ABUNDANCE, ZONATION AND ECOLOGICAL INDICES OF A COLEOPTERAN COMMUNITY FROM A SANDY BEACH-DUNE ECOSYSTEM OF THE SOUTHERN ADRIATIC COAST, ITALY

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COLEOPTERA
ABUNDANCE
ZONATION
DIVERSITY INDICES
SEASONAL CHANGES
BEACH-DUNE ECOSYSTEM
MEDITERRANEAN AREA

ABSTRACT. – A study on the Coleoptera community inhabiting a beach-dune ecosystem was carried out at Isola Varano, a site located along the southern Adriatic coast of Italy (Apulia). During 2002 bimonthly samples were taken using a standard system of traps: two transects with pitfall traps placed from the sealine limits to the first dune were used to collect spontaneously active individuals whereas core samples were taken in correspondence with each pitfall trap to sample burrowed beetles. Environmental variables such as beach profile, exposure, orientation, length, width, slope, mean grain size and dune height were also recorded. Temporal and spatial patterns were assessed for the most important Coleoptera species. Species were also studied both quantitatively and qualitatively using ecological indices: frequency and relative abundance were calculated together with species richness, α and β diversity, the evenness of the community and dominance index. Comparisons with other beach localities over the Mediterranean basin showed that the coleopteran community of Isola Varano followed the general trends, both in space and time, that occurred for other sites even if lower diversity values were obtained. The presence of certain bioindicator species indicated a relatively good state of beach health but the impoverished dune fauna showed that the habitat was under a stressful condition due to the presence of a pinewood plantation in the retrodunal areas.

COLEOPTERA
ABONDANCE
ZONATION
INDICES DE DIVERSITÉ
CHANGEMENT SAISONNIER
ÉCOSYSTÈME PLAGE-DUNE
RÉGION MÉDITERRANÉENNE

RÉSUMÉ. – Les Coléoptères de l'écosystème plage-dune de l'Isola Varano (mer Adriatique, Gargano, Apulie) ont été étudiés de façon bimestrielle au cours de l'année 2002. Ils ont été échantillonnés le long de deux transects, du niveau des laisses (niveau de marée haute) jusqu'au premier cordon dunaire, par un système standard de pièges (animaux actifs à la surface) et de tamis (animaux enfouis dans le sable). Les variables du milieu telles que profil de la plage, exposition, orientation, longueur, largeur, pente, diamètre moyen des grains et hauteur de la dune, ont été aussi enregistrées. Les variations spatiales et temporelles des espèces de Coléoptères les plus abondantes ont été évaluées. De même, une analyse quantitative et qualitative a été réalisée par les coefficients écologiques suivants : fréquence, abondance relative, richesse spécifique, diversité α et β, indices d'équitabilité et de dominance. Le résultat de l'analyse montre que la communauté des Coléoptères de l'Isola Varano suit, tant sur le plan spatial que temporel, la tendance générale observée en d'autres points de la Méditerranée malgré les faibles valeurs de diversité enregistrées. La présence de certaines espèces bioindicatrices indique un état relativement bon de la qualité de la plage alors que la faible diversité de la faune dunaire témoigne de conditions de stress dues à la présence d'une pinède implantée dans la zone de l'arrière-dune.

INTRODUCTION

Beach-dune systems are very delicate environments in which the forcing factors are mainly represented by a combination of physical factors such as marine currents, winds, exposure, sediment transportation etc. responsible for maintaining the habitat in a dynamic equilibrium (Brown & McLachlan 1990). Over the Mediterranean area the historical load of human occupation, land-use, fluvial regimentation and exploitation have continuously caused changes of beach ecosystems and coastlines through the centuries. However these changes were characterised by being gradual through time and generally permitted sandy beach ecosystems to reach new states of dynamic equilibrium without causing drastic perturbations of the environment. Contrarily during the past century, especially in highly developed countries, sandy beach environments have undergone rapid changes through urbanisation, industrial and/or agricultural encroachments, over-exploitation for recreational purposes and landscape homogeneisation. Since habitat diversity is strictly related to biological diversity these rapid changes have caused habitat loss with consequent loss of valuable species. Diversity monitoring thus represents an important tool to assess the state of sandy beaches and gives important information on how species react to different impacts.

Over the Mediterranean basin few studies have been concerned with terrestrial macrofauna of sandy beaches (Angelier 1950, Binaghi 1964, Bigot *et al.* 1982, Ponel 1983, Contarini 1992, Fallaci *et al.* 1994, Giménez Casalduero & Esteve Selma 1994) and these have mainly considered single localities with no comparisons being made between beaches. Recently a more comparative study was undertaken by Colombini *et al.* (2003). In this study the faunal composition of coleopterans and isopods of five beach localities located in the western Mediterranean was studied, compared and diversity indices were calculated. Comparisons were achieved thanks to the use of identical sampling techniques carried out in each locality in two seasons over a relatively short period of time (two years). The study pointed out that the community structure of the fauna at the different sites largely depended on the local beach features (vegetation, slope, exposure, human impact etc.) even though general trends were identified. In literature the only other study regarding the faunal composition and the spatial and temporal strategies of terrestrial arthropods along a beach-dune system in the Mediterranean basin was conducted at Burano, a beach along the Tyrrhenian coast of Italy (Chelazzi *et al.* 1990, Colombini *et al.* 1991, 1994, Fallaci *et al.* 1994). In this case the system was monitored over a one year period of time. Along the Adriatic coast of Romagna, Contarini (1992) reported a check list of the coleopterans from beach-dune ecosystems of ten sampling stations adding notes on the ecology of the main families that were captured.

The present study deals with the analysis of the coleopteran community in another beach-dune system along the southern Adriatic coast of Italy. The aim of the research was to analyse the population dynamics of the most abundant species for one year period of time together with their zonation patterns. Furthermore the study aimed at the evaluation of the community structure of coleopterans through analytical ecological coefficients and diversity indices in order to make comparisons with previous findings of other localities and to assess the state of beach health.

MATERIALS AND METHODS

Study Site: The study site was located on the Gargano promontory (Apulia) along the southern Adriatic coast of Italy. The entire coastal area belongs to the alluvial plain formed by sediment supplies of the Fortore river. These originated the sandy coastal belts which closed the lakes of Lesina and Varano during historical times (Mastronuzzi & Sansò 2002a, 2002b). The study was carried out on the beach-dune system in front of the Varano lake. This sand formation, called Isola Varano, extended for about 10 km from the western Capoiale outlet to the eastern Varano outlet. The length of the entire beach-dune system, extending from Capoiale to Rodi Garganico, was roughly 20 km. Isola Varano, about 700 m in width, presented a beach-dune system, a second dune belt, an extensive retrodune with a pinewood plantation and a marshland area extending landwards to the lake. The beach-dune system (Fig. 1) presented an eulittoral zone about 25 m in width, a 5.5% beach slope

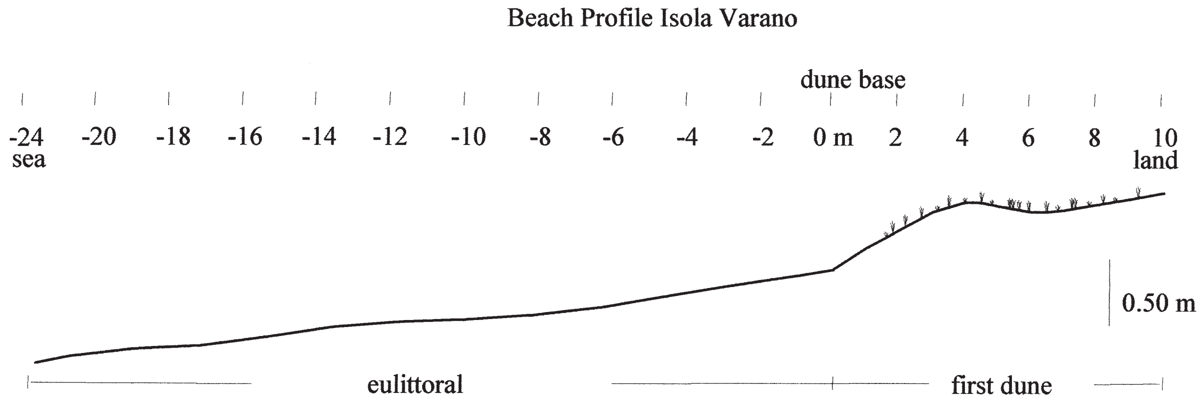

Fig. 1. – Scheme of the beach profile and transect with pitfall traps located every two m on the beach-dune system of Isola Varano.

