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Macroinfauna of Six Beaches near Guaratuba Bay, Southern Brazil

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ABSTRACT

Benthic macroinfauna of six beaches near to Guaratuba Bay, Paraná, Brazil were studied in summer and winter of 1994. Sampling stations were distributed along a transect, from upper of the drift line to depths of nearly 3 m behind the first break of the surf zone. Biological and sedimentological samples, slope, wave height and period were recorded. Subtidal samples were collected by scuba diving. The beaches varied from extremely inclined, composed of coarse sediments, to low inclined, composed of fine and very fine sands. The polychaete Scolelepis squamata*, was the numerically dominant species in those beaches composed by fine to very fine sand in the subaereal profile. The echinoderm* Mellita quinquiesperforata *occurred in the last stations of the surf zone and presented the biggest values of biomass. Crustaceans were the most diverse group across all beach type. Results of classification and ordination analyses showed that zonation pattern fitted better to Salvat's scheme, with minor differences between summer and winter data. CCA's analysis indicated the importance of sampling level and granulometric composition in the distribution of organism.*

Key words: Macroinfauna, sandy beaches, zonation, morphodynamics, Paraná, Brazil

INTRODUCTION

The ecology of sandy beaches are being subject of study of several authors in the last decades. It happens strongly after the international Symposium "Sandy Beaches as Ecosystems" realised in 1983 in South Africa. These environments are characteristically reworked by wave action. It is composed by an intertidal portion, from the base of the sand dunes to the upper limit of swash action, and a subtidal portion, from the swash zone to the nearshore zone, to depths at the wave base.

The composition and abundance of benthic macroinfauna in sandy beaches is commonly related to sediment characteristics. The latter results from coastal morphodynamics and from the geological history of the area (McLachlan, 1983). Many studies were done in sandy beaches resulting in several patterns being identified. These patterns were related to the abundance, diversity and zonation of macroinfauna on different beaches types (*e.g.* Allen and Moore, 1987; McLachlan, 1983, 1990; McLachlan *et al.,* 1993, 1996; Larsen and Dogget, 1990; Jaramillo, 1987, 1994, 1996; Defeo *et al.,* 1992; Dexter, 1992). Generally, these studies reported an increase in diversity and

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abundance with depth. They also suggested different zonation schemes, recognising usually 3 or 4 zones.

However, the above studies ignored the subtidal portion of the beaches. Actually, few studies have been done in this portion (Masse, 1972; Christie, 1976; Oliver *et al*., 1980; McLachlan *et al.*, 1984; Morin *et al*., 1985; Fleischack and Freitas, 1989; Borzone and Gianuca, 1990; Rakocinski *et al.*, 1993) and fewer considering both portions (Hill and Hunter, 1976; Leber, 1982; Borzone *et al*., 1996; Borzone and Souza, 1997). Leber (1982) suggested that benthic intertidal assemblages intergrades into the nearshore subtidal to such an extent that neither can be considered exclusive of the other.

Potential effects of beach erosion on benthic macrofauna are poorly known. Beaches near to Guaratuba Bay have been affected by coastal erosion during the last years (Soares *et al*., 1997). Beach nourishment has been proposed as a possible solution. Although, ecological studies that should be used as a baseline to minimise impacts of engineering works are scarce.

In this context, the present contribution represent the first description of benthic macroinfaunal of beaches near to Guaratuba Bay. In addition, the approach on sandy beach research analysing the abundance, diversity and zonation of sandy beach macroinfauna on the entire sandy beach environment (intertidal and subtidal portions) is renewed.

MATERIALS AND METHODS

The Parana Coast stretches for 105 km in an NE-SW direction and includes several Atlantic open beaches. The Coast includes two major bays, Paranagua Bay and Guaratuba Bay. The tides are characterised by diurnal inequality and attain a maximum and minimum amplitudes of approximately 2 and 0.5 m respectively (Knopers *et al*., 1987).

Six exposed beaches near the Guaratuba Bay (Fig. 1) in Parana State, southern Brazil (Lat. 25º 50` 55`` S; Long. 48º 35` 30`` W) were studied during March (summer) and August (winter) 1994. The beaches were named Nereidas (NE), Guaratuba-1 (G1), Guaratuba-3 (G3), Mansa (MA), Monte Carlo (MC) and Real (RE). Seven to ten sampling stations were distributed along a transect from the upper-intertidal beach until 3 m depth, generally behind the surf zone. Triplicate macroinfaunal samples were collected at each station with an iron core of 0.05 m^2 surface area, taken to a deep of 20 cm. Subtidal samples were collected by scuba diving. Samples were sieved through a 0.5 mm mesh and organisms were fixed in 10 % formalin. All organisms were identified to the lowest taxonomic level possible. The ash-free dry weight (dry weight (80°C/24h) - ash weight (550°C/6h)) were determined for each species in all stations.

Sediment samples were collected at each station for standard mechanical-sieving grain analysis. Mean and standard deviation were computed according to Folk and Ward (1957) and results expressed as ϕ values ($\phi = -\log_2$ diameter in mm).

Modal morphodynamic states were computed employing the dimensionless fall velocity parameter $\Omega = Hb / Ws.T$ (Dean, 1973), where Hb is the breaker height, Ws is the mean fall velocity of intertidal sand and T is the wave period (Wright and Short, 1984); and the surf-scaling parameter $\varepsilon = a_b . \omega^2/g . \tan^2.\beta$ (Guza and Inman, 1975), where a_b is the breaker amplitude, ω is incident wave radian frequency ($\omega = 2 \pi / T$), g is acceleration of gravity and β is the beach/surf zone gradient. Mean values of Hb and T were obtained from visually observations (Perillo and Piccolo, 1987) over one year.

