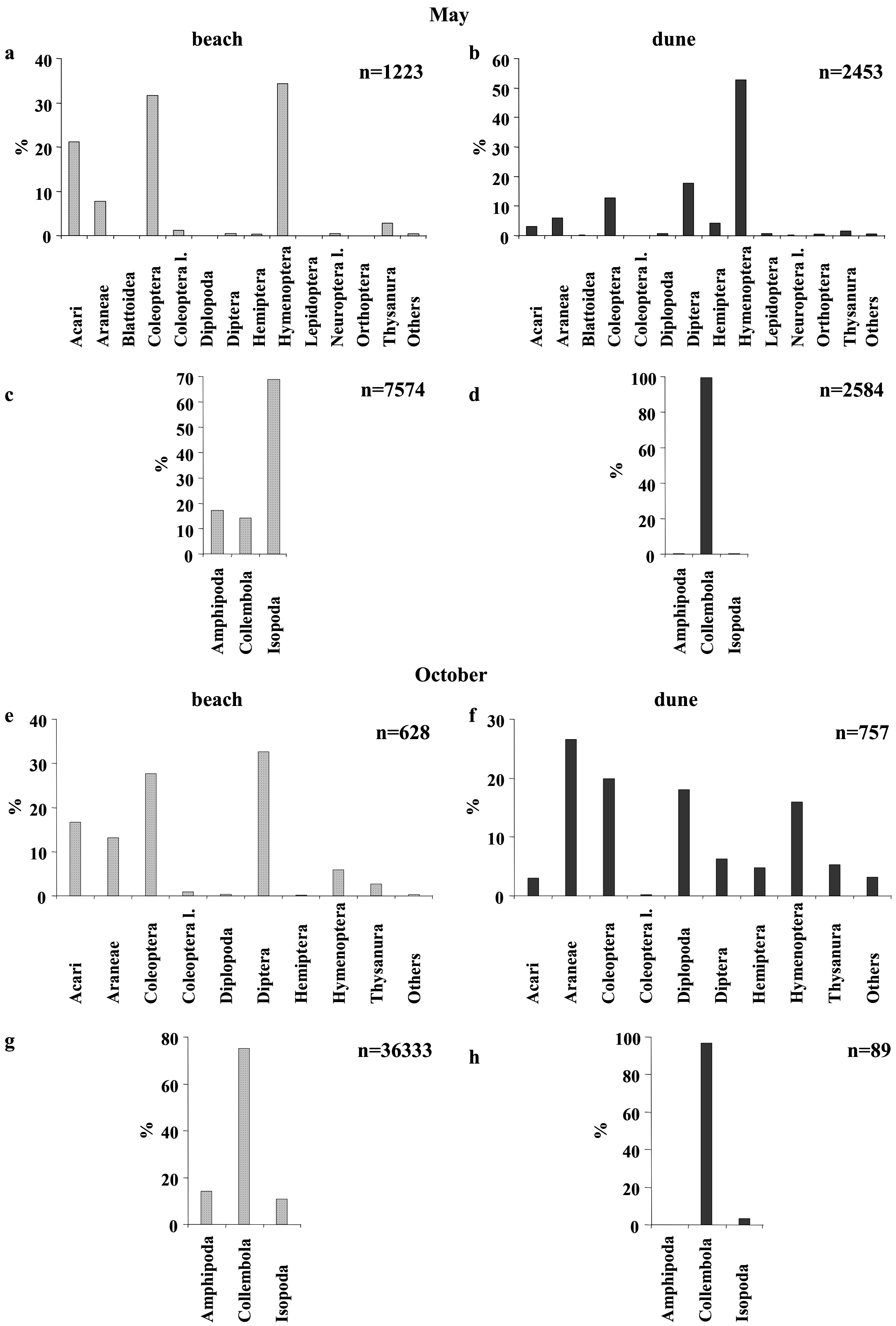

Figure 3. Percentage of captures of the different taxa sampled at Smir using pitfall cross traps calculated for the beach and dune zones separately during May (a-d) and October (e-h). The percentage of the Amphipoda, Isopoda and Collembola are shown separately, because of the high numbers.

