Temporal variability of benthic macrofauna on Cassino beach, southernmost Brazil

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ABSTRACT. The temporal variability of benthic macrofauna on Cassino beach, southernmost Brazil, was studied for a period of one year (June 2004 to May 2005) based on monthly sampling. Three sites were selected distant 50m from each other. At each site, 3 transects were established, 2m equidistant from one another. Each transect extended from the base of the primary dunes to the inner surf zone at approximately 1m in depth, with 7 or 8 sampling levels. Within transects, the distance between the levels was 20m until the upper swash zone, from which distance was 10m until the 1-meter isobath. The temporal variation in the abundance of benthic macrofauna observed in the present study can be attributed to (1) the positive effects of the recruitment peaks and migration of particular species to the swash zone and (2) negative effects of the migration of some species to deeper waters, as well (3) as mortality through natural causes (stranding and action of predators) and (4) human causes (harvesting and vehicle transit). We attribute the expressive abundance increase of benthic macrofauna to recruitment. The stranding, that is, the trapping of the organisms on the upper parts of the beach, is likely the main cause of abrupt drops in benthic macrofauna abundance.

KEYWORDS. Sandy beaches, benthic macrofauna, temporal variation, Cassino beach.

RESUMO. Variabilidade temporal da macrofauna bentônica na praia do Cassino, extremo sul do Brasil. A variabilidade temporal da macrofauna bentônica na praia do Cassino, Rio Grande do Sul, Brasil, foi estudada durante o período de um ano (junho 2004 a maio de 2005) com base em coletas mensais. Escolheram-se três locais, distantes 50m um do outro, sendo que em cada local foram fundadas três transversais 2m eqüidistantes. Cada transversal se estendeu desde a base das dunas primárias até aproximadamente 1m de profundidade no infralitoral. A distância dos níveis de coleta em cada transversal foi de 20m até o limite superior da zona de varrido, a partir do qual a distância foi de 10m. A variação temporal da abundância da macrofauna bentônica, constatada no presente trabalho pode ser atribuída a (1) efeitos positivos decorrentes dos picos de recrutamento e migração de determinadas espécies para a zona de varrido e a (2) efeitos negativos como a migração de algumas espécies para águas mais profundas, a (3) mortalidade por causas naturais (embancamento e ação dos predadores) e (4) antrópicas (extrativismo e o trânsito de veículos). Ao recrutamento é atribuída a responsabilidade pela expressiva elevação da abundância da macrofauna bentônica. Já o embancamento, isto é, o aprisionamento dos organismos nas partes superiores da praia, provavelmente seja a principal causa das abruptas quedas nas abundâncias do macrozoobentos.

PALAVRAS-CHAVE. Praias arenosas, macrofauna bentônica, variabilidade temporal, praia do Cassino.

The distribution, abundance and diversity of beach macrofauna have been related to different physical factors, from which the most important are wave action, the size of sand grains and the slope of the beach (McLachlan, 1983). The availability and search for food, dispersion and settling, modes of locomotion and aggregation patterns, intra- and interspecific competition and the effects of predation may also influence the structure of benthic macrofauna communities (Knox, 2000).

Several studies that characterize benthic assemblages on sandy beaches are restricted to a short sampling period from which it is not possible to assess the temporal variation of benthic macrofauna (Jaramillo, 1978; McLachlan, 1990; Defeo *et al.*, 1992a; Jaramillo & McLachlan, 1993; Borzone *et al.*, 1996; James & Fairweather, 1996; Hernandez *et al.*, 1998).

The temporal variability of benthic macrofauna around the world has been related to seasonality as well as periods of upwelling (Dexter, 1979), reproductive activities of the more abundant species (Dexter, 1984) and changes in temperature (Leber, 1982). However, Jaramillo *et al.* (1996b) observed that abundance patterns were generally not linked to physical factors, except for one species, whose temporal variation was related to beach morphodynamics.

