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TEMPORAL VARIATION OF SANDY BEACH MACROFAUNA AT TWO SITES WITH DISTINCT ENVIRONMENTAL CONDITIONS ON CASSINO BEACH, EXTREME SOUTHERN BRAZIL

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ABSTRACT

Temporal variations of the macrofauna of sandy beaches have been related to variations in the beach morphodynamics and also to the population dynamics of dominant species. The aim of this article is to describe the temporal variation of the intertidal macrofauna at two sites with distinct environmental condition on Cassino Beach, extreme southern Brazil. At each site three transect lines 50 m apart were defined perpendicular to the shore line, from which samples were collected monthly in triplicate at 4 intertidal levels (10 m apart) from June 2004 to May 2005. During winter a generally low density was observed, due to the absence of recruitments and to the mud deposition, which occurred just before sampling (in April 2004), and to low intensity stranding events. Spring witnessed a population explosion of *Scolelepis gaucha*, a migration of *Mesodesma mactroide*s adults from the subtidal zone, and a strong stranding event. In the summer, recruitment of *M. mactroides*, *Donax hanleyanus* and *Emerita brasiliensis* was observed. Fall was characterized by low densities, except for *D. hanleyanus* recruitment. The macrofauna at both sites showed a striking seasonal variation in density and diversity, perhaps attributable to the recruitment of numerically dominant species and physical disturbances (stranding and mud deposition).

RESUMO

Variações sazonais da macrofauna bentônica de praias arenosas têm sido relacionadas com variações da morfodinâmica da praia e também aos recrutamentos das espécies dominantes. Este trabalho objetiva avaliar a variabilidade temporal da macrofauna da zona entremarés de dois locais com distintas características ambientais na praia do Cassino, extremo sul do Brasil. Em cada local foram demarcadas três transversais (separadas por 50m) perpendiculares à linha de água, nas quais amostras foram coletadas em triplicata em 4 níveis entremarés (separados por 10 m), entre junho/2004 e maio/2005. Durante o inverno ocorreram baixas densidades da macrofauna, que foram relacionadas à ausência de recrutamentos, à deposição de lama no mês de abril e à embancamentos de baixa intensidade. Na primavera foi registrada a explosão populacional de *Scolelepis gaucha*, migração de adultos de *Mesodesma mactroides* do infralitoral e um evento de embancamento. Durante o verão destacaram-se os recrutamentos dos migradores mareais *M. mactroides*, *Donax hanleyanus* e *Emerita brasiliensis*. O outono foi caracterizado por baixas densidades, exceto pelo recrutamento de *D. hanleyanus*. A macrofauna bentônica nos dois locais mostrou variações sazonais na densidade e diversidade, que podem ser atribuídas ao recrutamento das espécies dominantes e a ocorrência de perturbações físicas (embancamento e depósito de lama).

Descriptors: Sandy beaches, Benthic macrofauna, Temporal variation, Cassino Beach.
Descritores: Praias arenosas, Macrofauna bentônica,Variabilidade temporal, Praia do Cassino.

INTRODUCTION

Sandy beaches are among the most dynamic aquatic habitats. Temporal variations in waves, climate and seaward gradients of physical conditions confer to these habitats their dynamic characteristics (BROWN; MCLACHLAN, 1990). Seasonal changes in beach macrofauna have been related to seasonal changes in beach morphology. The main factor that seems to control "life" on exposed sandy beaches is the wave action, which is closely related to sediment grain size and beach morphology (MCLACHLAN, 1990; MCLACHLAN et al., 1993; JARAMILLO et al., 1993; MCLACHLAN; JARAMILLO, 1995; MCLACHLAN, 1996). The most relevant physical factors in these habitats are: waves (types and energy), sediments (size, porosity, permeability), geomorphology, tidal regime and wind (BROWN; MCLACHLAN, 1990).

Depending on the wave energy, grain size and morphology, sandy beaches can be classified in three main types: (i) reflective, on which the wave energy is concentrated at the beach face, sediment is coarse, the slope is steep and the density and diversity of macrofaunal organisms are generally low; (ii) dissipative, where there is a wide surf zone, fine sediment, the slope is gentle and the density and diversity are generally high and; (iii) intermediate, where there is a combination of the factors found on the dissipative and reflective beaches (SHORT; WRIGHT, 1983).

There is a lack of information concerning the biological effects on temporal variation of sandy beach macrofauna. Some authors have found that seasonal variations are related to population dynamics of numerically dominant species (HOLLAND; POLGAR, 1976; DEXTER, 1979, 1984; DEFEO, 1996). The intra and interspecific competition between bivalves (BRAZEIRO; DEFEO, 1999) and isopodes (DEFEO et al., 1997; YANNICELLI et al., 2002) on sandy beaches may also play a major role in the dynamics of these assemblages. The temporal variability in biological marine macrofaunal assemblages is also influenced by physical disturbances, which are important to their dynamics and structure (HALL, 1994).

There are very few studies about sandy beach ecology in Southern Brazil (SOUZA; GIANUCA, 1995; BORZONE; SOUZA, 1997; BORZONE et al., 1996; BARROS et al., 2001) and most of them are from the state of Paraná. In extreme southern Brazil, studies of the ecology of sandy beaches (GIANUCA, 1983; BARROS et al., 1994) are poorly replicated. In this context, the present study seeks to ascertain the main factors that cause the temporal fluctuation in the densities and diversity of sandy beach macrofauna, among the following hypotheses: (1) this temporal variation is driven mainly by morphodynamic changes; (2) these temporal variations are caused by the populational dynamics of numerically dominant species; (3) the fluctuations are driven by the physical disturbances. We also seek to ascertain the differences between these dynamics at two sites with distinct environmental characteristics on Cassino Beach, RS, in extreme southern Brazil.

Materials and Methods

Study Site

Cassino Beach is located in the southeastern portion of the state of Rio Grande do Sul, just south of the mouth of the Patos Lagoon (Fig. 1). The samples were taken at two sites on the Cassino Beach, one known as Querência, 10.4 km south of the jetties (site 1) and another farther south (site 2), close to the stranded ship Altair, 17.2 km south of the jetties (Fig. 1).