To describe patterns of zonation, raw abundance data of species at each station were submitted to a cluster analysis of the root-root transformed matrix (Field *et al.*, 1982; Gray *et al.*, 1988) using a Bray-Curtis coefficient and the Group Average clustering method (Clifford and Stephenson, 1975). Additionally, non-metric multidimensional scaling (nMDS) ordination were plotted. Both analysis were performed with the PRIMER software package (Plymouth Marine Laboratory, UK).

Two Canonical Correspondence Analysis (CCA) were carried out with the root-root transformed matrixes of species data (Ter Braak, 1986), one from all beaches in summer and other from all beaches in winter, to establish the relationships between stations, species and environmental variables. These CCA`s were performed using the statistical package CANOCO 3-12. The selected variables were not significantly correlated ($p<0.05$) and, were selected by a Monte Carlo test ($p<0.001$) (Ter Braack, 1985). For this analysis only species with $n > 5$ were included. Stations where no species were present were excluded from all analysis.

RESULTS

The Beaches

Salinity and temperature of surf zone water varied from 26 to 33‰ and 24 to 30ºC respectively. The slopes, mean grain size and morphodynamic stages of all beaches are shown in Table 1.

The sediments were composed by quartsozes sands with fine material and with carbonates never exceeding 7.6% and 5.8% in winter, and 5.2% and 9.9% in summer, respectively. Textural characteristics varied from fine well sorted to coarse moderately sorted sand.

A clear dominance of fine sands on NE, G1, G3 and MC, was observed. Otherwise, some stations situated in the transition of the intertidal and subtidal portions of the beaches showed more coarse sediments. MA and RE showed coarse sands on the subaereous portions and fine sands on the subaqueous portions of the beach. These general characteristics were maintained on the two sampled occasions.

Profiles and modal morphodynamic states indicated that NE, G3 and G1 represented intermediate beaches. The first two had a subtidal profile with bars and the Ω and ε values were, respectively, 4 and 4.3; 31.5 and 19.5. MA was characterised as a typical reflective beach (Ω = 1.7; ε = 3.8) with a steep and stable profile always presenting intertidal beach cusps. MC presented the most dissipative characteristics, with a gentler slopes, higher waves and a surf zone usually composed by more than two breakers (Ω = 7.3; ε = 32). RE presented an unusual profile, with a very reflective intertidal beach face (slope 1/7; mean grain size < 1.15 ϕ) and a gentler dissipative surf zone. This was reflected on the different morphodynamical values, Ω indicating a strong reflective state (1.1) and ε showing a high dissipation (31). Data suggested that seasonal variation on the reflective and the dissipative beaches (MA and MC, respectively) were lowest, and prevailed a stable profile with slight changes of textural sediment characteristic.

Intermediate beaches (NE and G3) presented the biggest modification of the profile and sediment characteristics. Both showed a high mobilisation of a bar in their profile. RE beach also showed a strong subaerial and subtidal modification of sediment characteristics between situations, but the profile presented only subtidal modifications, with a more gentle profile during winter.

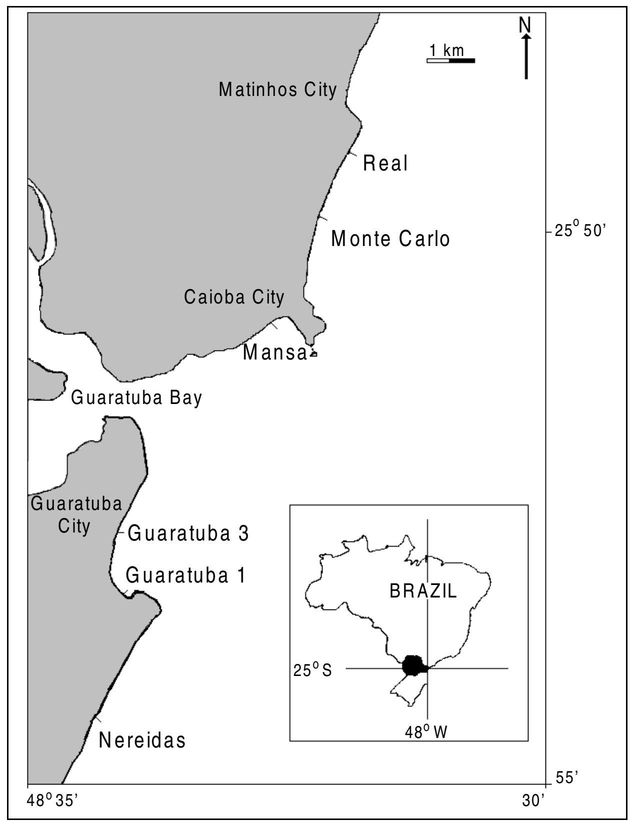

Figure 1 - Sandy beaches studied near Guaratuba Bay, Paraná, Brazil.

Table 1 - Slope (**S**), mean grain size (ϕ) and morphodynamics. **Sum**: summer; **Win**: winter; **sae**: subaereal beach; **saq**: suabaquous beach; **Sz**: width of surf zone in meters; **Hb**: wave height in centimetres; **T**: wave period in seconds; ε: surfscaling parameter; Ω: Deans parameter.

Beach	Sum		Win		Sum		Win						
	S		S		ϕ		ϕ		Sz	Hb	T	ε	Ω
	sae	saq	sae	saq	sae	saq	sae	saq					
NE	1:25	1:32	1:23	1:48	2.33	3.03	2.18	1.98	50	115	10.7	31.5	4
G1	1:55	1:63	1:60	1:60	2.73	2.30	2.62	2.41	100	73	10.5	56	3.6
G3	1:29	1:32	1:33	1:30	2.43	2.71	2.72	2.66	50	87	9.7	19.5	4.3
MA	1:25	1:17	1:32	1:21	1.88	2.53	1.80	2.75	1	50	8.8	3.8	1.7
MC	1:33	1:34	1:31	1:39	2.84	2.65	2.66	2.47	50	125	10.1	32	7.3
RE	1:70	1:30	1:70	1:64	1.14	2.17	0.76	2.63	70	75	10.4	31	1.1

The Macroinfauna

The crustaceans showed the greatest number of species in almost all beaches and, in the rest of these Polychaete showed the same number of species as Crustacea (Table 2). This general pattern was observed both for winter and summer situation. Polychaete was the group that most contributed to the total number of individuals (52 to 89% of total abundances). The only exception was Mansa beach in winter, where 63% of the total number of individuals were crustaceans.