(9.72%) and the Tenebrionidae (Te 15) of the *Xanthomus* genus (6.27%). Note that in May Cur 25, Cr 1 and Ca 11 were recedent species. The abundance of these species on the beach-dune system in autumn is principally related to their biological cycle. The same can be said for Te 8 that in October becomes influent showing that its presence is tied to spring-summer months.

Of the species found abundant in May (Tab. I), *Phaleria acuminata* was abundant exclusively on the beach zones (zones 1 and 2) whereas *Erodius* sp., being a more mobile species, was abundant in zone 2 and in the zones of the dune (zones 3 and 4) (Tab. II). The third abundant tenebrionid species of May was Te 8 that was present only on the dune zones. In October, the Curculionidae (Cur 25) was abundant in all four zones with higher values on the two zones of the dune (Tab. II). *Phytosus nigriventris* and *Phaleria acuminata,* being typical beach species, concentrated their presence in zones 1 and 2, whereas *Cryptophagus* sp. and *Xanthomus* sp. were tied to the vegetation of the high supralittoral (zone 2) and of the foredune (zone 3). Finally, *Amara* sp., a typical dune species was abundant on the two dune zones.

For the Isopoda (Tab. III) a total 6 species were sampled of which 5 in May and 3 in October. In both seasons the most abundant species was *Tylos europaeus* with 99.85% and 99.79% in May and October respectively. This species was found only on the two zones of the beach (Tab. IV). All other species were classified as recedent (Tab. III). C*tenoscia* sp., *Eluma purpurescens*, *Armadillo officinalis* and *Porcellionides pruinosus*, normally occupied more inland areas (Tab. IV) compared with *Tylos europaeus,* and the first three occurred in the samplings only during spring months

Table I. Abundance analysis of the Coleoptera found at Smir on the total of the sampled zones during the two seasons.

	May	N=695			October	N=319	
Abundant	Tenebrionidae	Te 29	44.460	Abundant	Curculionidae	Cur 25	23.511
		Te 1	25.612		Staphylinidae	St 5	16.301
		Te 8	7.050		Cryptophagidae	Cr 1	13.166
					Tenebrionidae	Te 29	11.285
					Carabidae	Ca 11	9.718
					Tenebrionidae	Te 15	6.270
Influent	Carabidae	Ca 36	4.173	Influent	Staphylinidae	St 13	2.821
	Staphylinidae	St 5	2.302		Histeridae	Hi 1	2.194
	Tenebrionidae	Te 7	"		Tenebrionidae	Te 8	"
Recedent	Carabidae	Ca 37	1.727	Recedent	Scarabaeidae	Sc 5	1.567
		Ca 16	1.439		Chrysomelidae	Ch 3	1.254
	Cucujidae	Cu 1	1.007		Anthicidae	An 4	0.940
	Curculionidae	Cur 25	"		Curculionidae	Cur 4	"
	Carabidae	Ca 11	0.863		Ptiliidae	Pt 1	"
	Cryptophagidae	Cr 1	"		Staphylinidae	St 11	"
	Histeridae	Hi 1	"		Carabidae	Ca 10	0.627
	Elateridae	El 6	0.576		Chrysomelidae	Ch 7	"
	Staphylinidae	St 4	"		Histeridae	Hi 3	"
	Curculionidae	Cur 4	0.432		Ptiliidae	Pt 2	"
	Malachidae	Ma 1	"		Tenebrionidae	Te 7	"
	Scarabaeidae	Sc 5	"		Anthicidae	An 1	0.313
	Staphylinidae	St 13	"		Carabidae	Ca 32	"
	Anthicidae	An 1	0.288		Chrysomelidae	Ch 6	"
	Carabidae	Ca 23	"		Cicindelidae	Ci 1	"
	Coccinellidae	Co 1	"		Clambidae	Cl 2	"
	Elateridae	El 7	"		Elateridae	El 7	"
	Scarabaeidae	Sc 2	"		Histeridae	Hi 2	"
		Sc 7	"		Staphylinidae	St 4	"
	Tenebrionidae	Te 16	"		Tenebrionidae	Te 1	"
	Carabidae	Ca 10	0.144				
		Ca 32	"				
	Cicindelidae	Ci 1	"				
	Curculionidae	Cur 23	"				
	Hydrophilidae	Hyd 2	"				
	Lathridiidae	La 1	"				
	Ptinidae	Pti 2	"				
	Scarabaeidae	Sc 9	"				
	Scirtidae	Sci 1	"				
	Staphylinidae	St 2	"				