Along the coast line south of the mouth of the Patos Lagoon, the beaches present some differentiation in their morphodynamic characteristics, influenced by the jetties. There is greater sedimentation in the southern sector. The jetties act as a barrier to the passage of sediment, causing a progradation of the beach line over 9 km (CALLIARI; KLEIN, 1993). The mean size of the sediments close to the jetties is fine, although there is an abrupt rise in the mean grain size towards the south (FIGUEIREDO, 2003, unpublished). The western jetty acts as a "shadow" for the entrance of winds from the northeast, decreasing the wave energy. The sector south of the jetties can be divided as follows: (i) an area of strong influence of the jetties, which extends as far as 10 km southwards from them; (ii) an area of moderate influence, from 10 to approximately 23 km to the south; and (iii) an area with no influence at all beyond 23 km to the south (Calliari, pers. com.).

Pereira (2004, unpublished), using 16 environmental parameters and multivariate analysis, divided the beaches of the Rio Grande do Sul coast into 5 groups according to their morphodynamic characteristics. According to this author, the region of Querência (site 1 of this study) is classified as a beach with dissipative tendencies, while the region of the stranded ship Altair (site 2 of this study) is considered to be a beach with intermediate characteristics.

These sites were selected to report the temporal fluctuation of the sandy beach macrofauna at two sites with distinct morphodynamics characteristics (intermediate *vs* dissipative).

Macrofauna Sampling

The macrofauna sampling was conducted monthly from June 2004 to May 2005. The sample design was planned at fixed intervals with transects changing according to the limit of the shoreline (DEFEO; RUEDA, 2002; SCHOEMAN et al., 2003). To characterize the structure and dynamics of the assemblage of benthic macroinvertebrates at each site, three transect lines were defined, perpendicular to the shore line, which extended from 10m above the upper swash zone passing through the lower mesolitoral zone, up to nearly 1m of depth in the inner surf zone. The transect lines were 50m apart at each site. Four sampling levels were established on each transect, 10m from each other. At each level, three samples horizontally 2m apart were collected (Fig. 2). The samples were collected with a 20 cm diameter core (0.031 m^2), by burying it 20 cm deep. The biological samples were sieved through 0.5 mm mesh and fixed in 10% formalin for later analysis. The macrofauna were sorted from the sample, in the laboratory, and identified to the lowest possible taxa. This sample design was similar to the design conduct by Neves and Bemvenuti (2006) at three sandy beaches in the northern coast of Rio Grande do Sul, to analyze the zonation pattern of sandy beaches with distinct environmental characteristics.

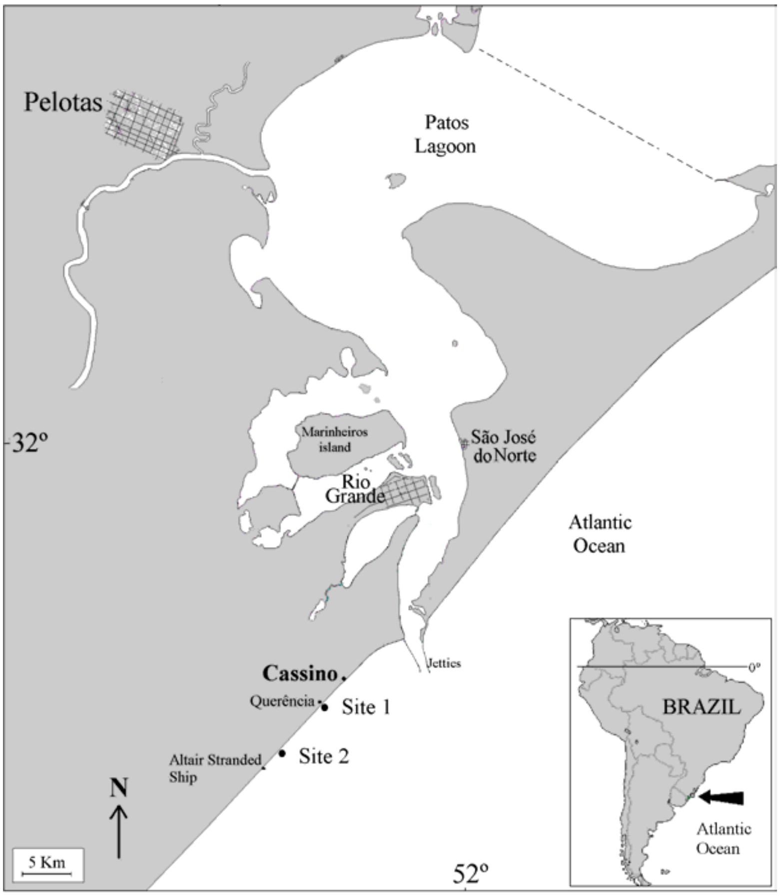

Fig. 1. Regional location of Cassino beach showing the position of sampling sites.

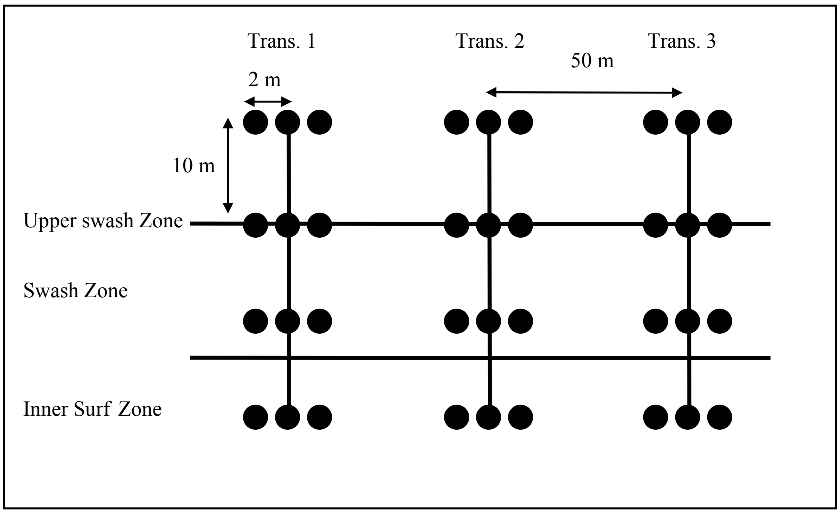

Fig. 2. Sampling design showing the positions of transversals and stations on the studied sites. Trans.- Transversals; Black circles – sample.