and an orientation of 350° perpendicular to the shoreline. This beach presented an exposure rate of 7 (McLachlan 1980) indicating that the beach was sheltered. During heavy storms the eulittoral could be completely invaded by the sea and a great quantity of litter and organic material, coming from illegal dumping and from mussel mariculture farms located in the low waters of the marine channel between Torre Mileto and the Isole Tremiti, could be washed ashore. In this point the littoral was in progradation (Mastronuzzi *et al.* 1989) and the 100 metres isobath was at a distance of 15 km from the shore (Ambrosano *et al.* 1986) with a marine mean slope of the substrate of 0.6%. The dominant marine water currents along the coast in this area presented a north-south direction. The first dune belt, 10 m in width and 1 m in height, was covered by a halo-psammophilous pioneer vegetation with a vegetation cover that varied from 5% at the base of the dune to 50-80% in the remaining 10 m landwards. The dominant species were about 20, of these three species (*Calystegia soldanella* (L.) R. Br, *Salsola kali* L. and *Sporobolus pungens* (Schreber) Kumth) were homogeneously distributed over the entire first dune. Whereas *Ammophila arenaria* (L.), *Echinophora spinosa* L., *Medicago marina* L. and *Otanthus maritimus* (L.) Hoffmanns et Links were distributed more towards land. The second dune belt, greater in height (8 m), was severely eroded by wind action (S-SW dominant wind direction) and presented a scarce vegetation cover (*Juniperus oxycedrus* L.). This beach dune system presented fine sands with coarser and well classified sands near the sea (mean grain size 2.238 Φ) and finer ones on the dune (mean grain size 2.312 Φ). The present study was conducted on the eulittoral and on the first dune belt in an area with low human impact located at the second fire cutting of the State Forest Corps (41° 55' 05" N - 15° 46' 19" E).

Sampling design: Samples were collected approximately at a bimonthly periodicity from January to December 2002 (January 22-25; March 19-22; May 07-10; July 09-12; October 01-04; December 03-06). Standard samples using pitfall traps were taken along two transects from sea towards land at a distance of 50 m from one another. These traps captured spontaneously active arthropods on the sand surface. Traps were placed every two meters from the base of the first dune to the sea and were connected with continuous fiberglass strips 10 cm in height. Transect length varied with the force of wave action and seasonal differences in sea level. Tetra-directional pitfall cross traps (Scapini *et al.* 1992) were instead placed on the dune at 2, 4, 6, 8 and 10 m from the base of the dune towards land. Traps were kept in function for a period of 48 consecutive hours and were controlled periodically.

To sample burrowed arthropods a third transect, consisting of sieving stations spaced 2 m from each other, was set at 50 m from the other two transects. Samples were taken alternatively to the east or to the west of the transects according to the sampling month and in correspondence to pitfall traps. Where vegetation was present it was sampled as well. Each station consisted of 0.25 m^2 patch of sand gathered to a depth of 20 cm. Sieves had mesh size of 2 mm.

All samples were fixed in 75% alcohol and stored in the laboratory. Only coleopterans were chosen and sorted to species level. Where species level was not reached, individuals were sorted with the criteria of the morphologically recognisable taxonomic units (RTUs) (Krüger & McGavin 1997). This method consisted in subdividing each order at family level (Ca= Carabidae; Cr= Cryptophagidae; El= Elateridae; La= Lathridiidae; Ma= Malachidae; Mo= Mordellidae; Oe= Oedemeridae, Sc= Scarabeidae; St= Staphylinidae; Te= Tenebrionidae) and then identifying the different species of each family with numbers (e. g. Ca1; Ca2 etc.).

Climatic data (monthly means of air temperature, relative humidity, rainfall, wind direction and speed), were obtained from the closest meteorological station at 1 km inland. For microclimatic data these were registered at 12:00 pm each day of sampling in correspondence to each pitfall trap. In this case substrate temperature at 10 cm in depth, substrate moisture and grain size were recorded.

Statistical analysis: Monthly capture frequency of surface-active and burrowing species were calculated in percent on the total annual captures.

For each month a mean zonation with 95% confidence limits was calculated for spontaneously active and burrowed individuals of each species considered. This was obtained calculating the distance in metres from the base of the dune (0 m, with positive values on the dune) of each individual found in the different pitfall traps or sieves of the transects.

For capture frequencies and zonation patterns species were considered only if capture numbers were $\geqslant 5$ with both pitfall traps and sieves.

For a quantitative analysis two ecological coefficients were used: frequency and relative abundance (Van Heerdt & Mörzer-Bruyns 1960, Bigot & Bodot 1973, Ponel 1983). The frequency was calculated on six samples considering each month as a sample. The species were classified as constant ($F \geqslant 50\%$), accessory ($25 \leqslant F < 50\%$) and accidental ($F < 25\%$). As regards the relative abundance, the abundances of individual species were computed as a function of the total number of coleopterans gathered in a particular zone (beach, dune) or month. Species were then grouped as abundant ($A \geqslant 5\%$), influent ($2 \leqslant A < 5\%$), recedent ($A < 2\%$).

Diversity indices were calculated to identify species richness. The analysis was carried out on a monthly basis both on the beach, the dune, and the total. Fisher *et al.*'s (1943) α diversity index was used and confidence limits were calculated using the standard error given in Williams' nomograph (1947). In order to calculate β diversity (Whittaker 1972) of the two zones (beach, dune) in the different months and on the total for each month, Renkonen's (1938) percentage similarity was computed. To analyse the evenness of the community Pielou's (1978) evenness index through Brillouin (1962) index was used. To express the abundance of the commonest species as a fraction of the total number of individuals Simpson's (1949) dominance index was calculated.

The analysis of all ecological indices was conducted only on adult individuals captured with both pitfall traps and sieves.

For climatic date monthly means were calculated. 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) (Folk & Ward 1957).

RESULTS

A. Climate

The highest monthly mean air temperatures were recorded during summer months with values varying between 22.12° C in June and 23.46° in August. During December 2001 and January 2002 the lowest values registered were around 5°C. Mean relative air humidity presented values that varied between 83.75% and 66.86% from April to June. April was the wettest month (106 mm of rain) followed by September (101.4 mm of rain) whereas the driest months were February and June with 9.6 and 2.9 mm of rain respectively. Maximum wind speed occurred in December with 5.2 ms^{-1} whereas the minimum values were obtained 1.6 ms^{-1} in October. Dominant winds blew from S-SW direction.

Microclimatic data showed that in-depth temperatures reached the lowest values (2.0°C) in January and the highest (35.7°C) in July. Substrate moisture was the highest in December (18.4% of water content) and the lowest in July (0.2% of water content). Mean grain size was 2.263 Φ, mean inclusive graphic standard deviation was 0.273, mean inclusive graphic skewness was –0.003 and mean graphic kurtosis was 1.169.

B. Capture frequency

At Varano, of all the Coleoptera sampled, the Tenebrionidae was the most representative family. The most abundant species was *Phaleria acuminata* Küster, 1852 followed by other tenebrionids such as *Erodius siculus dalmatinus* Kraatz, 1865, *Pseudoseriscius helvolus adriaticus* (Español, 1949), *Trachyscelis aphodioides* Latreille, 1809, *Xanthomus pallidus* Curtis, 1830, and *Ammobius rufus* Lucas, 1849, all quite common on the beach-dune system.

Another important family was the Carabidae with three dominant species: *Scarites buparius* (Forster, 1771), *Parallelomorphus laevigatus* (Fabricius, 1792) and *Eurynebria complanata* (Linneus, 1767). Very common were two staphylinid species, *Phytosus spinifer* Curtis, 1838 and *P. balticus* Kraatz, 1859 and two Scarabeidae (Aphodidea) both belonging to the genus *Psammodius* (*P. basalis* Mulsant et Rey, 1871 and *P. nocturnus* Reitter, 1896).

During the entire sampling period a total number of 3283 surface-active individuals were caught with pitfall traps whereas 359 burrowed individuals were captured with sieves (Fig. 2A). In the first case a peak of abundance was reached in July with 34.78% of captures, in the second case capture frequency reached its highest numbers in May and October with 30.08% and 37.04% of captures respectively. Regarding the Coleoptera larvae (Fig. 2B) there was a peak of abundance in May (63.31%) for surface-active individuals and two peaks in March and December for burrowed individuals (23.33% and 46.66% respectively).