Table II. Abundance analysis of the Coleoptera found at Smir in each of the sampled zones during the two seasons.

Zone 1	May (N=205)				October (N=57)			
	Abundant	Tenebrionidae	Te 29	83.902	Abundant	Staphylinidae	St 5	63.158
		Staphylinidae	St 5	6.341		Tenebrionidae	Te 29	22.807
		Carabidae	Ca 37	5.854		Curculionidae	Cur 25	5.263
					Influent	Cryptophagidae	Cr 1	3.509
	Recedent	Cryptophagidae	Cr 1	0.976	Recedent	Anthicidae	An 4	1.754
		Scarabaeidae	Sc 7	"		Cicindelidae	Ci 1	"
		Carabidae	Ca 10	0.488		Ptiliidae	Pt 1	"
		Cicindelidae	Ci 1	"				
		Hydrophilidae	Hyd 2	"				
		Tenebrionidae	Te 7	"				
Zone 2	May (N=181)				October (N=116)			
	Abundant	Tenebrionidae	Te 29	75.691	Abundant	Cryptophagidae	Cr 1	25.000
			Te 7	7.182		Tenebrionidae	Te 29	19.828
			Te 1	5.525		Curculionidae	Cur 25	18.103
						Staphylinidae	St 5	12.931
						Tenebrionidae	Te 15	11.207
						Histeridae	Hi 1	6.034
	Influent	Cryptophagidae	Cr 1	2.210				
	Recedent	Staphylinidae	St 5	1.657	Recedent	Chrysomelidae	Ch 7	1.724
		Carabidae	Ca 11	1.105		Ptiliidae	Pt 1	"
			Ca 16	"			Pt 2	"
		Coccinellidae	Co 1	"		Anthicidae	An 1	0.862
		Cucujidae	Cu 1	"		Staphylinidae	St 13	"
		Curculionidae	Cur 25	"				
		Anthicidae	An 1	0.552				
		Curculionidae	Cur 23	"				
		Histeridae	Hi 1	"				
		Scarabaeidae	Sc 9	"				
Zone 3	May (N=196)				October (N=99)			
	Abundant	Tenebrionidae	Te 1	57.143	Abundant	Curculionidae	Cur 25	34.343
			Te 8	11.735		Carabidae	Ca 11	20.202
		Carabidae	Ca 36	9.694		Cryptophagidae	Cr 1	11.111
						Tenebrionidae	Te 15	7.071
	Influent	Carabidae	Ca 16	3.571	Influent	Scarabaeidae	Sc 5	4.040
		Curculionidae	Cur 25	2.551		Staphylinidae	St 13	3.030
		Carabidae	Ca 11	2.041		Tenebrionidae	Te 8	"
		Elateridae	El 6	"		Anthicidae	An 4	2.020
		Histeridae	Hi 1	"		Carabidae	Ca 10	"
						Histeridae	Hi 3	"
						Tenebrionidae	Te 7	"
	Recedent	Curculionidae	Cur 4	1.531	Recedent	Carabidae	Ca 32	1.010
		Malachidae	Ma 1	"		Chrysomelidae	Ch 3	"
		Elateridae	El 7	1.020			Ch 6	"
		Staphylinidae	St 4	"		Clambidae	Cl 2	"
		Tenebrionidae	Te 7	"		Curculionidae	Cur 4	"
			Te 16	"		Elateridae	El 7	"
		Lathridiidae	La 1	0.510		Histeridae	Hi 2	"
		Scarabaeidae	Sc 5	"		Staphylinidae	St 5	"
		Scirtidae	Sci 1	"		Tenebrionidae	Te 1	"
		Staphylinidae	St 2	"				
Zone 4	May (N=113)				October (N=47)			
	Abundant	Tenebrionidae	Te 1	49.558	Abundant	Curculionidae	Cur 25	36.170
			Te 8	23.009		Carabidae	Ca 11	23.404
		Carabidae	Ca 36	8.850		Staphylinidae	St 13	10.638
						Tenebrionidae	Te 8	8.511
						Chrysomelidae	Ch 3	6.383
						Staphylinidae	St 11	"
	Influent	Cucujidae	Cu 1	4.425	Influent	Curculionidae	Cur 4	4.255
		Staphylinidae	St 13	2.655		Scarabaeidae	Sc 5	2.128
						Staphylinidae	St 4	"
	Recedent	Carabidae	Ca 23	1.770				
		Scarabaeidae	Sc 2	"				
			Sc 5	"				
		Staphylinidae	St 4	"				
		Anthicidae	An 1	0.885				
		Carabidae	Ca 16	"				
			Ca 32	"				
		Histeridae	Hi 1	"				
		Ptinidae	Pti 2	"				