Morphometric data of the bivalves *Mesodesma mactroides* and *Donax hanleyanus* were obtained by measuring the length of each individual with a pachymeter. For *M. mactroides*, adults (adults + juveniles) were considered to be those individuals 10 mm or longer and recruits those smaller than 10 mm (DEFEO et al., 1992). For *D. hanleyanus*, adults (adults + juveniles) were considered to be those organisms 5 mm or longer, and the smaller individuals considered recruits (DEFEO; DE ALAVA, 1995).

Environmental Parameters

Sediment samples were collected seasonally using a 20 cm diameter core, for granulometric analysis. One sample was collected at each level of the respective transect, thus giving a total of 24 samples per season. In addition, each month, the wave height, period and type and the width of the surf zone (visual observations) were also recorded. The dimensionless Dean's parameter $\Omega = Hs/(Ws.T)$ was calculated to help to characterize the beach stage, where Hs is the wave height in meters, T is the wave period in seconds and Ws represents sediment fall velocity in $m.s^{-1}$. When $\Omega < 1$ the beaches tend to be reflective, when it is > 6 they tend to be dissipative and intermediate when $1 < \Omega < 6$ (SHORT; WRIGHT, 1983). According to these authors dissipative beaches have a wide surf zone and the waves are of the spilling type, while reflective beaches have a narrow surf zone and the waves are of the plunging type.

Topographic profiles were traced seasonally on the same transects as were used for the biological sampling, from the base of the dunes out to the inner surf zone, to register the form of the beach, thus contributing to its characterization. A topographic level (model Nikon dtm 330) was used for this purpose. The water and air temperatures (thermometer) and water salinity (refractometer) were also registered monthly.

Statistical Analyses

The analysis of the data was undertaken with the software STATISTICA v 6.0 and PRIMER v 5.0. Among the univariate statistical techniques used, the Shannon-Wiener (H') diversity index (Log_e), which integrates the number of species and their abundance in assemblages, was calculated. Bi-factorial analyses of variance were used to test the significance of the differences in the total density and diversity as also of the densities of selected species (those that accounted for more than 1 % of the total density) between the sites (1 and 2) as well as between seasons. The data were transformed to log(X+1) in order to increase the homogeneity of the variances, which was tested with the Cochran C test. The statistical differences ($p < 0.05$) were evaluated *a posteriori* using the Newman-Keuls test (UNDERWOOD, 1997). The percentage of explication of the variance of each factor (site, season, site*season and error) was calculated as follows: % of explication = SS*100/TSS, where SS is the sum of the squares (for each factor) and TSS is the total sum of the squares. The same bi-factorial analysis of variance used for biotic variables was used to test the significance of the differences of the abiotic variables: wave height, width of surf zone, sediment size and Dean's Parameter.

For the multivariate analyses, similarity matrixes with paired samples using the Bray-Curtis index were prepared. Multidimensional scaling analyses MDS were undertaken based on the similarity matrix. To verify possible differences between the seasons and the months, the analyses were conducted separately for each site and in these analyses the densities of each species, at each level, were summed up (replicates were not summed) in order to try reduce the variability of vertical distribution (CLARKE; WARWICK, 1994).

RESULTS

Environmental Parameters

There was little seasonal variation in salinity at both sites, although it was a bit higher in the summer and fall and lower in the winter and spring. The air and water temperatures at both sites were higher in the summer, intermediate in the fall and spring and much lower in winter (Table 1).

Despite the fact that Dean's parameter (Ω) had similar main values at both sites, at site 1 Ω =3.821 and at site 2 Ω = 3.863 (p = 0,895), site 1 had the visible characteristics of a dissipative beach, while site 2 had those of an intermediate beach. The wave heights were significantly higher at site 2 (mean Hs = 0.75 m) than at site 1 (mean Hs = 0.5 m) (p =0,021). At site 1, the width of the surf zone (mean = 80m) and the type wave (spilling) were typical of dissipative beaches, while at site 2, the width of the surf zone (mean = 50 m) and the type of wave (plunging) were typical of intermediate beaches (p = 0,001). The sediment size was larger at site 2 (mean of 0.185mm) than at site 1 (mean of 0.174mm) although did not show significant difference (p=0,067) (Table 1). The slopes showed little variation during the year with periods of accretion and erosion (Fig. 3), although in the summer the formation of a "berm" close to the shoreline was observed. The mean declivity during the year demonstrated a beach with a gentler slope at site 1 (1.4º) and a slightly steeper at site 2 (1.7º).

Table 1. Environmental characteristics of the sampled sites. * Same at both sites. Diss – dissipative; Inter. - intermediate

	Site 1				Site2			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Salinity*	31.5	31	34.5	34.5				
Air temperature*	16.5	20.5	24.7	21.1				
Water temperature*	15	18.8	23.8	20.6				
Wave height (m)	0.5	0.5	0.5	0.5	1	1	0.5	0.5
Wave period (s)	7.8	11.2	10.7	10.4	9.4	11.2	10.8	9.9
Type of waves	Spilling	Spilling	Spilling	Spilling	Plunging	Plunging	Plunging	Plunging/ spilling
Width of surf zone (m)	100	75	75	75	50	40	40	50
Mean sediment size (mm)	0.174	0.192	0.171	0.161	0.211	0.171	0.185	0.171
Selection of sediment (Φ)	0.548	0.586	0.566	0.477	0,668	0,53	0,591	0,537
	moderate	moderate	moderate	Good	moderate	moderate	moderate	moderate
Textural group of sediment	Fine Sand	Fine Sand / medium	Fine Sand	Fine Sand	Fine Sand / medium	Fine Sand	Fine Sand / medium	Fine Sand
Dean's Parameter (Ω)	5.708	2.137	2.976	4.464	4.956	4.097	3.269	3.131
Beach type	Diss	Diss	Diss	Diss	Diss/Inter	Diss/Inter	Diss/Inter	Diss/Inter