The distribution of the capture frequency for *Phaleria acuminata* (Fig. 2C) showed the highest captures in March and July both for surface-active (27.68% and 45.24% respectively) and burrowed individuals (35.71% and 35.71% respectively).

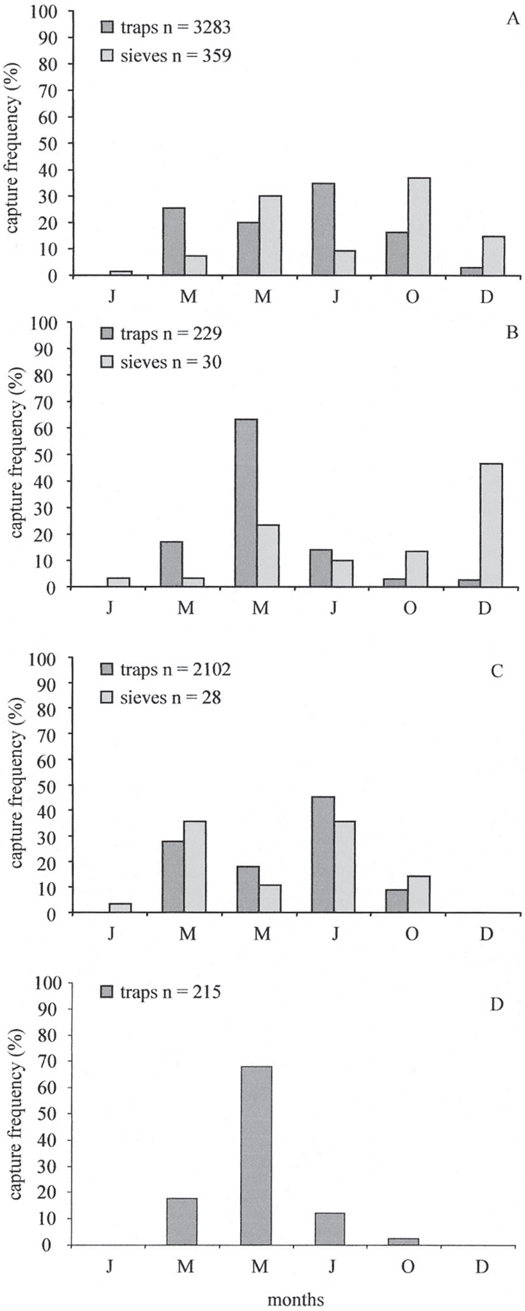

Fig. 2. – Annual capture frequency of the entire Coleoptera community captured with pitfall traps and sieves: A) adults B) larvae, is shown together with the annual capture frequency of *Phaleria acuminata*: C) adults D) larvae.

Instead of *Phaleria* larvae (Fig. 2D) presented only one peak of abundance in May for the surface-active individuals with 67.90% of captures.

The distribution of the capture frequency of the other tenebrionid species active at the sand surface (Fig. 3A) showed that some species were typically spring species *(Pachychila* sp. and *Stenosis angustata* Herbst, 1799), others were spring summer species (*Erodius siculus*), spring-autumn species (*Trachyscelis aphodioides*), autumn species (*Pseudoseriscius helvolus*, *Halammobia pellucida* Herbst, 1799), autumn-winter species (*Xanthomus pallidus*) and species active on the sand surface from March to October (*Ammobius rufus*).

Apart from *P. acuminata* only three other tenebrionid species were found burrowed in the sand (Fig. 3B). *A. rufus* was the most abundant with 51.39% of captures in May, followed by *E. siculus* with 50% of captures in May and by *T. aphodioides* with 46.97% of captures in October.

Considering the percentage of captures of the different tenebrionid species (excluding *P. acuminata*) within each sampled month (Fig. 3C) no tenebrionid was found active on the sand surface in January. In March *T. aphodioides* was the most abundant surface-active species with 67.31% of captures. The following two months *E. siculus* dominated the captures whereas *P. helvolus* and *X. pallidus* presented the greatest capture frequencies in October and December respectively.

The percentage of captures within each sampled month of the burrowed tenebrionid species (Fig. 3D) (excluding *P. acuminata*) showed that *A. rufus* was the dominant species in January, May, October and December vis *T. aphodioides* in March and July.

Of the two Scarabeidae species (Fig. 4A) *Psammodius basalis* was captured in both pitfall traps and sieves with greatest percentages of captures in December (59.42%) and October (61.90%) respectively. In contrast *P. nocturnus* was captured in smaller quantities with pitfall traps and was found almost exclusively burrowed in the sand presenting the highest capture frequency in December (63.33%).

Both staphylinid species (Fig. 4B) were found active only at the sand surface and greatest capture frequency was obtained in March and May for *Phytosus balticus* (98.98%) and *P. spinifer* (75.13%) respectively.

Also the Carabidae species (Fig. 4C) were exclusively caught in the pitfall traps with *Scarites*

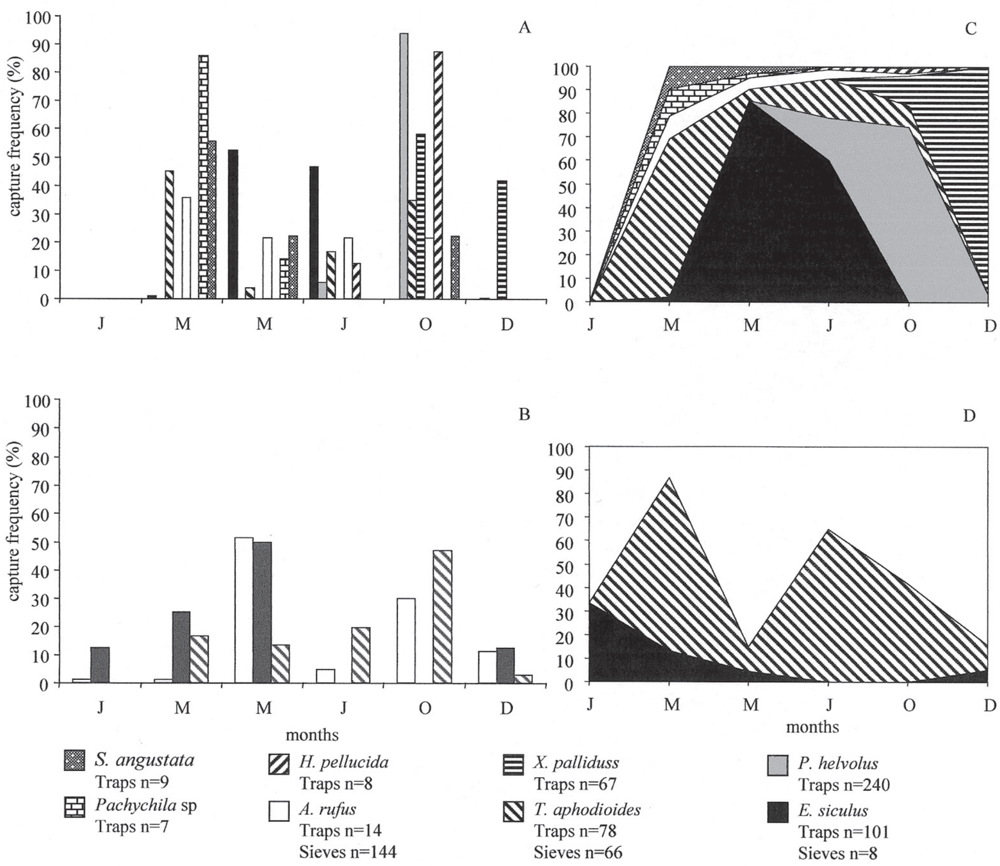

Fig. 3. – Annual capture frequency of the most represented tenebrionid species caught with pitfall traps (A, C) and sieves (B, D). In C and D percentages are calculated within each month.