Table III. Abundance analysis of the Isopoda found at Smir on the total of zones during the two seasons.

	May	n=5219				October	N=3933	
Abundant	Tylidae	*Tylos europaeus*	99.847		Abundant	Tylidae	*Tylos europaeus*	99.797
Recedent	Philosciidae	*Ctenoscia* sp.	0.077		Recedent	Halophilosciidae	*Stenophiloscia zosterae*	0.127
	Armadilliidae	*Eluma purpurascens*	0.038			Porcellionidae	*Porcellionides pruinosus*	0.076
	Armadillidae	*Armadillo officinalis*	0.019					
	Porcellionidae	*Porcellio nidespruinosus*	"					

Table IV. Abundance analysis of the Isopoda found at Smir in each zone during the two seasons.

	May					October		
	Zone 1	n=5088				Zone 1	n=3841	
Abundant	Tylidae	*Tylos europaeus*	100		Abundant	Tylidae	*Tylos europaeus*	99.87
					Recedent	Halophilosciidae	*Stenophiloscia zosterae*	0.13
	Zone 2	n=123				Zone 2	n=89	
Abundant	Tylidae	*Tylos europaeus*	100		Abundant	Tylidae	*Tylos europaeus*	100
	Zone 3	n=1				Zone 3	n=2	
Abundant	Porcellionidae	*Porcellionides pruinosus*	100		Abundant	Porcellionidae	*Porcellionides pruinosus*	100
	Zone 4	n=7				Zone 4	n=1	
Abundant	Philosciidae	*Ctenoscia* sp.	57.143		Abundant	Porcellionidae	*Porcellionides pruinosus*	100
	Armadilliidae	*Eluma purpurascens*	28.571					
	Armadillidae	*Armadillo officinalis*	14.286					

Analysing the Coleoptera community of this beach-dune system with Fisher's diversity index (Tab. V, A) the α coefficient was slightly higher in May (8.06) than in October (7.75) but the difference was not significant. The diversity index in each of the four zones showed that in both seasons the highest values were obtained in zone 3 (4.83 in May and 7.56 in October) and the lowest in zone 1 (1.92 and 2.10 in the two seasons respectively). Confidence limits of α showed that in both periods zone 1 and 3 were significantly different from one another. The α values of the beach and dune alone were 5.37 and 9.17 respectively. In particular, the highest diversity index was obtained in October on the dune (7.19) and the lowest on the beach (3.26) during this same period. The value of α for the entire beach dune system was 10.20. Analysing the isopoda community of the beach-dune system with Fisher's diversity index (Tab. V, B) again the α coefficient was higher in May (0.55) than in October (0.32). Considering the single zones, the highest value of α was obtained in zone 4 in May (1.99) and in zone 3 (0.80) in October. The α values of the beach and dune alone were 0.19 and 2.26 respectively. The value of α for the entire beach dune system was 0.63.