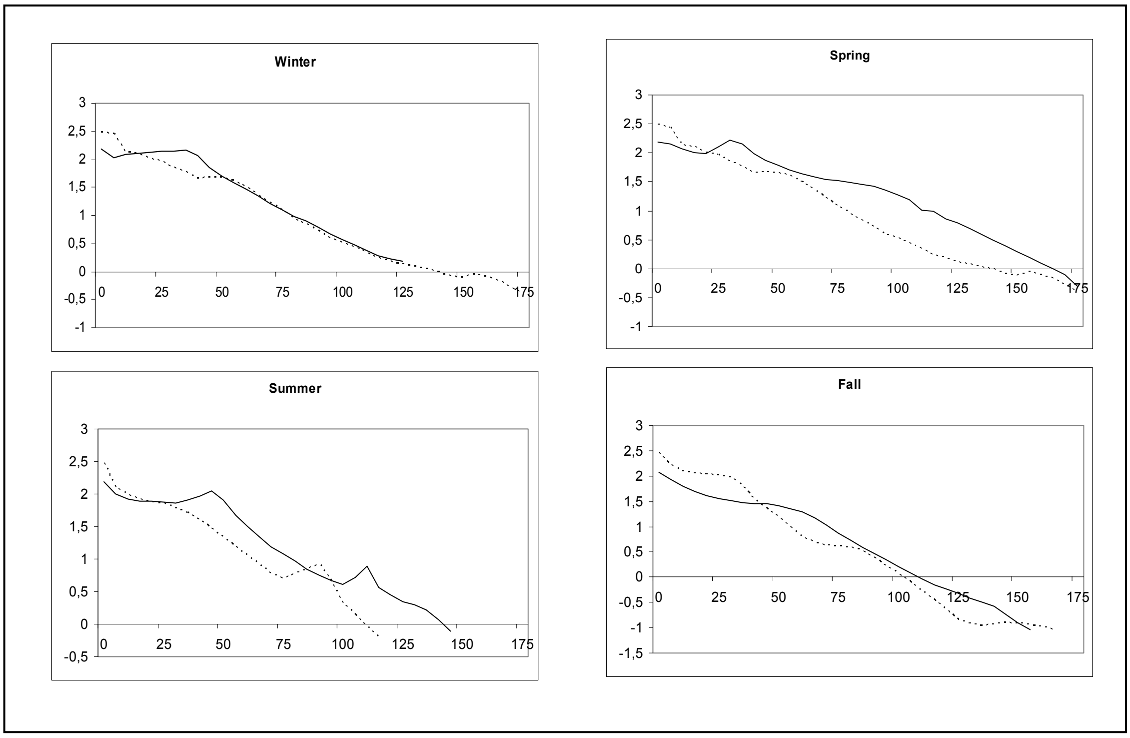

Fig. 3. Beach profiles. The abscissas axis represents the distance from the dunes (m) and the ordinate axis the elevation (m). ── site 1; .... site 2.

Both sites demonstrated little seasonal variation concerning the beach stage, the sediment size, wave height and period, width of surf zone and wave type. Dean's parameter had higher values in the winter at both sites, followed by fall at site 1 and spring at site 2, and lower values in summer and spring at site 1 (p=0,001). The wave height was higher in winter and spring (mean Hs = 1m) at site 2, while at site 1 there was little variation (mean Hs = 0.5m), although did not show significant differences among the seasons (p=0,129) and the interaction seasons*sites (p=0,083). The sediment size was significantly greater in spring at site 1 (mean = 0.192 mm, fine to medium sand) and in the winter (mean = 0.211mm, fine to medium sand) at site 2 than the others seasons at both sites (p=0,009) (Table 1).

Macrofauna

At site 1 a total of 121,572 individuals belonging to 33 taxa were quantified, while at site 2 143,100 individuals belonging to 35 taxa were quantified (Table 2), during the 12 months of sampling. The population densities vary from 0 to 177,808 ind.m^{-2}. The polychaeta *Scolelepis gaucha* Orensanz and Gianuca, 1974 (Spionidae), *Euzonus furciferus* Ehlers, 1897 (Spionidae), the bivalves *Mesodesma mactroides* Deshayes, 1854 (Mesodesmatidae) and *Donax hanleyanus* Philippi, 1847 (Donacidae), the amphipods *Bathyporeiapus* sp. Schellenberg, 1931 (Haustoriidae), *Phoxocephalopsis* sp. Schellenberg, 1931 (Phoxocephalopsidae) and an unidentified specie of Platyschnopidae were the most numerous (considering both sites), with individual densities higher than 1% of the total density.

Table 2. List of taxa identified and their respective mean densities (ind.m^{-2}) at each one of the sites sampled.

	Site 1	Site2		Site1	Site2
Coelenterata	0,000	0,234	**Anphipoda**		
Nemertea	5,851	17,710	*Bathyporeiapus* sp.	836,344	760,745
Mollusca			Platyischnopidae	7,646	280,160
Gastropoda			*Phoxocephalopsis* sp.	16,306	278,287
Olivancillaria auricularia	0,000	0,156	*Puelche orensansi*	4,057	3,901
Bivalvia			**Isopoda**		
Mesodesma mactroides	1251,161	1365,690	*Excirolana armata*	0,078	31,909
Donax hanleyanus	631,315	727,900	**Cumacea**		
Donax gemmula	19,816	44,158	*Diastylis sympterigiae*	0,156	0,000
Buccinanops duartei	0,000	0,702	**Tanaidacea**		
Janthina janthina	0,078	0,078	*Hemikalliapseudes* sp.	0,468	0,078
Annelida			**Mysidacea**		
Polychaeta			*Mysidopsis tortonesi*	40,413	85,351
Scolelepis gaucha	6534,610	7344,358	**Insecta**		
Euzonus furciferus	65,612	72,790	Staphynelidae	0,468	1,170
Hemipodos olivieri	19,504	18,100	Unidentified A	1,092	1,014
Sigalion cirriferum	1,170	3,667	Chironomidae	0,390	0,312
Parandalia sp	0,234	0,000	Formicidae	0,390	0,234
Polidora sp.	0,078	0,000	Unidentified B	0,312	0,000
Grubeulepis bracteata	0,000	0,078	Scarabaeidae	0,078	0,312
Hyalinoecia sp.	0,078	0,000	Chrisomelidae	0,000	0,234
Artropoda			Phoridae	0,000	0,078
Arachnida	0,000	0,390	Nematocera	0,000	0,078
Crustacea			Unidentified coleóptero	0,000	0,078
Decapoda			Gryllotalpidae	0,000	0,078
Emérita brasiliensis	44,782	103,295	Carabidae	0,078	0,000
Pinnixa patagoniensis	0,390	0,546	**Equinodermata**		
Callinectes sapidus	0,078	0,000	**Ophiuridae**	0,078	0,000
Arenaeus cribarius	0,000	0,078	**Bryozoa**	0,078	0,000

During the sampling period, diversity was significantly lower at site 1 (mean H' = 0.57) than at site 2 (mean H'= 0.99). Seasonally, the diversity fluctuated, and was significantly lower in the spring at site 1 than in the other seasons of the year at both sites (Fig. 4; Table 3). The lower diversity coincided with the period of greater density and a high dominance of the polychaeta *Scolelepis gaucha*.