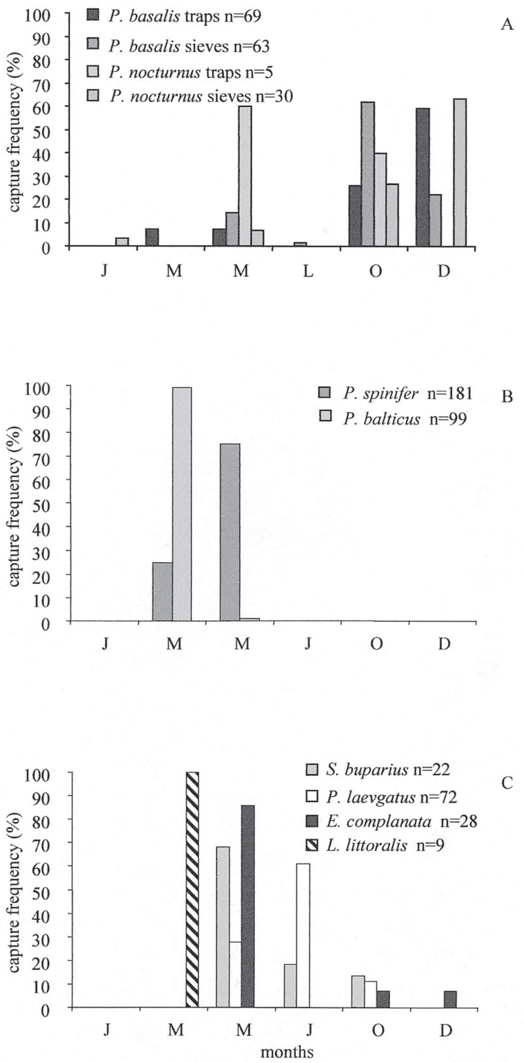

Fig. 4. – Annual capture frequency of two scarabeid species (A), two staphylinid species (B) and four carabid species is shown. Data report captures with both pitfall traps and sieves (A) or only with pitfall traps (B, C).

buparius and *Parallelomorphus laevigatus* presenting peaks of activity in May (68.18%) and July (61.11%) respectively. *Eurynebria complanata* being a spring-autumn breeder was mainly caught in May (85.71%) whereas *Lophyridia littoralis nemoralis* (Olivier, 1790) exclusively in March.

C. Spatial distributions of species

The analysis of the mean zonation patterns along the sea-land axis of surface-active and burrowed species in each month (Fig. 5) clearly showed that some species (*Phaleria acuminata, Trachyscelis aphodioides, Phytosus spinifer, P. balticus, Lophyridia littoralis, Parallelomorphus laevigatus, Eurynebria complanata, Mesites* sp.) were generally tied to the eulittoral zones whereas others were found more in dunal areas (*Ammobius rufus, Pachychila* sp., *Psammodius basalis, Psammodius nocturnus*, *Cardiophorus exaratus* Erichson, 1840, *Erodius siculus*, *Scarites buparius, Pseudoseriscius helvolus, Hypocaccus* sp., *Halammobia pellucida*). However, there were some intermediate species living on the foredune that were zoned more towards the eulittoral like *Notoxus* sp. or more towards the dune like *Stenosis angustata*, *Xantomus pallidus,* and the Cryptophagidae Cr1. Some species of the eulittoral, such as *P. acuminata, T. aphodioides* and *P. laevigatus*, varied their mean zonation according to the season with a decrease in the distance from the sea during summer months followed by an increase during autumn months (Fig. 5A, D). Other differences were found in the zonation patterns of *P. acuminata* between adults and larvae in May (Fig. 5B) and between surface-active and burrowed adults in March and July (Fig. 5A, C). When contemporaneously present (March, Fig. 5A) the two staphylinid species *Phytosus spinifer* and *P. balticus* showed significant differences in the mean zonation when active on the sand surface with *P. spinifer* more landwards compared to *P. balticus*. The scarabeid *Psammodius basalis*, when active or burrowed, never changed its mean zonation as the season changed (Fig. 5A, B, D, E), however comparing the mean zonation of surface-active individuals with that of burrowed ones only in the month of October (Fig. 5D) individuals were active in a more seaward area. *Psammodius nocturnus*, captured prevalently with sieves showed no differences in the mean zonation when different months were compared (Fig. 5D, E). The burrowed individuals of *Psammodius nocturnus* presented a significant seaward zonation compared to the burrowed individuals of *P. basalis* only in the month of October (Fig. 5D).

D. Frequency and abundance analysis

Frequency analysis showed that there was a total of 38 species on the beach, 32 on the dune and 48 on the total (Table I). Of the species classified as constant five (three tenebrionids and two scarabeids) were in common between the beach and the dune, five other species were typical of the beach and five of the dune. Only *Ammobius rufus* was always caught in all six months on the dune. On the total the constant species were 17, the same recorded as constant on the beach and dune with the exception of *Stenosis angustata* and *Hypocaccus* sp. In fact the first species previously was accessory on both the beach and dune while the second was accidental on the beach and accessory on the dune.

Abundance analysis calculated on the percentage of captures of the single species for each month separately on the beach, on the dune and on the total (Tables II, III) showed that of the

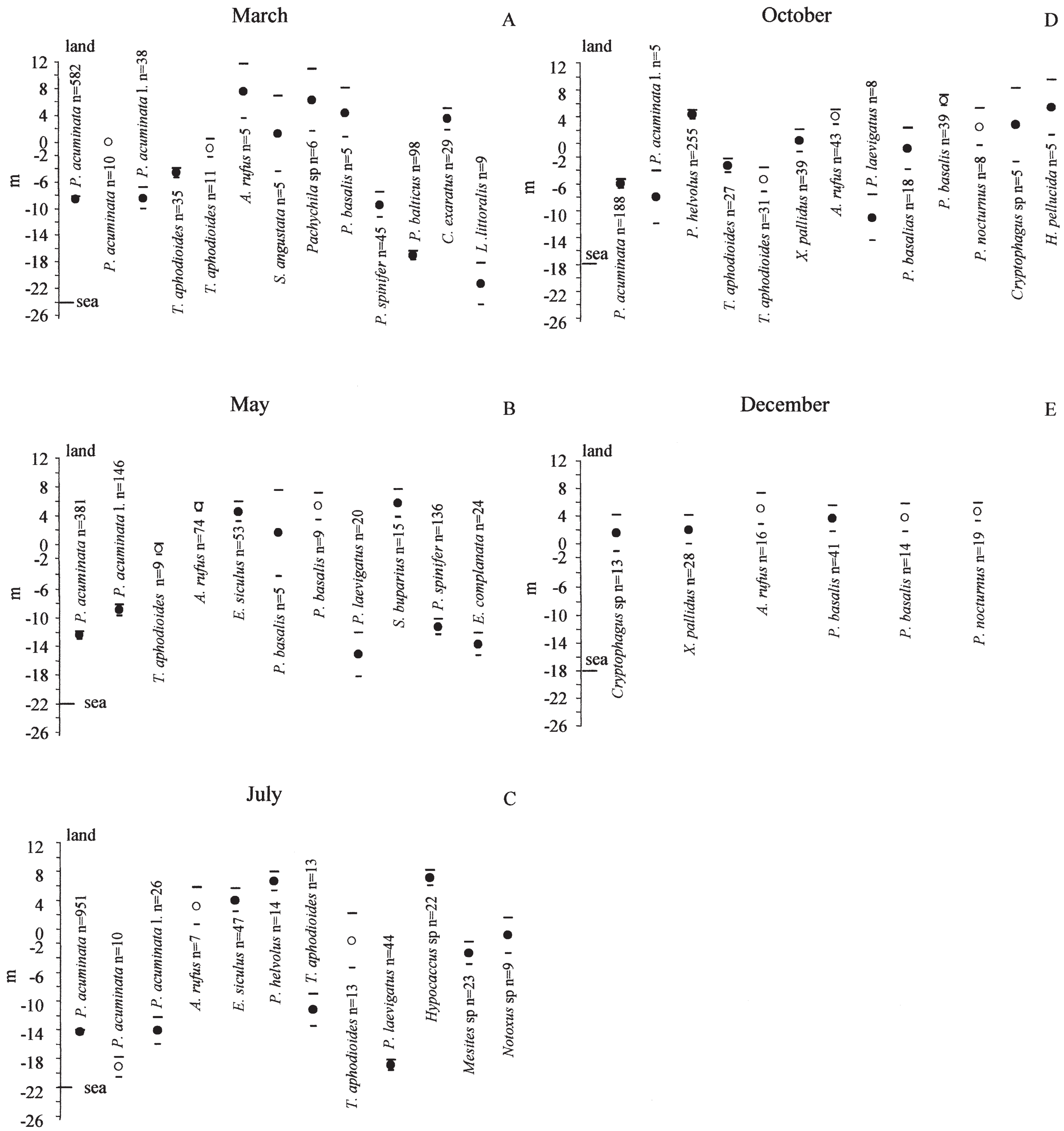

Fig. 5. – Mean zonations (with 95% confidence limits) perpendicular to the shoreline of the different species from March to December 2002 (A-E) on the beach-dune system of Isola Varano. Full circles: pitfall traps, empty circles: sieves. Capture numbers are also reported for each species.