The index of evenness, estimated for the Coleoptera over the entire beach-dune system by means of the Pielou-Brillouin method, was 0.628 (Tab. V, A). This value was higher in October (0.721) than in May (0.530). The analysis in the single zones showed that the highest values were obtained in zone 4 (0.608 in May; 0.816 in October) and the lowest in zone 1 (0.299 in May; 0.557 in October). This index calculated for the beach and dune separately was 0.475 and 0.655 respectively. In contrast the equivalent value of evenness for the Isopoda community over the same beach dune system was extremely low (0.008) when estimated by this method (Tab. V, B). In May the value of evenness is 0.008, in October 0.014. During May in the first three zones being present only one species it was not possible to calculate this index. The same occurred in October for zones 2-4. On the beach and dune the values obtained by means of the Pielou-Brillouin method were 0.006 and 0.914 respectively.

Simpson's dominance index calculated for the Coleoptera was 0.166 (Tab. V, A) and more dominant species were found in May (0.271) than in October (0.125). In both seasons the highest value was found in zone 1 (0.710 in May; 0.446 in October) whereas the lowest in zone 4 in May (0.305) and in zone 2 in October (0.161). A greater number of dominant species was found on the beach (0.403) than on the dune (0.180) and in particular the highest dominance index was found on the beach in May (0.645). For the Isopoda, Simpson's dominance index for the entire system was 0.997 (Tab. V, B). This value was more or less the same in both seasons: 0.997 in May and 0.996 in October. Considering the zones individually, in May in zone 1 and 2 the dominance index reached its maximum value (1) due to the presence of only *Tylos europaeus*. In zone 3 a single individual, *Porcellionides pruinosus* was collected so the index was not calculated. In October the maximum value (1) was obtained in zone 2 and 3 with the presence of two species respectively: *Tylos europaeus* and *Porcellionides pruinosus*. In zone 4 only one species with one individual was collected so the index was not calculated. In general the dominance index was higher on the beach (0.999) than on the dune (0.236).

DISCUSSION

On the beach dune system of Smir, the structure of the community of arthropods changed both quantitatively and qualitatively with the change of the season. The high numbers registered in October in the pitfall traps were mainly due to the Collembola that greatly increased in this season together with the Amphipoda. The dominance of Collembola over the other categories within catches is a feature common to other beach environments of both Mediterranean (Chelazzi *et al.* 1990) and tropical areas (Colombini *et al.* 1998) and in general to arid environments (Wallwork 1976). The differences in captures of Collembola on the beach and dune in the two seasons were mainly due to the dominance of different families according to the period of the year. In May, the Entomobryidae family was dominant and occurred on the dune, whereas in October the Isotomidae family was most abundant and was restricted to beach areas. During autumn the increase of Amphipoda, represented by *Talitrus saltator*, was in relation to the species biological cycle, with the month of October representing a breeding period (Scapini *et al.* 1992, Fallaci *et al.* 2003, Marques *et al.* 2003). The other categories decreased from spring to autumn, including the Isopoda that were principally composed by a single species (*Tylos europaeus*). The general decrease of Isopoda that occurred in the capture numbers in October at Smir showed an opposite trend to that obtained on a Tyrrhenian sandy beach (Burano, southern Tuscany) where the higher numbers in the autumn months were due to the birth of a new generation (Fallaci *et al.* 1996). The presence of faunal assemblages in one zone (beach) more than another (dune) in a certain season was probably in relation to the guilds to which the different taxa belonged (scavengers, predators, wood-eaters, fungal-eaters, herbivores etc.) and to their seasonal occurrence.

The analysis of the data obtained from mobile cages showed that the number of individuals per plant material remained more or less the same in the two seasons. However, comparing this result with the beach-dune system of Zouara (Tunisia, Mediterranean Sea) (unpublished data), the values of Smir were about one fifth of those of the other locality. This indicates that the vegetation of the dunes of Smir supports a lower quantity of arthropods.