The total density was significantly lower in the winter than in the other seasons and in this season no significant differences were found between the sites. In this season, site 1 was characterized by low densities of all the taxa, the amphipod *Bathyporeiapus* sp. and the bivalve *M. mactroides* (recruits) being dominant. A greater diversity of species was verified at site 2: *M. mactroides*, *Bathyporeiapus* sp., *D. hanleyanus* (juveniles+adults) and *E. furciferus* being the dominant ones (Figs 4 and 5; Table 3).

In the spring the total density was significantly higher than in the other seasons, and it was significantly higher at site 2 than at site 1. In this season there were three events (a population explosion of *S. gaucha,* migration of *Mesodesma mactroides* to the intertidal zone and a strong stranding event) which influenced the entire macrobenthic assemblage of the intertidal zone. In September a "bloom" of *S. gaucha* was noted at site 1, with densities that reached 134,209 ind.m^{-2}. This population explosion took place at site 2 only in November, when the densities reached 174,274 ind.m^{-2}. The higher densities of this organism lasted until January, and it had much lower densities in the other sampling periods (Fig. 4 and 5; Table 3).

A large number of *M. mactroides* (juveniles+adult), which had migrated from the subtidal zone, were observed in the intertidal zone in October. This bivalve showed higher densities at site 2 (Fig. 5). Between Oct. 22 – 26, after the passage of a cold front, a large number of these organisms were noticed stranded in the upper mesolitoral zone. Other organisms, both from the subtidal (e.g. *Mactra* sp.) as well as from the intertidal zone (*E. brasiliensis* and amphipods), were also found dead on the beach. In November, a reduction in the density of the bivalve *M. mactroides* (juveniles+adults) and of the amphipods *Bathyporeiapus* sp., *Phoxocephalopsis* sp. and Plastyschnopidae was observed at both sites (Fig. 5 and 6). Individuals (adults+juveniles) of *D. hanleyanus* were found in high densities in the intertidal zone during the spring and early summer at both sites. Nevertheless, mortalities were not registered of these organisms that were linked to the stranding event of October (Fig. 5).

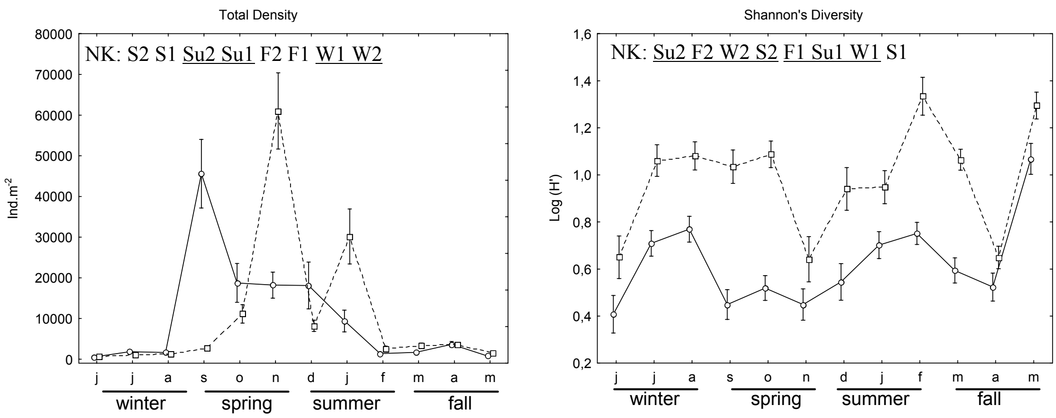

Fig. 4. Total density and diversity during the 12 months sampled. Mean + Standard Error. —— site 1; - - - site 2. NK - Newman-Keuls results representation of de interaction seasons*sites; Seasons/sites symbols: W- winter; S – Spring; Su – summer; F – Fall; 1 – season at site 1; 2 – season at site 2. Lines connecting seasons/sites symbols represent no significant differences.