14 tenebrionid species that were captured 8 were abundant at least once. *Phaleria acuminata* was always classified as abundant on the beach from March through October and on the dune only in January and March. Another tenebrionid, *Trachyscelis aphodioides,* was an abundant species of the beach in March and October and of the dune in July. Autumn-winter species like *Xanthomus pallidus* and *Pseudoseriscius helvolus* were abundant both on the beach and on the dune in October and in December only for the first species. The remaining four tenebrionid species were always captured on the dune. *Ammobius rufus* was always classified as an abundant species in all months

Table I. – Frequency of Coleoptera: constant (F≥50%), accessory (25≤F<50%), accidental (F<25%).

	Beach total n=2863			Dune total n=766			Total n=3629	
Constant	A. rufus	83.3	Constant	A. rufus	100.0	Constant	A. rufus	100.0
	T. aphodioides	83.3		E. siculus	83.3		E. siculus	83.3
	P. acuminata	66.7		P. basalis	83.3		P. acuminata	83.3
	P. basalis	66.7		Sitona variegatus	83.3		P. basalis	83.3
	P. balticus	66.7		P. nocturnus	66.7		Sitona variegatus	83.3
	E. complanata	50.0		P. acuminata	50.0		T. aphodioides	83.3
	La1	50.0		P. helvolus	50.0		P. nocturnus	66.7
	Notoxus sp	50.0		S. buparius	50.0		P. balticus	66.7
	P. nocturnus	50.0		St1	50.0		E. complanata	50.0
	P. laevigatus	50.0		T. aphodioides	50.0		Hypocaccus sp	50.0
Accessory	Algerinus sp	33.3	Accessory	Cr1	33.3		La1	50.0
	A. fenestratus	33.3		Hypocaccus sp	33.3		Notoxus sp	50.0
	Cr1	33.3		S. angustata	33.3		P. helvolus	50.0
	E. siculus	33.3		X. pallidus	33.3		S. buparius	50.0
	Formicomus sp	33.3	Accidental	Algerinus sp	16.7		P. laevigatus	50.0
	H. pellucida	33.3		Blaps sp	16.7		St1	50.0
	Pachychila sp	33.3		C. exaratus	16.7		S. angustata	50.0
	S. buparius	33.3		Catomus sp	16.7	Accessory	Algerinus sp	33.3
	P. spinifer	33.3		El1	16.7		Anthicus fenestratus	33.3
	S. angustata	33.3		El2	16.7		Cr1	33.3
	X. pallidus	33.3		H. pellucida	16.7		Formicomus sp	33.3
Accidental	Acritus sp	16.7		Mesites sp	16.7		H. pellucida	33.3
	Bledius unicornis	16.7		Mo1	16.7		Pachychila sp	33.3
	Ca1	16.7		Notoxus sp	16.7		P. spinifer	33.3
	Ca2	16.7		Ocypus compressus	16.7		X. pallidus	33.3
	C. exaratus	16.7		Otiorhynchus juvencus	16.7	Accidental	Acritus sp	16.7
	El1	16.7		Pachychila sp	16.7		Blaps sp	16.7
	H. dimidiatus	16.7		P. spinifer	16.7		Bledius unicornis	16.7
	Hypocaccus sp	16.7		Te1	16.7		Ca1	16.7
	L. littoralis	16.7		Te2	16.7		Ca2	16.7
	Ma1	16.7		Te3	16.7		C. exaratus	16.7
	Mesites sp	16.7		Trachyphloeus sp	16.7		Catomus sp	16.7
	Mo1	16.7					El1	16.7
	Oe1	16.7					El2	16.7
	P. helvolus	16.7					H. dimidiatus	16.7
	Sc1	16.7					L. littoralis	16.7
	St1	16.7					Ma1	16.7
	St2	16.7					Mesites sp	16.7
							Mo1	16.7
							Ocypus compressus	16.7
							Oe1	16.7
							Otiorhynchus juvencus	16.7
							Sc1	16.7
							St2	16.7
							Te1	16.7
							Te2	16.7
							Te3	16.7
							Trachyphloeus sp	16.7

together with *Erodius siculus* which was absent in October and recedent in December. Instead, *Stenosis angustata* and *Pachychila* sp. were found abundant only in March.

Of the seven carabid species that were caught during the entire sampling period, three, *Eurynebria complanata, Parallelomorphus laevigatus* and *Scarites buparius*, were abundant at least once. All species were found abundant in spring-summer months with the first two species on the beach and the third on the dune.

The staphylinids *Phytosus spinifer* and *P. balticus* were abundant only on the beach in spring whereas the Cryptophagidae Cr1 on both beach and dune in December. The remaining species (*Sitona variegatus*, *Psammodius basalis, P. nocturnus, St1*, *Cardiophorus exaratus*, *Hyppocaccus* sp.) were always abundant on the dune except *P. basalis* and *P. nocturnus* that were also abundant on the beach in December.

Generally speaking the number of abundant species was greater on the dune than on the beach (except in May and October where the same number was found) and reached its highest number (n=8) in March (Table II, III). The same trend was observed on the total of the beach and dune (Table III) for the abundant species. More than 50% of the total captured individuals was represented by *P. acuminata*, a typical beach species, while the second most abundant species was *P. helvolus*, a typical dune species.

E. Ecological indices

Species richness and capture numbers calculated in each month for the beach and dune separately (Table IV) showed that the number of species on the beach were greater than those of the dune from March to July. In October the same values were reached whereas in winter months an opposite trend occurred. However on the total the number of beach species was higher than those of the dune.

Table II. – Abundance analysis of Coleoptera in January, March, May and July on the beach, the dune and the total. Species are classified as abundant (A⩾5%), influent (2⩽A<5%) and recedent (A<2%).