When the Coleoptera and Isopoda were further analysed, some general trends occurred at Smir confirming the results obtained for other beaches over the Mediterranean (Colombini *et al.* 2003). First of all, there was a general decrease in the number of coleopteran species and in capture numbers from spring to autumn. The reduction of the total number of coleopteran species that were sampled during autumn was generally associated with an increase of the number of species classified as abundant. Furthermore the beach of Smir supported more Tenebrionidae than Staphylinidae, whereas on the beach of Zouara and in

Table V. Ecological indices of the Coleoptera (A) and Isopoda (B) at Smir were calculated in the different zones (zone 1 eulittoral, zone 2 supralittoral, zone 3 and 4 seaward and landward face of the dune), in the two seasons (May, October) and on the total.

A	May Zone 1	May Zone 2	May Zone 3	May Zone 4	Oct. Zone 1	Oct. Zone 2	Oct. Zone 3	Oct. Zone 4	May beach	May dune	Oct. beach	Oct. dune	May	Oct.	beach	dune	total
n	205	181	196	113	57	116	99	47	386	309	173	146	695	319	559	455	1014
Number of species	9	14	18	14	7	11	20	9	19	25	13	22	36	29	25	36	47
Fisher et al.	1.92	3.54	4.83	4.21	2.10	2.98	7.56	3.31	4.19	6.42	3.26	7.19	8.06	7.75	5.37	9.17	10.20
Fisher’s conf. lim.	0.69	1.12	1.38	1.49	1.08	1.16	2.55	1.54	1.05	1.53	1.09	1.57	1.39	1.75	1.12	1.74	1.47
Brillouin	0.629	0.978	1.542	1.473	0.976	1.805	1.946	1.565	0.904	1.648	1.773	2.021	1.835	2.299	1.479	2.239	2.347
Brillouin max	2.105	2.488	2.713	2.423	1.754	2.226	2.677	1.918	2.835	3.054	2.418	2.829	3.465	3.186	3.115	3.418	3.740
Pielou-Brillouin	0.299	0.393	0.568	0.608	0.557	0.811	0.727	0.816	0.319	0.540	0.733	0.714	0.530	0.721	0.475	0.655	0.628
Simpson	0.710	0.580	0.351	0.305	0.446	0.161	0.174	0.198	0.645	0.330	0.185	0.179	0.271	0.125	0.403	0.180	0.166

B	May Zone 1	May zone 2	May Zone 3	May zone 4	Oct. Zone 1	Oct. zone 2	Oct. zone 3	Oct. zone 4	May beach	May dune	Oct. beach	Oct. dune	May	Oct.	beach	dune	total
n	5088	123	1	7	3841	89	2	1	5211	8	3930	3	5219	3933	9141	11	9152
Number of species	1	1	1	3	2	1	1	1	1	4	2	1	5	3	2	4	6
Fisher et al.	0.09	0.15		1.99	0.20	0.16	0.80		0.09	3.18	0.20	0.53	0.55	0.32	0.19	2.26	0.63
Fisher’s conf. lim.																	
Brillouin	-	-	-	0.665	0.009	-	-	-	-	0.842	0.009	-	0.012	0.015	0.004	0.950	0.015
Brillouin max	-	-	-	0.764	0.692	-	-	-	-	0.979	0.692	-	1.606	1.096	0.693	1.039	1.789
Pielou-Brillouin	-	-	-	0.870	0.014	-	-	-	-	0.860	0.013	-	0.008	0.014	0.006	0.914	0.008
Simpson	1	1	-	0.333	0.997	1	1	-	1	0.25	0.997	1	0.997	0.996	0.999	0.236	0.997