The polychaete *Scolelepis squamata* showed abundances (around 70%) among the total of organisms collected in NE and MC (in winter and summer), in G1 (in summer) and in G3 (in winter) (Table 3). In G1 (winter) and G3 (in summer) this species contributed with more than 30% of the total number of organisms. The polychaete *Scoloplos scoloplos* represented more than 40 % of the organisms in MA in summer. In winter this beach was dominated by cumaceans that together with *Metamysidopsis neritica* and *Cheiriphotys megacheles* represented 36.5% of the organisms. In RE, the numerically dominant species were *Saccocirrus* sp. and *Hesionura* sp.

The greatest values of biomass were showed by *Mellita qunquiesperforata* (Table 4). This echinoderm presented values over 70% of the total of ash free dry weight on G3, MC, and MA (summer and winter) and in RE in summer.

Table 2 - Contribution of the major faunal groups, in percentage, for the total number of individuals per beach, in parenthesis number of species. **B**: beach; **Sum**: summer; **Win**: winter; **P**: polychaetes; **C**: crustaceans; **M**: molluscs; **o**: others groups.

B		P	C	M	o
NE	Sum	79.2	4.1	14.4	2.3
		(5)	(9)	(3)	(1)
	Win	86.5	5.2	6.4	1.9
		(4)	(6)	(2)	(1)
G1	Sum	87.1	3.7	9	0.2
		(4)	(5)	(2)	(1)
	Win	86	9.8	4.2	-
		(5)	(5)	(1)	
G3	Sum	51.8	18.4	16.7	13.1
		(8)	(8)	(4)	(4)
	Win	79.9	3.8	6.5	9.8
		(6)	(10)	(3)	(4)
MA	Sum	54	17.5	21.7	6.7
		(12)	(12)	(5)	(4)
	Win	15.7	63.3	11.1	9.9
		(12)	(25)	(7)	(3)
MC	Sum	89.3	2.4	2.6	5.7
		(7)	(10)	(4)	(3)
	Win	88.3	3.1	1.6	7.1
		(6)	(11)	(3)	(5)
RE	Sum	74.3	8.4	3.5	13.8
		(7)	(7)	(3)	(3)
	Win	94.9	4.2	0.5	0.4
		(7)	(8)	(2)	(2)

Table 3 - Contributions of each specie, in percentage, for the total numbers of individuals per beach and mean total number of individuals per square meter, in summer and winter. Sum: summer; Win: winter.

	NE		G1		G3		MA		MC		RE	
	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win	Sum	Win
Scolelepis squamata	72.1	71.5	73.8	39.9	33.1	74.0	-	-	86.5	79.5	-	-
Mellita quinquiesperforata	2.3	-	-	-	12.1	9.0	5.2	2.5	5.5	6.6	13.6	-
Donax gemmula	7.1	-	4.3	4.1	11.1	4.6	6.7	5.2	-	-	2.6	-
Hemipodus olivieri	6.0	11.2	7.2	5.6	13.1	-	-	-	-	-	-	19.8
Euzonus furciferus	-	-	6.0	32.2	-	2.3	-	-	-	5.7	-	-
Donax sp. (spat)	4.1	-	4.8	-	-	-	-	-	-	-	-	-
Donax hanleyanus	3.2	4.9	-	-	4.9	-	-	-	-	-	-	-
Excirolana braziliensis	2.2	-	-	-	-	-	4.3	3.4	-	-	-	-
Excirolana armata	-	-	3.1	5.6	3.3	-	-	-	-	-	-	-
Bowmaniella brasiliensis	-	-	-	-	11.5	-	4.0	3.3	-	-	4.4	-
Psionidens indica	-	3.4	-	-	-	-	-	-	-	-	-	-
Corophium acherusicum	-	-	-	2.8	-	-	-	-	-	-	-	-
Paraonis pygoenigmatica	-	-	-	7.7	-	-	3.6	-	-	-	-	-
Saccocirrus sp.	-	-	-	-	-	-	-	-	-	-	39.0	19.4
Hesionura sp.	-	-	-	-	-	-	-	-	-	-	32.4	54.7
Diopatra viridis	-	-	-	-	-	-	3.8	-	-	-	-	-
Nephtys simoni	-	-	-	-	-	-	2.9	-	-	-	-	-
Strigilla carnaria	-	-	-	-	-	-	10.5	-	-	-	-	-
Scoloplos scoloplos	-	-	-	-	-	-	41.0	5.2	-	-	-	-
tanaidacea	-	-	-	-	-	-	3.1	4.2	-	-	-	-
Metamysidopsis neritica	-	-	-	-	-	-	-	12.4	-	-	-	-
cumacea	-	-	-	-	-	-	-	14.3	-	-	-	-
Cheiriphotys megacheles	-	-	-	-	-	-	-	9.8	-	-	-	-
Tivela mactroides	-	-	-	-	-	-	-	2.9	-	-	-	-
nemertinea	-	-	-	-	-	-	-	4.2	-	-	-	-
ofiuroidea	-	-	-	-	-	-	-	3.3	-	-	-	-
ostracoda	-	-	-	-	-	-	-	3.1	-	-	-	-
others	3.0	10.9	0.8	2.1	10.9	10.1	14.9	26.2	8.0	8.2	8.0	6.1
Total number of individuals	1456	267	587	143	305	612	446	523	1790	1005	882	758
Mean total number of individuals per square meter	970	178	435	106	203	408	330	387	1193	670	840	722