	Beach January n=1			**Dune January n=8**			**Total January n=9**	
Abundant	*Formicomus* sp	100	**Abundant**	*A. rufus*	25	**Abundant**	*A. rufus*	22.2
				Sitona variegatus	25		*Sitona variegatus*	22.2
				E. siculus	12.5		*E. siculus*	11.1
				P. acuminata	12.5		*P. acuminata*	11.1
				P. nocturnus	12.5		*P. basalis*	11.1
				St1	12.5		*St1*	11.1
							Formicomus sp	11.1
	Beach March n=808			**Dune March n=55**			**Total March n=863**	
Abundant	*P. acuminata*	72.5	**Abundant**	*C. exaratus*	40.0	**Abundant**	*P. acuminata*	68.6
	P. balticus	12.1		*A. rufus*	10.9		*P. balticus*	11.4
	P. spinifer	5.6		*P. acuminata*	10.9		*T. aphodioides*	5.3
	T. aphodioides	5.4		*Pachychila* sp	9.1		*P. spinifer*	5.2
Recedent	*L. littoralis*	1.1		*P. basalis*	7.3	**Influent**	*C. exaratus*	3.4
	C. exaratus	0.9		*E. siculus*	5.5	**Recedent**	*L. littoralis*	1.0
	St1	0.5		*Sitona variegatus*	5.5		*A. rufus*	0.8
	La1	0.4		*S. angustata*	5.5		*Pachychila* sp	0.7
	Anthicus fenestratus	0.2	**Influent**	*T. aphodioides*	3.6		*St1*	0.6
	S. angustata	0.2	**Recedent**	*St1*	1.8		*P. basalis*	0.6
	Acritus sp	0.1					*S. angustata*	0.6
	A. rufus	0.1					*Sitona variegatus*	0.3
	Bledius unicornis	0.1					*E. siculus*	0.3
	Formicomus sp	0.1					*La1*	0.3
	Notoxus sp	0.1					*Anthicus fenestratus*	0.2
	Pachychila sp	0.1					*Formicomus* sp	0.1
	P. basalis	0.1					*Acritus* sp	0.1
	St2	0.1					*Bledius unicornis*	0.1
							Notoxus sp	0.1
							St2	0.1
	Beach May n=603			**Dune May n=161**			**Total May n=764**	
Abundant	*P. acuminata*	63.7	**Abundant**	*A. rufus*	47.2	**Abundant**	*P. acuminata*	50.3
	P. spinifer	22.4		*E. siculus*	29.8		*P. spinifer*	17.8
	E. complanata	4.0		*S. buparius*	8.1		*A. rufus*	10.1
	P. laevigatus	3.3		*P. basalis*	7.5		*E. siculus*	7.5
Influent	*T. aphodioides*	2.0	**Influent**	*Hypocaccus* sp	3.1	**Influent**	*E. complanata*	3.1
Recedent	*E. siculus*	1.5	**Recedent**	*P. nocturnus*	1.2		*P. laevigatus*	2.6
	P. nocturnus	0.5		*S. variegatus*	0.6		*S. buparius*	2.0
	Notoxus sp	0.3		*P. spinifer*	0.6	**Recedent**	*P. basalis*	1.8
	P. basalis	0.3		*Te1*	0.6		*T. aphodioides*	1.6
	Sc1	0.3		*Te2*	0.6		*P. nocturnus*	0.7
	S. buparius	0.3		*Trachyphloeus* sp	0.6		*Hypocaccus* sp	0.7
	S. angustata	0.3					*S. angustata*	0.3
	Algerinus sp	0.2					*Notoxus sp*	0.3
	A. rufus	0.2					*Sc1*	0.3
	La1	0.2					*P. balticus*	0.1
	Ma1	0.2					*Pachychila sp*	0.1
	Pachychila sp	0.2					*Sitona variegatus*	0.1
	P. balticus	0.2					*La1*	0.1
							Algerinus sp	0.1
							Ma1	0.1
							Te1	0.1
							Te2	0.1
							Trachyphloeus sp	0.1
	Beach July n=1077			**Dune July n=99**			**Total July n=1176**	
Abundant	*P. acuminata*	89.2	**Abundant**	*E. siculus*	37.4	**Abundant**	*P. acuminata*	81.7
	P. laevigatus	4.1		*Hypocaccus* sp	22.2	**Influent**	*E. siculus*	4.0
Influent	*Mesites* sp	2.0		*P. helvolus*	14.1		*P. laevigatus*	3.7
Recedent	*T. aphodioides*	1.6		*T. aphodioides*	9.1		*T. aphodioides*	2.2
	E. siculus	0.9		*A. rufus*	8.1		*Mesites sp*	2.0
	Notoxus sp	0.7	**Influent**	*S. buparius*	3.0	**Recedent**	*Hypocaccus* sp	1.9
	H. dimidiatus	0.6	**Recedent**	*Blaps* sp	1.0		*P. helvolus*	1.2
	A. rufus	0.2		*Catomus* sp	1.0		*A. rufus*	0.9
	Anthicus fenestratus	0.1		*El1*	1.0		*Notoxus sp*	0.8
	El1	0.1		*Mesites* sp	1.0		*H. dimidiatus*	0.5
	H. pellucida	0.1		*Notoxus* sp	1.0		*S. buparius*	0.3
	La1	0.1		*P. basalis*	1.0		*El1*	0.2
	Oe1	0.1					*P. basalis*	0.1
	S. buparius	0.1					*P. balticus*	0.1
	P. balticus	0.1					*La1*	0.1
							Anthicus fenestratus	0.1
							Blaps sp	0.1
							Catomus sp	0.1
							H. pellucida	0.1
							Oe1	0.1

Table III. – Top, Abundance analysis of Coleoptera in October and December on the beach, the dune and the total. Bottom, Abundance of Coleoptera in the two zones separately and on the total. Species are classified as abundant (A≥5%), influent (2≤A<5%) and recedent (A<2%).

	Beach October n=332			**Dune October n=341**			**Total October n=673**	
Abundant	*P. acuminata*	54.2	**Abundant**	*P. helvolus*	55.4	**Abundant**	*P. helvolus*	33.9
	T. aphodioides	16.3		*P. basalis*	13.2		*P. acuminata*	28.5
	P. helvolus	11.7		*A. rufus*	12.3		*T. aphodioides*	8.6
	X. pallidus	6.3		*X. pallidus*	5.6		*P. basalis*	8.5
Influent	*P. basalis*	3.6	**Influent**	*P. acuminata*	3.5		*A. rufus*	6.8
	P. laevigatus	2.4		*P. nocturnus*	2.3		*X. pallidus*	5.9
Recedent	*A. rufus*	1.2	**Recedent**	*H. pellucida*	1.8	**Recedent**	*P. nocturnus*	1.5
	Cr1	0.9		*Algerinus* sp	1.2		*P. laevigatus*	1.2
	Algerinus sp	0.6		*T. aphodioides*	1.2		*H. pellucida*	1.2
	E. complanata	0.6		*Otiorhynchus juvencus*	0.9		*Algerinus sp*	0.9
	H. pellucida	0.6		*S. buparius*	0.9		*Cr1*	0.7
	P. nocturnus	0.6		*Cr1*	0.6		*S. buparius*	0.4
	Ca1	0.3		*S. angustata*	0.6		*Otiorhynchus juvencus*	0.4
	Hypocaccus sp	0.3		*Sitona variegatus*	0.3		*E. complanata*	0.3
	P. balticus	0.3		*Te3*	0.3		*S. angustata*	0.3
							Hypocaccus sp	0.1
							P. balticus	0.1
							Sitona variegatus	0.1
							Ca1	0.1
							Te3	0.1

	Beach December n=42			**Dune December n=102**			**Total December n=144**	
Abundant	*X. pallidus*	31.0	**Abundant**	*P. basalis*	42.2	**Abundant**	*P. basalis*	38.2
	P. basalis	28.6		*P. nocturnus*	15.7		*X. pallidus*	19.4
	Cr1	14.3		*X. pallidus*	14.7		*P. nocturnus*	13.2
	P. nocturnus	7.1		*A. rufus*	13.7		*A. rufus*	11.1
Influent	*A. rufus*	4.8		*Cr1*	6.9		*Cr1*	9.0
	E. complanata	4.8	**Recedent**	*El2*	1.0	**Recedent**	*T. aphodioides*	1.4
	T. aphodioides	4.8		*E. siculus*	1.0		*E. complanata*	1.4
	Ca2	2.4		*Mo1*	1.0		*Mo1*	1.4
	Mo1	2.4		*Ocypus compressus*	1.0		*P. helvolus*	0.7
				P. helvolus	1.0		*Sitona variegatus*	0.7
				Sitona variegatus	1.0		*E. siculus*	0.7
				St1	1.0		*St1*	0.7
							Ca2	0.7
							El2	0.7
							Ocypus compressus	0.7

	Beach total n=2863			**Dune total n=766**			**Total n=3629**	
Abundant	*P. acuminata*	73.7	**Abundant**	*P. helvolus*	26.6	**Abundant**	*P. acuminata*	58.7
	P. spinifer	6.3		*A. rufus*	19.3		*P. helvolus*	6.7
Influent	*T. aphodioides*	4.5		*P. basalis*	13.7		*P. spinifer*	5.0
	P. balticus	3.5		*E. siculus*	11.7	**Influent**	*A. rufus*	4.4
	P. laevigatus	2.5	**Influent**	*X. pallidus*	4.4		*T. aphodioides*	4.0
Recedent	*P. helvolus*	1.4		*Hypocaccus* sp	3.5		*P. basalis*	3.6
	X. pallidus	1.2		*P. nocturnus*	3.5		*E. siculus*	3.0
	E. complanata	1.0		*C. exaratus*	2.9		*P. balticus*	2.8
	P. basalis	0.9		*P. acuminata*	2.5		*P. laevigatus*	2.0
	Mesites sp	0.8		*S. buparius*	2.5	**Recedent**	*X. pallidus*	1.9
	E. siculus	0.7		*T. aphodioides*	2.0		*P. nocturnus*	1.0
	Notoxus sp	0.4	**Recedent**	*Cr1*	1.2		*C. exaratus*	0.8
	A. rufus	0.3		*Sitona variegatus*	1.0		*E. complanata*	0.8
	Cr1	0.3		*H. pellucida*	0.8		*Hypocaccus* sp	0.8
	L. littoralis	0.3		*Pachychila* sp	0.7		*Mesites* sp	0.6
	P. nocturnus	0.3		*S. angustata*	0.7		*S. buparius*	0.6
	C. exaratus	0.2		*Algerinus* sp	0.5		*Cr1*	0.5
	H. dimidiatus	0.2		*Otiorhynchus juvencus*	0.4		*Notoxus* sp	0.3
	La1	0.2		*St1*	0.4		*H. pellucida*	0.2
	St1	0.1		*Blaps sp*	0.1		*L. littoralis*	0.2
	S. angustata	0.1		*Catomus* sp	0.1		*S. angustata*	0.2
	Algerinus sp	0.1		*El1*	0.1		*Sitona variegatus*	0.2
	Anthicus fenestratus	0.1		*El2*	0.1		*Algerinus* sp	0.2
	H. pellucida	0.1		*Mesites* sp	0.1		*Pachychila* sp	0.2
	S. buparius	0.1		*Mo1*	0.1		*St1*	0.2
	Formicomus sp	0.1		*Notoxus* sp	0.1		*H. dimidiatus*	0.2
	Pachychila sp	0.1		*Ocypus compressus*	0.1		*La1*	0.1
	Sc1	0.1		*P. spinifer*	0.1		*Anthicus fenestratus*	0.1
	Hypocaccus sp	0.0		*Te1*	0.1		*Otiorhynchus juvencus*	0.1
	El1	0.0		*Te2*	0.1		*El1*	0.1
	Mo1	0.0		*Te3*	0.1		*Formicomus* sp	0.1
	Acritus sp	0.0		*Trachyphloeus* sp	0.1		*Mo1*	0.1
	Bledius unicornis	0.0					*Sc1*	0.1
	Ca1	0.0					*Acritus* sp	0.0
	Ca2	0.0					*Blaps* sp	0.0
	Ma1	0.0					*B. unicornis*	0.0
	Oe1	0.0					*Ca1*	0.0
	St2	0.0					*Ca2*	0.0
							Catomus sp	0.0
							El2	0.0
							Ma1	0.0
							Ocypus compressus	0.0
							Oe1	0.0
							St2	0.0
							Te1	0.0
							Te2	0.0
							Te3	0.0
							Trachyphloeus sp	0.0