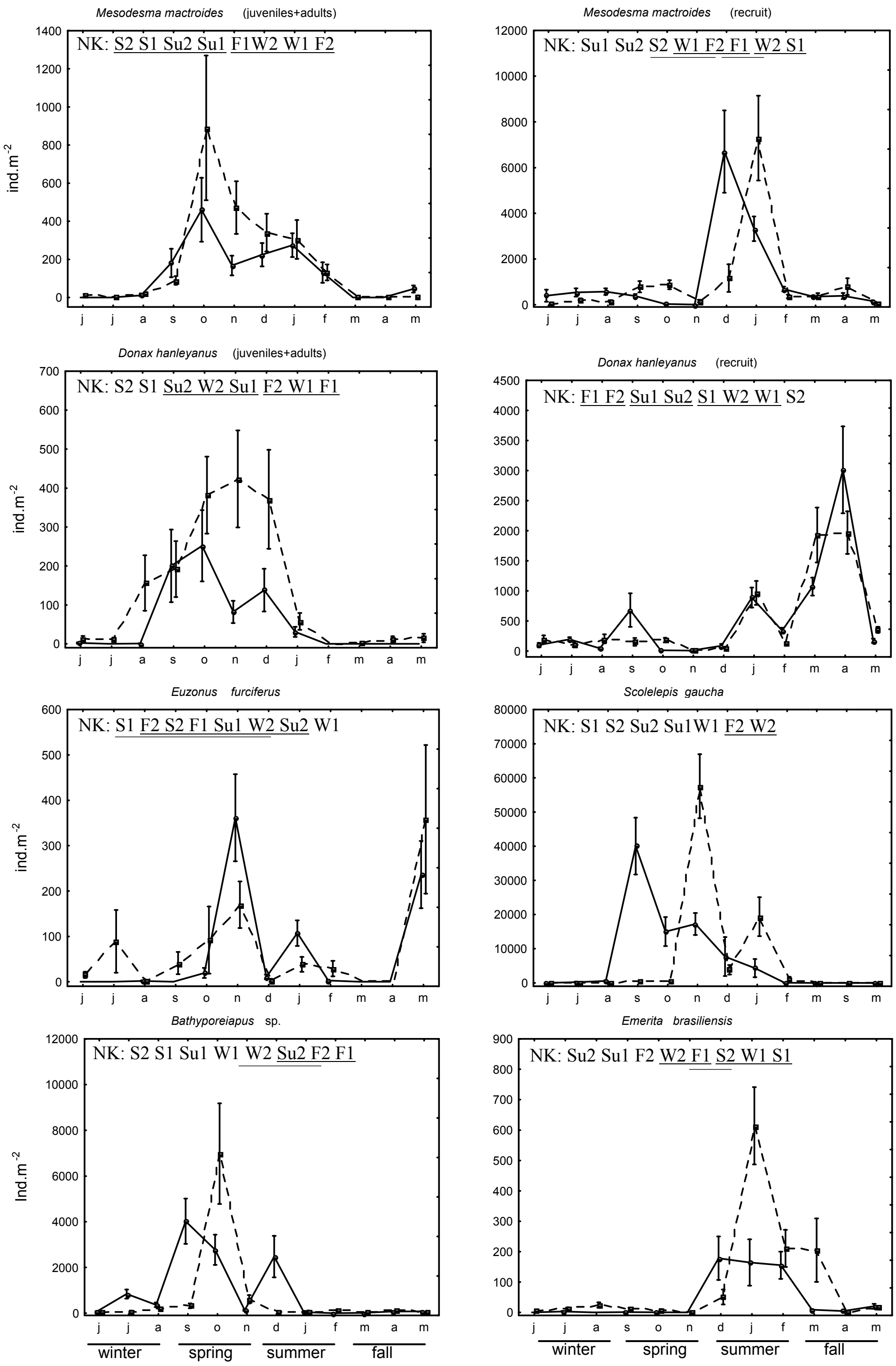

Fig. 5. Density of *Mesodesma mactroides*, *Donax hanleyanus*, *Euzonus furciferus*, *Scolelepis gaucha*, *Bathyporeiapus* sp. and *Emerita brasiliensis* during the sampling period. Mean + Standard Error. ── site 1; - - - site 2. NK - Newman-Keuls results representation of de interaction seasons*sites; Seasons/sites symbols: W- winter; S – Spring; Su – summer; F – Fall; 1 – season at site 1; 2 – season at site 2. Lines connecting seasons/sites symbols represent no significant differences.

In the summer the total density was significantly lower than in spring, although greater than in fall and winter, and no significant differences were noticed between the sites. This high density was due to the recruitment of the tidal migrants *M. mactroides*, *D. hanleyanus* and *E. brasiliensis,* which took place at both sites. *M. mactroides* (recruits) showed a considerable increase in density, with a peak in December at site 1 and in January at site 2. The beginning of the recruitment of *D. hanleyanus* was observed by virtue of its greater densities in January at both sites. *E. brasiliensis*, which had low densities during the year, was observed with high densities during summer at both sites and in fall at site 2 (Fig. 5; Table 3).

In the fall, the total density was significantly higher than in winter, although lower than in spring and summer, and in this season it was lower at site 1 than at site 2. During this season, low densities were found at both sites, except for expressive recruitment of *D. hanleyanus*, whose densities reached 15,820 ind.m^{-2} (site 1) and 11,140 ind.m^{-2} (site 2), with a peak in April at site 1 and March and April at site 2. The polychaeta *E. furciferus* was also found in high densities in May (Fig. 5; Table 3).

The amphipods *Phoxocephalopsis* sp. and Platyschnopidae, which were found in higher densities at site 2 and had lower densities at site 1, during the entire sampling period (Fig. 6).

The multidimensional scaling ordination MDS showed a separation of some of the months. The seasonal differences were clearly evident at site 1, given that the samples from each season were grouped (Fig. 7a). At site 2, the seasonal influence was less evident, the June, July, August, November and February samples formed a group, while those of December and January formed another group. The samples of the other months form distinct groups, revealing monthly fauna variations (Fig. 7b).

Table 3. Results of the bi-factorial analysis of variance for diversity, total density and density of the species that accounted for more than 1% of the total density during the months sampled. * 0.05 > p > 0.01; ** p < 0.01; % of expl.- percentage of explanation of each factor.

		Scolelepis gaucha			*Mesodesma mactroides* (adult)			*Mesodesma mactroides* (recruit)			*Donax hanleyanus* (adult)		
	DF	% expl.	MS	F	% expl.	MS	F	% expl.	MS	F	%exp.	MS	F
sites	1	0,4	10,780	7.653**	0,2	1,900	2,005	0,1	1,887	1,279	2,0	15,659	19.992**
seasons	3	46,7	380,152	269.876**	21,6	70,744	74.639**	15,0	74,143	50.249**	16,6	43,129	55.065**
sites*seasons	3	3,5	28,617	20.315**	0,3	1,143	1.205*	4,2	20,628	13.980**	0,3	0,705	0,9
error	856	49,4	1,409		77,9	0,948		80,6	1,476		81,1	0,783	

		Donax hanleyanus (recruit)			Plastyschnopidae			*Phoxocephalopsis* sp.			*Emerita brasiliensis*		
sites	1	0,0	0,157	0,116	32,4	349,917	432.191**	24,2	257,680	301.112**	2,3	16,199	25.029**
seasons	3	22,9	108,874	80.720**	2,4	8,650	10.684**	2,9	10,218	11.940**	17,1	39,290	60.709**
sites*seasons	3	0,8	3,606	2.673*	1,1	3,897	4.813**	4,1	14,571	17.027**	0,2	0,543	0,838
error	856	76,3	1,349		64,1	0,810		68,8	0,856		80,3	0,647	

		Euzonus furciferus			*Bathyporeiapus* sp.			Diversity			Total Density		
sites	1	0,0	0,047	0,065	0,1	0,840	0,693	13,7	1,528	140.850**	0,1	0,406	1,109
seasons	3	3,3	7,068	9.850**	18,5	80,010	66.054**	2,7	0,100	9.261**	36,5	60,735	165.933**
sites*seasons	3	1,2	2,593	3.614*	1,7	7,569	6.249**	0,4	0,016	1,468	0,8	1,280	3.498*
error	856	95,5	0,718		79,7	1,211		83,2	0,011		62,7	0,366	