In RE, in winter *Emerita brasiliensis* presented more than 44 % of the total biomass. G1 was dominated, in terms of biomass, by *Donax gemmula* and *Euzonus furciferus* in summer, and by latter species in winter. NE was dominated by *Loxopagurus loxochelis* in summer and by *Lepidopa richmondi* in winter (Table 4). The clusters diagrams and n-MDS plots (Fig. 2) shows the patterns of macroinfaunal zonation during summer and winter. Results suggested the existence of biological zones coincident with the four physical zones of Salvat (1964). The first zone of Salvat, drying zone, will be discussed latter. The retention zone was characterised by the presence of cirolanid isopods *Excirolana armata* and/or *E.braziliensis* sometimes with *E.furciferus*. The polychaete *S.squamata* indicated the resurgence zone in NE, G1, G3 and MC generally accompanied by *Donax hanleyanus.*

On the more reflective profiles, RE and MA, the resurgence zone was not very evident. The saturation zone was characterised by several species between the intertidal and subtidal portions of the beaches like *Donax gemmula, Hemipodus olivieri, Emerita brasiliensis, Lepidopa richmondi, Paraonis pygoenigmatica, Bowmaniella brasiliensis* and *Metamysidopsis neritica.* The last zone suggested was called outer surf zone and was characterised by high densities of *M. quinquiesperforata* and other species from subaqueous portion of these beaches. The canonical correspondences analysis (CCA) confirmed the trends observed and revealed new ones. The selected environmental variables were sampling level and percent of very fine sand and coarse sand in both occasions. In summer, percent of granule was added to the analysis (Table 5, Figures 3A-B and 4A-B).

Table 4 - Contributions of each specie, in percentage, for the total ash-free dry weight (AFDW) per beach and mean total ash-free dry weight per square meter, in summer and winter. The total AFDW presented in milligrams times 10^2. Where: s = summer and w = winter.

	NE		G1		G3		MA		MC		RE	
	s	w	s*	w	s	w	s	w	s	w	s	w
Scolelepis squamata	7.0	16.3	23.5	2.7	-	-	-	-	-	-	-	-
Mellita quinquiesperforata	34.2	-	-	-	96.9	93.1	71.2	73.3	99.7	96.3	99.7	10.9
Donax gemmula	2.1	-	32.1	-	-	-	-	-	-	-	-	-
Hemipodus olivieri	-	2.6	4.1	-	-	-	-	-	-	-	-	29.0
Euzonus furciferus	-	-	27.2	77.9	-	-	-	-	-	-	-	
Donax hanleyanus	-	12.0	-	-	-	-	-	-	-	-	-	3.5
Excirolana armata	-	-	8.7	8.1	-	-	-	-	-	-	-	
Saccocirrus sp.	-	-	-	-	-	-	-	-	-	-	-	5.3
Hesionura sp.	-	-	-	-	-	-	-	-	-	-	-	2.3
Diopatra viridis	-	-	-	-	-	-	5.0	13.9	-	-	-	-
Strigilla carnaria	-	-	-	-	-	-	2.6	-	-	-	-	-
Loxopagurus loxochelis	47.4	-	-	-	-	-	-	3.1	-	-	-	-
Lepidopa richmondi	-	65.7	-	-	-	2.5	-	2.3	-	-	-	-
Dispio remanei	-	-	-	9.5	-	-	-	-	-	-	-	-
Emerita brasiliensis	-	-	-	-	-	-	17.7	-	-	-	-	44.5
Olivella minuta	-	-	-	-	-	-	-	-	-	2.8	-	-
Pinnixa patagoniensis	-	-	-	-	-	-	-	-	-	-	-	2.6
others	11.4	3.4	4.4	1.8	3.1	4.4	3.5	7.4	0.3	0.9	0.3	1.9
Total biomass (AFDW) in mg.10^2	14.3	1.5	7.3	1.8	63.9	40.1	47.8	24.3	805.3	389.3	453.8	1.9
Mean total biomass (AFDW) in mg.10^2 per square meter	9.5	1.0	5.4	1.3	42.9	26.7	35.4	18.0	536.9	260	432	1.81

*dry weight

Table 5 - Level of explanation of each variable utilised in CCA's.

	level	coarse sand	very fine sand	granule
summer	54.56%	12.1%	6.8%	26.5%
winter	57.5%	28.4%	14.1%	-