another one of tropical areas (Sar Uanle, Somalia, Red Sea) beach dune communities were dominated by fungivorous and predator Staphylinoidea respectively (Colombini *et al.* 1998, 2000, 2003). However, the seasonal abundance analysis showed that at Smir during springtime Tenebrionidae were most abundant, whereas during autumn Staphylinidae together with Curculionidae were the most represented. The type of community present on a beach is generally associated with the presence and type of marine allochthonous inputs (macrophytes, wood debris, carrion, etc.) that occur on the beach itself, with the duration of the stranding and the extension of the tidal excursions (Colombini & Chelazzi 2003). Also the zonation of the single species along the beach dune system of Smir showed a trend simalar to that of other beaches (Fallaci *et al.* 1994) with certain scavenger or predator species (*Phaleria acuminata, Scarites laevigatus*) concentrated on the aphytoic part of the beach and other herbivorous or litter-inhabiting species (*Xanthomus* sp., *Cryptophagus* sp.) on the vegetated part of the dune.

The abundance analysis made on the Isopoda showed similar trends with those found for the Coleoptera. As a matter of fact, the number of species was again higher in spring compared to autumn even if species numbers were always very low except for one case. *Tylos europaeus* was always the most abundant species in both seasons and was distributed exclusively on the beach areas. The other Isopoda species found at Smir were all found on the dune being typical species of more inland areas.

Analysing capture numbers spatially, at Smir there was a general decrease in abundance from the beach to the dune in both the coleopteran and Ispoda communities. This was particularly evident for the Isopoda where *T. europaeus* was the dominant species.

Diversity indices offer a method of summarising and standardising information on the variety and abundance of species within a particular biotic assemblage. The results obtained for the community of Coleoptera and Isopoda are substantially the same. For the Coleoptera, there were no significant differences in the indices of α diversity calculated in the two seasons. This phenomenon contrasts with the finding obtained for other beaches where, generally, values of α diversity were higher in spring than in autumn (Colombini *et al.* 2003). When α diversity was analysed in the single zones individually or on the beach and dune areas for each season separately, there was always an increase in its value from sea towards land. This is in accordance with the idea that in beach ecosystems faunal responses change along gradients from the beach landwards and in particular insect diversity increases from beach to dune areas (McLachlan 1991). Comparing the value of α for the entire beach dune system with those of other beaches (Colombini *et al.* 2003) it appears that Smir presents a value closer to beaches that in some way have undergone a human impact such as Zouara and the Malta beaches. Smir presents several impacts such as a dam, a small port close to the study site, a main road in the immediate retrodune, houses built directly on the dune and the presence of eucalypt trees planted on the landward face of the dune, and these all seem to be factors implicated in the loss of diversity.

When the evenness of the coleopteran community was compared between the two seasons the higher values found in autumn were in accordance with the lower dominance values obtained in this season. Furthermore, a greater uniformity was obtained on the dune and consequently, higher dominance indices were found on the beach. The high dominance index found in spring on the beach at Smir was due to the presence of the tenebrionid *Phaleria acuminata* that was extremely abundant in this zone. For the Isopoda community the high dominance value obtained on the beach was instead in relation to the presence of *Tylos europaeus*. In particular in May on the beach and in October on the dune this index reached its maximum value because only one species was present in each zone (*Tylos europaeus* and *Porcellionides pruinosus* respectively).

The overall results obtained for the beach of Smir give us important indications on its present state of conservation. Samplings were conducted in an area that, at least from a morphological point of view, seemed to be the best preserved long the coast between Sebta and Cabo Negro. In fact, this beach presented some general features that were typical of beaches in good state of conservation (presence of certain bioindicator species, trends in abundance, etc.). However, the relatively low α diversity found on this beach indicates that it is suffering from several impacts that have influenced the surrounding environment and that urgent measures are needed to enhance its protection. The importance of a "relict area" along a part of coast that has been destroyed in large parts by urbanisation, tourist settlements and roads should be emphasised because it could serve as a buffer area for faunal assemblages of bordering beaches. An important role of ecologists should be to increase the understanding of the social and cultural context of conservation and to improve communication with decision-makers or different stakeholder groups, especially in cases of rapidly developing coastal areas.

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