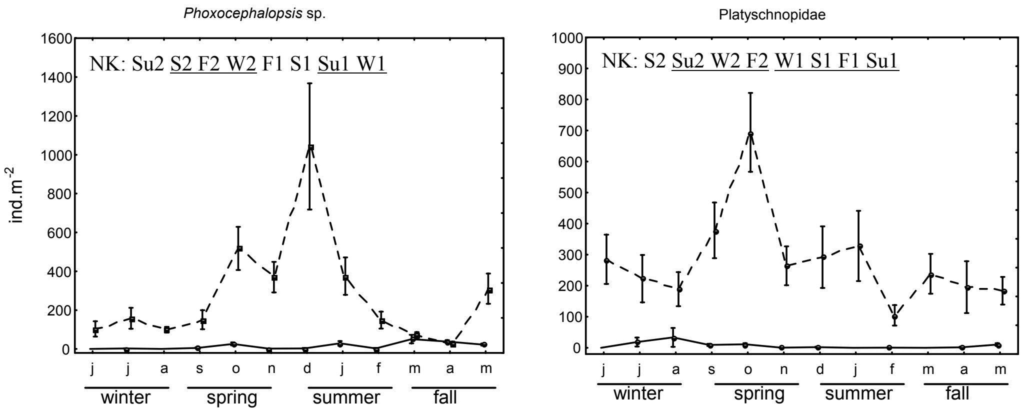

Fig. 6. Density of Plastyschnopidae, *Phoxocephalopsis* sp. during the sampling period. Mean + Standard Error. ── site 1; - - - site 2. NK - Newman-Keuls results representation of de interaction seasons*sites; Seasons/sites symbols: W- winter; S – Spring; Su – summer; F – Fall; 1 – season at site 1; 2 – season at site 2. Lines connecting seasons/sites symbols represent no significant differences.

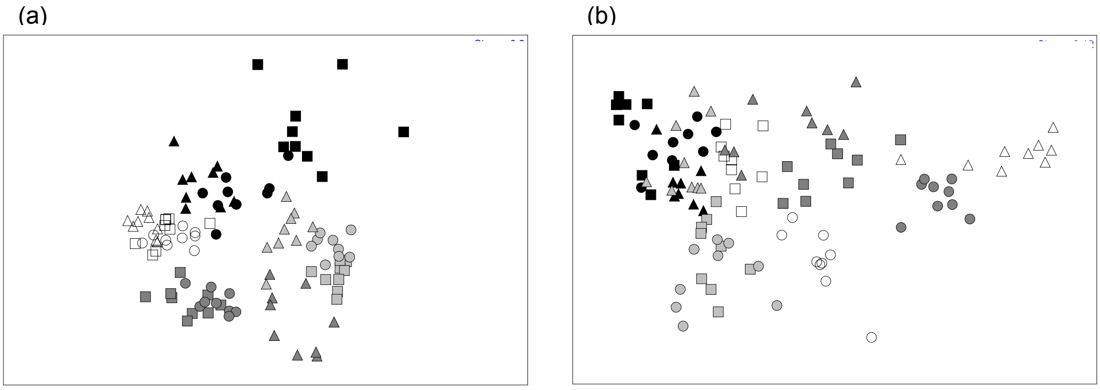

Fig. 7. Analysis of multidimensional scaling (MDS), comparison of the macrofauna assemblages among the months sampled. (a) site 1; (b) site 2. ■ – June; ● – July; ▲ – August; ○ – September; Δ - October; □ – November; ■ – December ● – January; ▲ – February; ■ – March; ● – April; ▲ – May. Stress a = 0,2 and b = 0,12.

Discussion

The macrobenthic assemblages of Cassino Beach showed a striking dynamic over the twelve months of sampling. The main variations were linked to the population dynamic of the dominant species. Despite the fact that sandy beaches are classically considered as physically controlled environments (MCLACHLAN, 1990, 1996; MCLACHLAN et al., 1993; JARAMILLO et al., 1993; MCLACHLAN; JARAMILLO, 1995), many authors have found that fluctuations in diversity, equitability and density were clearly influenced by the population dynamic of the numerically dominant species (HOLLAND; POLGAR, 1976; DEXTER, 1979, 1984; DEFEO, 1996).

In general, the macrozoobenthic assemblages of the temperate and subtropical regions have high temporal variability in abundance and diversity (DEXTER, 1979, 1984; LEBER, 1982; JARAMILLO et al., 1996; HAYNES; QUINN, 1995), and these are related to the seasonality of the recruitments (HOLLAND; POLGAR, 1976; DEXTER, 1979, 1984; DEFEO, 1996). On the other hand, in tropical regions, the fluctuations in density and diversity may be less evident, since seasonality pattern does not always occur in the recruitments. On the sandy beaches of Rio de Janeiro, Brazil, Veloso and Cardoso (2001) found no significant differences in density and diversity between the seasons of the year. It can thus be inferred that temperature is an important factor that generates the temporal variability of the sandy beaches macrobenthic assemblages, since it contributes to the seasonal variation of the recruitments.

Although our environmental results revealed no clear differences between the sites morphodynamics, especially as regards Dean's parameter values, Pereira's (2004) and Figueiredo's (2003, unpublished) results show that site 1 of the present study has dissipative characteristics and site 2 intermediate characteristics. In this study we were able to observe some of these morphodynamic differences (in sediment size, wave height and periodicity, width and type of surf zone). Exposed sandy beaches have higher density, diversity and biomass of macrobenthic organisms from dissipative beaches towards reflective beaches (BROWN; MCLACHLAN, 1990). Nevertheless, in the present study a greater diversity of macrozoobenthic organisms was observed at site 2 (an intermediate beach) than at site 1 (a dissipative beach).

During the entire sampling period, site 2 presented greater diversity, probably due to the presence of the amphipods *Phoxocephalopsis* sp. and Plastyschnopidae that were abundant at this site but rare at site 1. Reflective beaches have communities dominated by crustaceans, which have greater tolerance to wave impact on the beach face and greater mobility and burrowing capacity (ELEFTHERIOU; NICHOLSON, 1975; MCLACHLAN et al., 1981; DEXTER, 1985). On the other hand, the proportion of mollusks and polychaetas tends to grow on dissipative beaches. The higher diversity found at site 2, in the present study, is probably due to its dissipative/intermediate character, as it presents the macrobenthic assemblag of dissipative beaches in addition to amphipods, which are better able to survive the more active hydrodynamic conditions at the beach face and the coarser sediments.