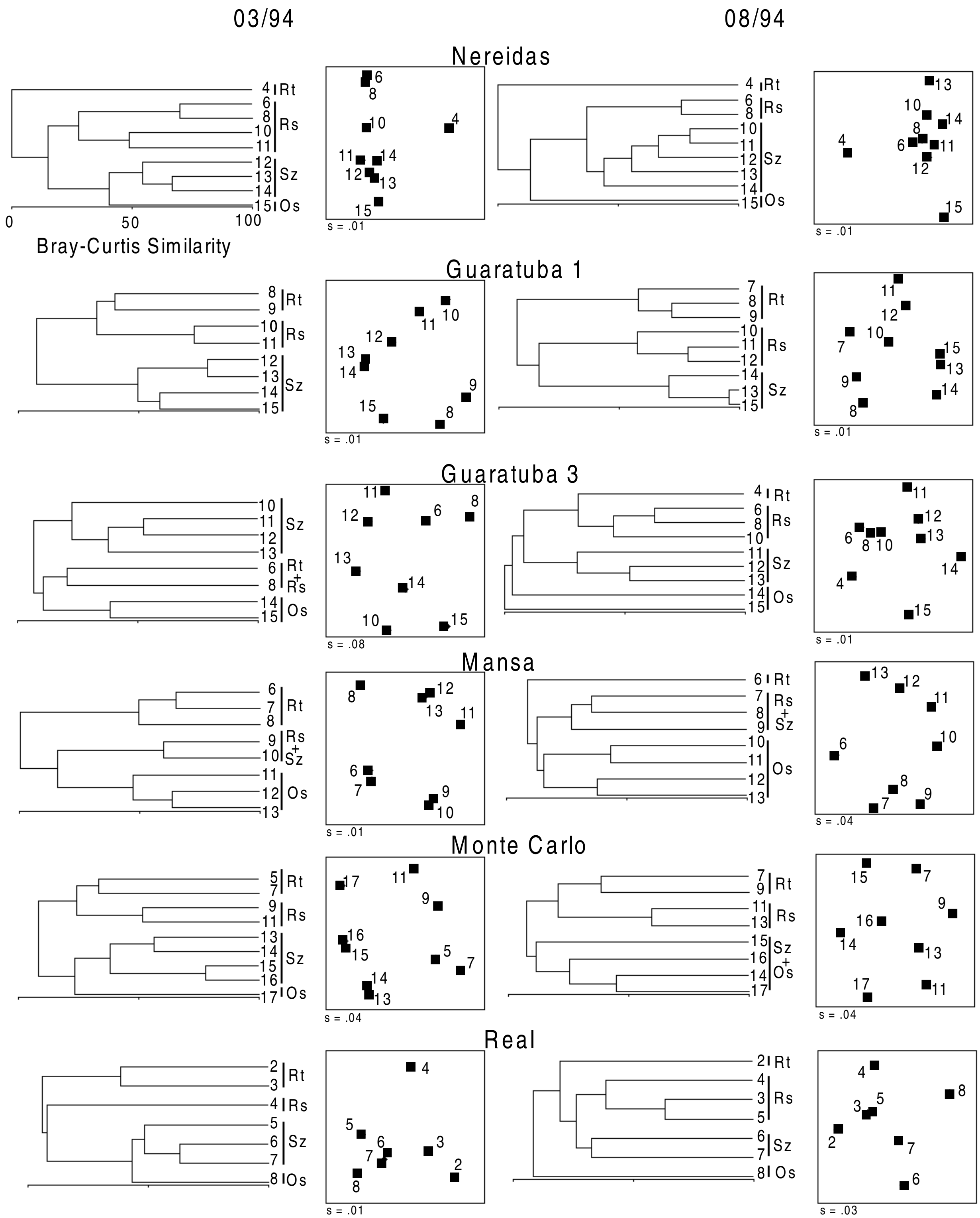

Figure 2 - Clusters diagrams and n-MDS ordinations of each beach in summer (left column) and winter (right column). Numbers are sampling stations. The biological zones were named (in part) according to Salvat's physical scheme (Salvat, 1964). Rt = retention zone; Rs = resurgence zone; Sz = surf zone and Os = Outer surf zone. (s = stress values).

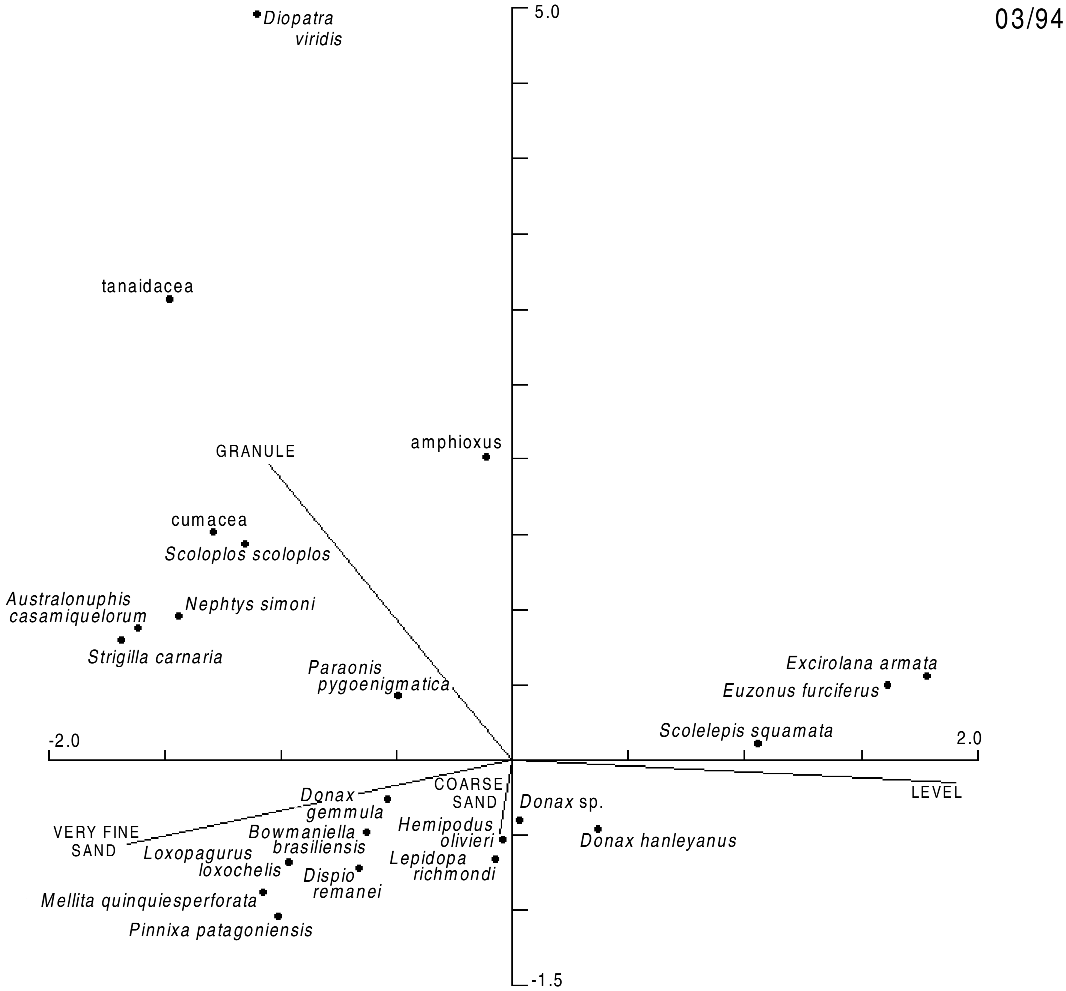

Figure 3A - Summer CCA diagram. Species and environmental variables.