Table IV. – Ecological indices of the Coleoptera at Isola Varano calculated in the different beach areas (b = beach; d = dune) for each month separately and on the total.

	b/J	d/J	J	b/M	d/M	M	b/M	d/M	M	b/J	d/J	J	b/O	d/O	O	b/D	d/D	D	beach	dune	Total
n	1	8	9	808	55	863	603	161	863	1077	99	1176	332	341	673	42	102	144	2863	766	3629
n specie	1	6	7	18	10	20	18	11	20	15	12	20	15	15	20	9	12	15	38	32	48
alpha s. l.				3.64	4.46	4.05	3.88	3.15	4.05	2.76	4.27	3.77	3.68	3.65	4.31	4.48	4.22	4.88	6.60	7.36	8.28
alpha div		10.91	14.49	3.26	3.58	3.66	3.49	2.67	3.66	2.47	3.58	3.42	3.23	3.21	3.87	3.51	3.53	4.21	6.19	6.75	7.81
alpha i. l.				2.89	2.69	3.27	3.10	2.19	3.27	2.18	2.88	3.08	2.78	2.76	3.44	2.54	2.85	3.55	5.78	6.14	7.35
beta div				0.14	0.12	0.22	0.01	0.04	0.22	0.10	0.02	0.26	0.16	0.02	0.20	0.20	0.08	0.10	0.08	0.00	0.24
Brillouin	0	1.15	1.27	1.01	1.68	1.21	1.15	1.34	1.21	0.52	1.63	0.86	1.46	1.50	1.82	1.54	1.56	1.70	1.22	2.25	1.80
Pielou Brillouin		1	1	0.36	0.83	0.41	0.41	0.59	0.41	0.20	0.71	0.29	0.56	0.57	0.62	0.81	0.68	0.67	0.34	0.67	0.47
Simpson		0.07	0.06	0.55	0.19	0.49	0.46	0.32	0.49	0.80	0.22	0.67	0.34	0.34	0.22	0.19	0.24	0.22	0.55	0.15	0.36

The total number of species captured each month was the highest in May (n=23). Fisher's diversity index calculated on the beach and dune for each month separately showed that α values of the beach in July were significantly lower than those of the beach in March, May and October whereas no significant differences were obtained when α values of the dune were compared. Comparisons of the α values of the beach and dune within each month showed significant differences only in July when lower values were found on the beach. However when the total α values were analysed between the beach and the dune no differences were found. Comparisons of the α values between months on the total showed significant differences only between May and July.

β diversity calculated in each zone and month separately (Table IV) showed that 50% of the composition of the coleopteran community changed in a very variable way. For example, on the beach, values varied from a minimum of 0.0146 in May to a maximum of 0.2036 in December, showing that in the latter month 50% of the community changed in its composition every 4.91 m. On the dune β diversity was lower than on the beach with the smallest values found in July and October and the highest in March, with changes of the community every 8.36 m. Calculating β diversity on the total beach dune system for each month, July presented the highest values (0.2558) while the lowest were found in December (0.0993) with changes of the coleopteran community every 3.90 m and every 10 m respectively.

Pielou index of evenness over the entire beach-dune system was 0.4707 (Table IV) with higher values on the dune compared to the beach. Monthly comparisons showed the highest value in January (due to a very low number of captures compared to the number of species) and December while the lowest one in July. Simpson's dominance index was 0.3589 on the total with a greater number of dominant species on the beach compared to the dune. July was the month that presented the highest number of dominant species and December the lowest (not considering January).

DISCUSSION

Comparing the coleopteran community captured at Isola Varano with that of Burano (Chelazzi *et al.* 1990), a locality on the Tyrrhenian coast of southern Tuscany, similar trends in the annual capture frequency of surface-active individuals were found. In both localities peaks of abundance were found in spring-summer months but at Isola Varano about 30% of captures were registered already in March. In both localities the distribution patterns were mainly due to species belonging to the Tenebrionidae family that dominated the scenario in each season. The dominance of this family over other families, such as the Staphylinidae, is a common feature over the Mediterranean area and was reported for other beaches by Colombini *et al.* (2003). Contrarily the presence of Staphylinoidea was generally associated to beaches with a massive presence of organic beach-cast material in which fungivorous and/or predator species occurred (Colombini *et al.* 1998, 2000, 2002). The dominant coleopteran species at Isola Varano was the tenebrionid *Phaleria acuminata* whereas at Burano other two *Phaleria* species occurred (*P. provincialis* Fauvel, 1901 and *P. bimaculata* Linneus, 1777). Shifts in the distribution patterns of the coleopteran community were probably associated to the presence of these species, that presenting differences in their biological cycles, occurred on the beach at different times (Fallaci *et al.* 2002). Data on the capture frequency of the larvae of the *Phaleria* species confirm these differences showing the maximum presence of larvae in March and May for *P. provincialis* (Fallaci *et al.* 2002) and *P. acuminata* respectively. At Isola Varano the life cycle of *P. acuminata* can be deduced analysing the capture frequency of both the adult and larvae phase, confirming patterns already observed for other species of the same genus (Fallaci *et al.* 2002). Over-wintering adults, captured only with sieves during January, started reproducing in March and produced the highest number of larvae by the month of May. The old generation was then replaced by new born individuals that reached their highest number during July. For both adults and larvae of *P. acuminata* shifts in mean zonations towards sea were registered from spring to summer for both active and resting individuals. These were followed by shifts towards land in autumn months. Similar changes in mean zonations had also been recorded for *P. provincialis* at Burano (Colombini *et al*. 1994) and for *P. acuminata* at Zouara a beach in north-western Tunisia (Colombini *et al*. 2002). Variations in the zonation patterns of these species had been explained considering the changes of the microclimatic conditions of the eulittoral in accordance to seasonal changes. In *P. acuminata* the differences in mean zonation registered for the active and burrowed adults showed that in months with unstable climatic conditions in which there was a greater uniformity of the microclimatic conditions of the sand (March when storms are frequent) individuals tended to burrow higher up on the eulittoral. Conversely, in summer months when the climatic conditions tended to ameliorate with the progressive drying up of the eulittoral adults burrowed closer to the sea. However in both seasons foraging occurred in the mid eulittoral showing that there was a specific beach fascia where the most adequate food items could be found all year round.