Low fauna population densities were found during the winter, with the exception of *Bathyporeiapus* sp. and the recruitment of *Mesodesma mactroides,* the latter having lower densities than those found in the recruitments registered in December and January. At site 2, the diversity was much higher, highlighted by the occurrence of amphipods and the polychaeta *Euzonus furciferus*. During the fall-winter period the macrobenthos of the intertidal zone underwent a series of physical disturbances. Nearly one month before the period analyzed in this study (April 2004), there was a mud deposition event at site 1, which caused high mortality among the organisms in the intertidal zone. In extreme southern Brazil, a typical phenomenon on the Cassino Beach is the sporadic mud (silt + clay) deposition in the intertidal zone. According to Calliari and Fachin (1993), sporadic mud depositions at the Cassino Beach extend only as far as Querência, and they have never been observed south of this site. It is possible that in the winter period the macrobenthic assemblage at site 1 was still affected by the impact of this event. On the other hand, small-scale stranding events are relatively common in the fall-winter period (RAMIRES et al., 2004) and these may have caused the low densities observed at both sites.

In the spring, the entire macrobenthic assemblage of the intertidal zone was influenced by the population explosion of *Scolelepis gaucha*, by the migration of adults of *M. mactroides* from the subtidal to the intertidal zone and a large-scale stranding event that occurred in October. In September at site 1, *S. gaucha* presented densities of up to 134,209 ind.m^{-2} and in November at site 2 they attained 174,275 ind.m^{-2}. According to Santos (1994), *S. gaucha* presented high fecundity and great temporal fluctuations of abundance, the recruitment pattern being bi-annual, with the first cohort in the fall (of lower densities) and a second cohort in the spring. The above-cited author found its population reaching densities up to 1,106,250 ind.m^{-1}, in spring at Querência, Cassino beach. The second cohort had a higher mortality rate. This was attributed to the greater declivity of the beach slope, lower wave dynamic and a consequent lesser availability of food resources (re-suspension of the diatom *Asterionellopsis glacialis*). Reductions in diversity were observed due to the high dominance of *S. gaucha*.

The adult population of *M. mactroides* was found in low densities in the winter, early spring and fall, while from October to February they were found in high densities in the intertidal zone. *Mesodesma mactroides* is a suspension feeder that inhabits dissipative beaches with gentle slopes and fine sediments (OLIVIER et al., 1971). This bivalve is a seasonal migrant that lives in the subtidal zone during winter, where it may have the habits of a deposit feeder (DEFEO; SCARABINO, 1990), and during the spring migrates *en masse* to the intertidal zone (COSCARÓN, 1959; OLIVIER et al., 1971).

In late October, after strong southerly winds - up to 55 km.h^{-1} – followed by a heavy swell, a large-scale stranding event occurred in the study area. A partial mortality of the macrobenthic assemblage was related to this event. The organism most affected was the tidal migrant *M. mactroides*. The massive mortality of the populations of this bivalve, attributed to the passage of cold fronts, was registered over 350 km of beach in southern Brazil from 30º to 33ºS in March 93 and again in December 94 (MÉNDEZ, 1995; ODEBRECHT et al., 1995). During stranding events in the province of Buenos Aires, *M. mactroides* is the organism most affected (RAMÍREZ et al., 2004).

High densities of *Donax hanleyanus* (adults + juveniles) occurred during the spring and early summer, although it was found in very low densities in other sampling periods. The variations in the densities of adults were influenced by the migrations from the subtidal zone, the horizontal movements, mortality linked to the passage of vehicles, fishing and predatory birds, invertebrates and fish. The bivalve *D. hanleyanus* is widespread in South America, occurring from tropical regions (17°S Caravelas: Cardoso and Veloso, 2003) to temperate ones (37°S Punta Mogotes: Penchaszadh; Oliver, 1975). It is capable of inhabiting all types of beach morphologies (VELOSO et al., 1997; PENCHASZADH; OLIVER, 1975). According to Leber (1982), in North Carolina, *Donax parvula* migrates to the subtidal zone during the winter. Horizontal movements of *Donax serra* are common on exposed sandy beaches in South Africa (DUGAN; MCLACHLAN, 1999).

During the summer, high densities of macroinvertebrates were found mainly due to recruitments of the tidal migrants *M. mactroides*, *D. hanleyanus* and *Emerita brasiliensis*. The peak density of the recruits of *M. mactroides* and *E. brasiliensis* took place in December at site 1 and in January at site 2. According to Defeo et al. (1992), on the beaches of the Uruguayan coast the main recruitment of *M. mactroides* was registered from February to May with a secondary one between November and December. In this study, the main recruitment of *M. mactroides* occurred from November to January. The mole crab *E. brasiliensis*, throughout the 2,700 km of its geographical distribution in the South Atlantic ocean from Rio de Janeiro to Montevideo (EFFORD, 1976), presents a seasonal recruitment pattern. On the temperate beaches it occurs from 1-5 months.year^{-1}, whereas it is continuous on the tropical beaches during 10 - 12 months.year^{-1} (DEFEO; CARDOSO, 2004). At Cassino Beach, a 4-month seasonal pattern of recruitment was found, from December to March.

In the fall, low densities were found for the entire macrobenthic assemblage at both sites, with the exception of *D. hanleyanus,* which had its peak recruitment in March and April. The recruits commonly present a high peak during the summer and fall, from February to May, on the Uruguayan coast (DEFEO; DE ALVA, 1995).

Several studies on sandy beaches have shown consistent macrofauna seasonal variations that may be largely explained by seasonal variations in physical factors and the consequent changes of the beach stage (MCLACHLAN, 1990, 1996; MCLACHLAN et al., 1993; JARAMILLO et al., 1993; MCLACHLAN; JARAMILLO, 1995). In the present study, the benthic macrofauna at the two sites studied showed seasonal variations in density and diversity that may be attributed mainly to the recruitment of the dominant species and the occurrence of physical disturbances (stranding and mud deposition).

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