Borzone (1994) showed that depth represented an indirect measure of the wave sediment interaction and it was an important variable in the characterisation of subtidal portions of sandy beaches. Here, the level was considered a super-variable, because it was related to a series of environmental variables such us moisture and degree of desiccation at the subaerial portion of the beach and also turbulence at the subtidal portion of the beach. In summer, the polychaete *Diopatra viridis* was strongly associated to granules, *Hemipodus olivieri* and *Lepidopa richmondi* were associated to coarse sand and *Mellita quinquiesperforata* and *Pinnixa patagoniensis* to very fine sand.

Excirolana braziliensis, *Saccoccirus* sp. and *Hesionura* sp. were eliminated in CCA's, because of their low similarities with all others species in the samples, introducing too much noise in the analysis (Gauch, 1982). During both period (summer and winter), *E.armata, E.furciferus, S.squamata* and *D.hanleyanus* were associated with the superior levels (Figs. 3A and 4A).

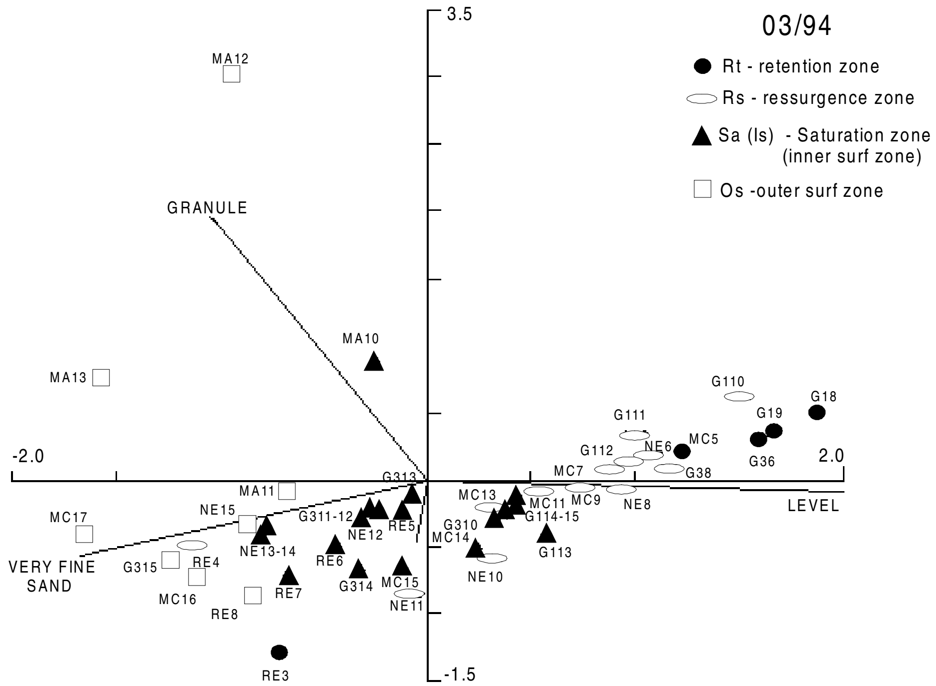

Figure 3B -: Summer CCA diagram. Stations and environmental variables.

DISCUSSION

The Beaches

Variability of sand beaches profiles are manly attributed to a seasonal cycle (winter and summer profiles). However, drastic alterations in physical conditions of a beach may occur in a few hours (Aubrey, 1983). Some patterns have been identified by several authors in Southern Brazil (Gianuca,1983; Santos, 1990; Calliari and Klein, 1993; Angulo and Soares, 1993). These latter authors suggested that in Parana state sandy beaches usually presented constructive and destructives profiles, respectively during summer and winter months. These authors also observed that differentiated patterns of erosion and accretion could occur in function of the characteristics of each micro region. Ours results agree with these observations.

This picture can be much more complex when considering that MA, MC and RE have suffered many anthropogenic alterations in a series of actions, not always successful, to contain beach erosion. These alterations were considered by Angulo and Soares (1993) the main factor that determined the modifications on profiles of these beaches.

The dominance of fine and very fine sands on NE, G1, G3 and MC was evident, although some stations in the interface between intertidal and subtidal environments presented an increase in coarse sands. Swart (1983) showed that this point indicated an intense wave action. So, these stations probably indicated an intense physical stress zone, high turbulence and strong currents, difficulting the fine sediment deposition. MA and RE presented more contrast between the two portions of the beach; the intertidal were dominated by coarse sand and the subtidal by fine sand. The first represented a typical reflective profile and in RE probably as a consequence of its profile disequilibrium.

The Macroinfauna

Gianuca (1983), Escofet *et al.* (1979) and Santos (1990) in south of Brazil and Defeo *et al*. (1992) in Uruguay showed that the Spionidae family was very abundant in intertidal portions of sandy beaches. Souza and Gianuca (1995) and Borzone *et al.* (1996) studied other beaches in Parana state and verified that usually *S.squamata* was the dominant species. In this study *S.squamata* was numerically dominant in almost all beaches. Only in MA and RE, this species was not abundant due to the coarse sands recorded in the subaerial portions of this profiles. This resulted in the dominance of crustacea during winter in MA and the appareances of *Scaccoccirus* sp. and *Hesionura* sp., in RE, two species of small polychaetes (< 10 mm) that may be better considered as components of the meiofauna.