Of the other Tenebrionidae species sampled at Isola Varano the annual appearance of species on the beach-dune system strictly depended on their biological cycles with a succession of typical spring species, followed by spring-summer species, spring-autumn species, autumn species, and autumn-winter species. Most of these species were found also at Burano (Colombini *et al*. 1994) where similar trapping techniques had been applied and similar phenological patterns had been recorded. Conversely slight differences in the annual patterns of the same species were found when these were compared with the study of Carpaneto and Fattorini (2001) at Castelporziano, a beach locality close to Rome. In this case differences in trapping methods probably generated different annual patterns. However differences with both Burano and Castelporziano occurred when the composition of the tenebrionid autumn-winter species were analysed. In fact at Isola Varano only one specie of *Xanthomus* occurred instead of the two sympatric species (*X. pallidus*, *X. pellucidus* Mulsant, 1856) sampled in the two beach localities of the Tyrrhenian coast. On the Gargano promontory *X. pellucidus* seems to have been replaced by a typical dune species *Pseudoseriscius helvolus*. The presence of *X. pallidus* in association with species of the genus *Pseudoseriscius* had been already recorded in other beaches such as Ir-Ramla l-Hamra a Maltese beach on the island of Gozo (Colombini *et al*. 2003, Mifsud & Scupola 1998) and at Zouara (Colombini *et al*. 2003) showing a greater similarity with these beaches than with the Tyrrhenian ones. On the Adriatic coasts of Romagna, at about 350 km to the north of the Gargano promontory, in a study of ten beach-dune systems Contarini (1992) had reported the presence of *X. pallidus* but this species was never found associated with *X. pellucidus* nor with species belonging to the genus *Pseudoseriscius*.

The two Scarabeidae species that were caught at Isola Varano were contemporaneously present on the dune in autumn winter months with *Psammodius basalis* more active at the sand surface than *P. nocturnus* that definitively was more fossorial. These species had also been reported by Contarini (1992) on other beaches of the Adriatic coast but in this case *P. basalis* had been found more frequently in association with *Psammodius pierotti* Pittino, 1978 than with *P. nocturnus* that was considered a species tied to more pristine dune environments. Contarini (1992) reported concentrations up to 36 adults per m^2 preferably in association with *Ammophila arenaria* whereas at Isola Varano *P. basalis* and *P. nocturnus* reached concentrations of 108 and 32 adults per m^2 respectively. These species were generally found in association with a larger number of pioneer plants with the exception of *Ammophila arenaria* that was quite scarce in this locality. On the Tyrrhenian site of Burano only *Psammodius porcicollis* Illiger, 1803 was sampled and this species was mainly found burrowed in the sand up to a depth of 15 cm at the base of dune plants such as *Crucianella maritima*, *Otanthus maritimus* and *Stachys recta* (personal observations). Generally speaking it appears that the *Psammodius* genus is strictly tied to dune formations with a well developed vegetation cover and that species change according to vegetation types.

The two staphylinid species sampled at Isola Varano were temporally and spatially separated being *Phytosus balticus* mainly present in March in the low eulittoral and *Phytosus spinifer* prevalently in May in the mid eulittoral. Thus competition never occurred between these species even if similar ecological niches were exploited being both fungivorous and scavenger species. At Burano on a total of 44 staphylinid species (Lucarelli *et al*. 1992) sampled with pitfall traps on the entire beach-dune-lagoon system during a one year period of study 43 species had been captured only on the beach and dune areas. Instead at Isola Varano only 6 species had been found in the corresponding areas showing that Burano supported a more complex system of ecological niches due to the presence of a Mediterranean maquis. Since species diversity is strongly correlated with habitat diversity, at Isola Varano the presence of a pinewood plantation in the retrodunal area caused a greater homogeneity of the habitat and probably decreased the number of staphylinid species in the entire area.

Of the four carabid species three (*Lophyridia littoralis*, *Eurynebria complanata* and *Parallelo-*

morphus laevigatus), prevalently hunted sandhoppers (*Talitrus saltator* Montagu, 1908) and therefore were found active on the low eulittoral. These species occurred on the beach with peaks of abundance in different months and were active in different hours of the day being *L. littoralis* diurnal, *E. complanata* nocturnal (Colombini & Chelazzi 1996) and *P. laevigatus* both nocturnal and diurnal. The differences found in the mean zonation of *L. littoralis* and *E. complanata* during surface activity were mainly due to the fact that the first species hunted talitrids along the sealine limits during daytime hours when burrowed sandhoppers were disturbed by wave action. In contrast, the second species, hunting during night hours, exploited more inland areas where sandhoppers had the tendency to move to reach foraging areas (Scapini *et al*. 1992). The fourth carabid species, *Scarites buparius,* presented a larger spectrum of preys compared to the previous species and at Isola Varano was zoned mainly on the dune. Differently to other psammophilous species, *S. buparius* is considered a highly plastic species being able to exploit retrodunal areas including cultivated dune fields (Fallaci *et al*. 1994).

Frequency analysis showed that Isola Varano presented a relatively high number of constant species of which the Tenebrionidae family was the most represented with species exploiting both beach and dune areas. At Burano (Fallaci *et al*. 1994) the number of species classified as constant was more or less the same (n=15) but in this case the most represented species belonged to the Tenebrionidae and Staphylinidae families. Noteworthy was the total absence at Isola Varano of the diurnal species belonging to the *Pimelia* and *Tentyria* genera, species generally found associated with *Erodius siculus* on the dunes (Fallaci *et al*. 1997, Carpineto & Fattorini 2001). However at Isola Varano *Pachychila* sp. probably represented the ecological equivalent of *Tentyria* sp. even if it was found only as an accessory species.

On the whole abundance analysis showed that the number of individuals present on the beach was higher than those of the dune and this was generally correlated with body size, the smallest beetles being the most abundant (Ayal & Merkl 1994, Carpaneto & Fattorini 2001). The most abundant species on the beach was *P. acuminata* a species generally considered as a r-strategist (Carpaneto & Fattorini 2001) whereas on the dune larger size species, such as *E. siculus*, generally supported smaller population size and were regarded as k-strategist (Fallaci *et al*. 1997, Carpaneto & Fattorini 2001). The decrease in abundance from the beach landwards found at Isola Varano is consistent with the general pattern found on other beaches (McLachlan 1991, Carpaneto & Fattorini 2001, Colombini *et al*. 2003). Furthermore there was an increase of the number of abundant species proceeding from the beach to the dune with a guild of dune species typically tied to a specific vegetation cover. Also the ecological indices that were calculated for this locality showed specific trends when analysed from a spatial point of view. Species richness decreased from beach areas to the dune whereas α diversity values increased. This depended on the fact that beach species were generally more abundant than dune species. Consequently dominant species occurred on the beach whereas higher values of evenness of the community were obtained on the dune. Considering temporal patterns such as the changes of the coleopteran community from spring (May) to autumn (October) at Isola Varano there was a decrease in species richness, capture numbers, α diversity values and dominance index whereas the number of abundant species and the evenness of the community increased. All patterns that occurred at Isola Varano followed the same trends that had been previously found for other beaches over the Mediterranean area (Colombini *et al*. 2003) with the exception of species richness that decreased from the beach to the dune. Furthermore α diversity values of Isola Varano were the lowest found when compared to other beach sites. In all other studied beach localities (Colombini *et al*. 2003) an increase of species of the coleopteran community occurred on the dune and this was generally related with a well preserved dune system. Furthermore a positive correlation between beach slope and species diversity had been found. Beaches with higher beach slopes presented a higher number of species in relation to the presence of a more stable foredune with a higher number of plant species that attracted a richer faunal community (Hesp 1991). At Isola Varano the low number of species of the dune and the lower α diversity values of the entire system were probably due to a combination of factors: a relatively low beach slope that prevented the development of a foredune rich in plant species, a small dune size with a scarce pioneer vegetation cover and an absence of a typical Mediterranean maquis, a pinewood plantation in the retrodune that caused a greater homogeneity of the system and a heavy human impact during summer months. Also the low values of β diversity on the dune confirmed that the coleopteran community was homogeneously distributed in relation to a more homogeneous environment.

As conclusion it can be stated that the beach of Isola Varano is currently in a moderate state of good health given the presence of certain bioindicator species such as *E. complanata* and *P. laevigatus*. This means that the entire invertebrate beach community, at the moment, is not particularly suffering from strong perturbations. This was also confirmed by a recent study on beach stability of the littoral area of the Gargano promontory through the computation of the "comparative foredune instability index" (Tessari *et al*. 2003). According to this parameter the beach system of Isola Varano is at present in an apparent state of stability. Nevertheless, it is evident that the dune has undergone and is still undergoing a phenomenon of stress due to the encroachment of the pinewood plantation. Consequently this has generally impoverished the diversity levels of the entire system. However it must be stressed that other important environmental factors, such as exposure and dune morphology, could be implicated in the process. Unfortunately diversity levels before the presence of the pinewood plantation (1977) are unknown therefore it is difficult to say what exactly are the forcing factors. Only the study of faunal communities of a greater number of beaches with similar characteristics but with lower impacts will provide baseline information necessary for the understanding of the processes.

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