In summer, *Diopatra viridis* was observed in the subaqueous portions of MA. It was distributed in paths, about 1m diameter, and its tubes were constructed with biodetritical fragments (visual observations). According to Woodin (1978) the structures produced by this species could be used as refuges to other macrobenthic species. The increase in heterogeneity of this habitat probably facilitated the coexistence of several peracarids in this stations (Fig. 3A).

McLachlan (1983) suggested that Molluscs usually dominated the intertidal portions of sandy beaches in terms of biomass. Considering only this portion, the beaches here studied did not present this pattern. NE, G1, MC (in both occasions) and G3 (in winter) were dominated by polychaetes and MA and RE (in both occasions) and G3 (in summer) were dominated by Crustaceans. When we analysed the entire beach (intertidal plus subtidal portions), the echinoderm *M.quinquiesperforata* was the dominant species in terms of biomass. Borzone *et al.* (1998) studied the distribution of this species in Parana state and showed that *M.quinquiesperforata* presents high densities forming beds parallel to the coast near the first break point. According to these authors, the distribution of this specie is related with beach morphodynamics, usually near from the intertidal portion of the beach in more reflective profiles. The high values of biomass recorded in this study indicated the importance of *M.quinquiesperforata* in benthic production of these beaches.

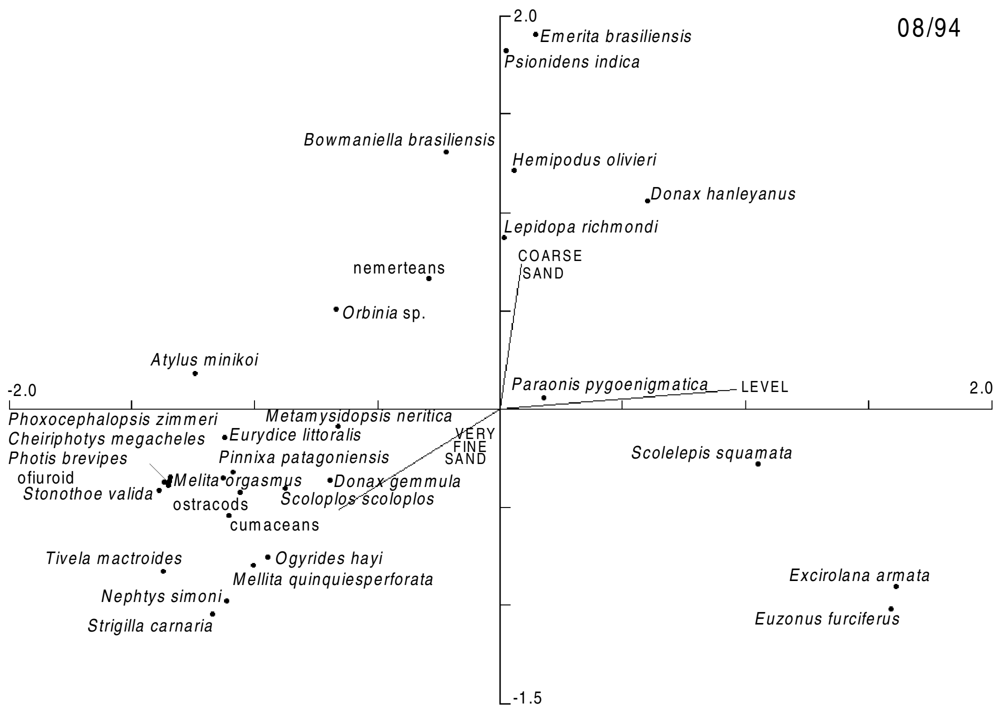

Figure 4A - Winter CCA diagram. Species and environmental variables.

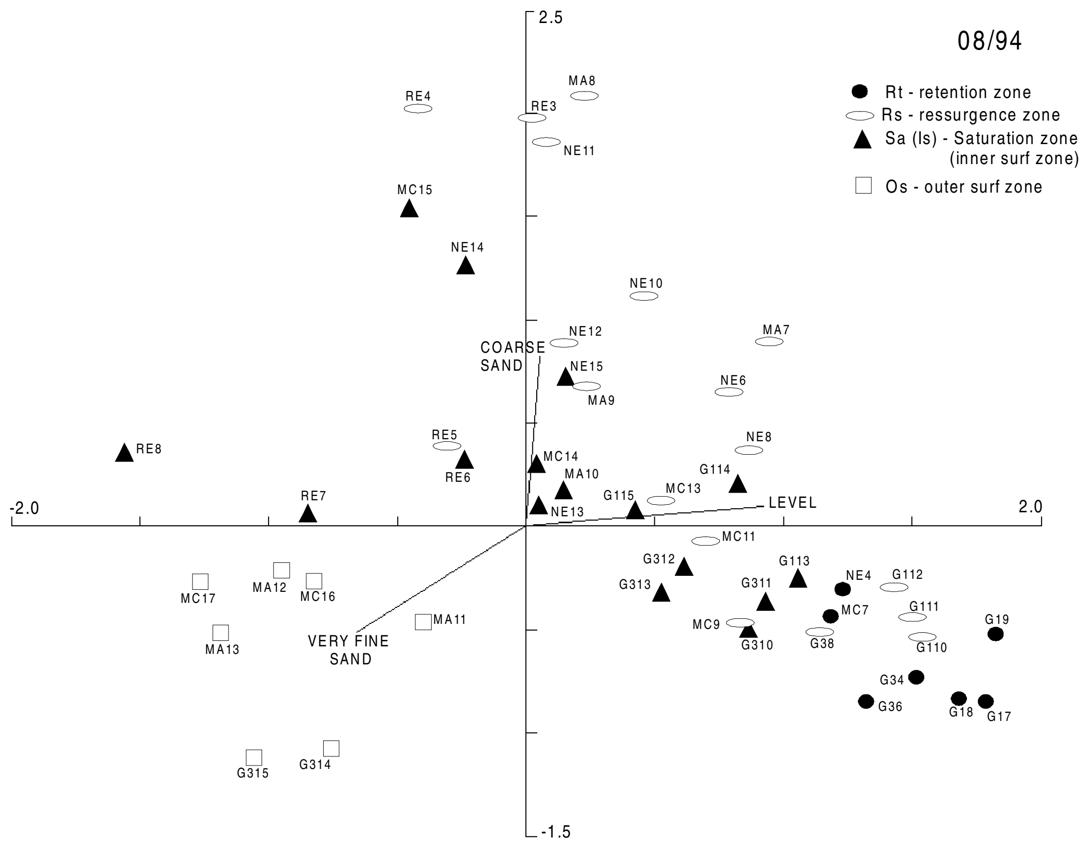

Figure 4B - Winter CCA diagram. Stations and environmental variables.

The most diversified group in this study were Crustaceans. Only Polychaetes showed the same numbers of species. Generally, the high levels of the beaches presented fewer species than the lower levels, agreeing with various authors (Jaramillo, 1994, 1996; Dexter, 1984, Souza and Gianuca, 1995; Borzone *et al*, 1996; McLachlan *et al*, 1984; Day *et al*, 1971; Christie, 1976; Fleischack and Freitas, 1989). Fleischack and Freitas (1989) studied the intertidal and subtidal portions of some beaches and suggested an inverse relation between diversity and turbulence in the subtidal environment. In fact, in the present work MA, a typically reflective beach was the most diversified profile in both occasions.

In intertidal portions of sandy beaches the zonation schemes most adopted were that proposed by Dahl (1952) and Salvat (1964). The former scheme was based on biological zones and the latter on physical characteristics of the beaches. These schemes have been intensively discussed in the literature and have been the subject of discussion in almost all macroinfauna's sandy beach studies. However, there are little information about macroinfauna of surf zones and few authors identified zonation patterns in this portions of sandy beaches (Christie, 1976; McLachlan *et al.*, 1984; Fleischack and Freitas, 1989; Borzone and Gianuca, 1990; Borzone *et al.* 1996).

The distribution and diversity of macroinfauna on sandy beaches are determined by physical factors (McLachlan *et al.*, 1984; Fleishack and Freitas, 1989), mainly by wave action, mean grain size and beach slope (Brown and McLachlan, 1990). Sandy beaches are physically controlled environments and animal populations have little influence one over the other (Noy-Meir, 1979). The community is structured by each of the species answering independently to physical environment more than to biological interactions.

Mills (1969) and Hughes and Thomas (1971) observed that the different distribution patterns of species was a continuum of overlapping and so, usually difficult to establish well defined biological zones. Biological zonation in the present study may be related to Salvat's scheme, as was described by Borzone *et al*. (1996) and Souza and Gianuca (1995) for other beaches in Northern Parana State. Here, the first zone of Salvat was characterised by *Bledius bonariensis*, *B.microcephalus*, *Orchestoidea platensis* and *Phaleria brasilinesis*. The complete absence of these species in the present study could be attributed to urban impacts such as the complete destruction of the dune fields for the construction of roads and buildings immediately before the beach face. Another factor that need to be considered is the high level of recreational activities (trampling) and the usual practice of removal of artificial and natural detritus from these beaches, the latter provides refuge and/or food to several benthic animals.

The second Salvat's zone (retention zone) was characterised by the cirolanid isopods *Excirolana armata* and *E.braziliensis* and occasionally by the polychaete *Euzonus furciferus*. The third zone of Salvat (resurgence zone) was characterised by the peaks of abundance of the spionidae *Scolelepis squamata*, generally accompanied by *Donax hanleyanus*. In RE, this zone was characterised by *Saccocirrus* sp. and *Hesionura* sp. but in MA these were not identified. This confirmed that some zones could be absent in more reflective beaches (McLachlan and Jaramillo, 1995; Borzone *et al.*, 1996). The Salvat's fourth zone (saturation zone) was identified in our profiles by the presence of several species that extended their distributions to the surf zone. These included *Donax gemmula*, *Hemipodus olivieri*, *Emerita brasiliensis*, *Lepidopa richmondi*, *Paraonis pygoenigmatica*, *Pinnixa patagoniensis*, *Bowmaniella brasiliensis* and *Metamysidopsis neritica*. This zone was more appropriately called inner surf zone. The last zone we identified was called outer surf zone and was characterized manly by the peaks of *Mellita quinquiesperforata* and others species. The outer surf zone indicated the start of a more deep zone, free from the high levels of turbulence (Borzone and Gianuca, 1990).

In spite of the fact that the species above described do not present any commercial value, they are links of a complex trophic network with other subtidal species that are important fisheries resources for regional fisherman. Different human impacts like erosion prevent works (e.g. beach nourishment, groynes, sand dune restoration) and recreational activities (e.g. trampling, fishing, off-road vehicles) must be considered for their possible effects on the biotic components of sandy beach ecosystems. Much more research on the effects of these impacts must be done before the realisation of any major developmental work on the region.

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RESUMO

A macroinfauna bentônica de seis praias próximas a Baía de Guaratuba, no Paraná, Brasil, foi estudada no verão e no inverno de 1994. Estações de coleta biológica e sedimentológica foram distribuídas desde a linha de detritos, na parte superior da praia, até uma profundidade de 3 metros, no infralitoral. O poliqueta *Scolelepis squamata* foi a espécie numericamente dominante em praias compostas por areia fina a muito fina. O equinóide *Mellita quinquesperforata* ocorreu nas ultimas estações na zona de arrebentação, e apresentou os maiores valores de biomassa. Os crustáceos foram o grupo mais diverso em todos os tipos de praia. Resultados das analises de classificação e ordenação mostraram um padrão de zonação similar ao esquema de Salvat, com pequenas diferenças entre o verão e o inverno. A analise de correspondência canônica indicou a importância do nível da estação de coleta e da composição granulométrica do sedimento na distribuição dos organismos.

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