In Brazil, Veloso *et al.* (1997) reported in the state of Rio de Janeiro, that the temporal variation of benthic macrofauna was subject to reproductive activities and recruitment, and that these variations were not related to non-biological factors. Veloso & Cardoso (2001) compared three beaches, and observed that one of them exhibited more temporal variation than the others. Veloso *et al.* (2003) did not verify significant differences in macrofauna density and biomass on fifteen beaches studied between winter and summer. In the state of Paraná, Brazil, a year-long follow-up by Souza & Gianuca (1995) indicated that the variation in benthic macrofauna abundance was mainly due to recruitment, whereas changes in the richness of the species were caused by the organisms that recruit but did not remain on the beach. In another year-long study on a sandy beach in Paraná, Borzone & Souza (1997) verified a striking seasonality in macrofauna abundance due to the recruitment of dominant species and variability in the occurrence of the organisms.

Gianuca (1983, 1987) and Borzone & Gianuca (1990) analyzed the composition and distribution of benthic macrofauna at distinct levels on beaches in the southern state of Rio Grande do Sul, Brazil. However, no studies have been carried out with quantitative sampling replicated between the supralittoral zone and the inner surf zone with a focus on the temporal variation of benthic macrofauna on sandy beaches in the southernmost region of Brazil.

Considering the lack of information of this nature for the region, this study aimed to analyze the temporal variation of the benthic macrofauna assemblage during one year on Cassino Beach, southernmost Brazil.

MATERIAL AND METHODS

The sandy beaches of southernmost Brazil are exposed, slightly declined, with fine sand, moderate to strong wave action and well-developed surf zone, presenting dissipative to intermediate morphodynamic states (Gianuca, 1983; Borzone & Gianuca, 1990; Garcia & Gianuca, 1998). The astronomical tides have a microtidal regime, and meteorological factors are the main cause of variations in water level (Calliari & Klein, 1993). The site of present study is located on Cassino beach, Rio Grande, state of Rio Grande do Sul, 17.2 Km to the south of the western jetty (052º14’04”W, 32º15’55”S) (Fig. 1).

The sampling of benthic macrofauna was performed monthly for a period of 12 months (June 2004 to May 2005). Three sites were selected at a distance of 50m from one another. At each site, three transects were established, 2m equidistant from one another. Each transect extended from the base of the primary dunes to the inner surf zone at approximately 1m in depth, with between 7 and 8 sampling levels. Within transects, the distance between the levels was 20m until the upper swash zone, from which distance was 10m until the 1-meter isobath (Fig. 1). The smaller distance between levels on the lower parts of the beach was due to the greater number of species and organisms that tend to concentrate in this area (Gianuca, 1983; Degraer *et al.*, 2003).

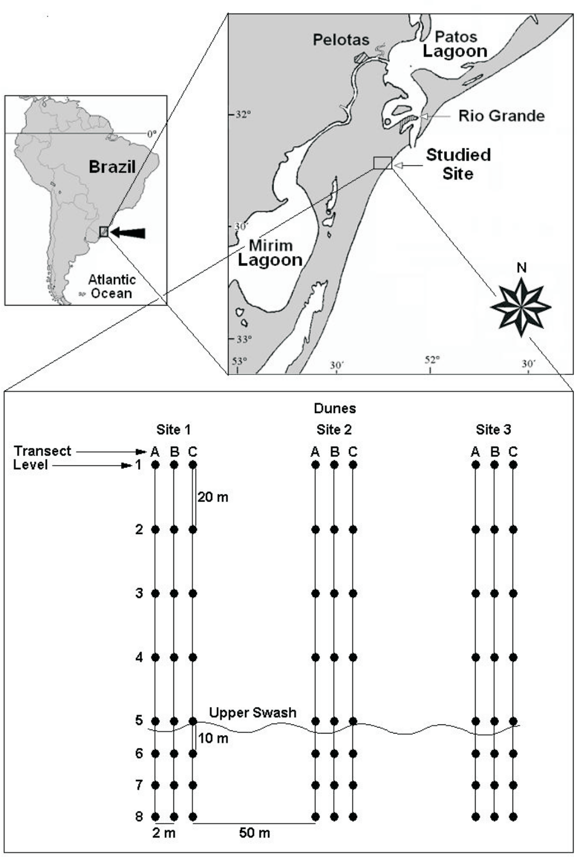

Fig. 1. Location of study area and sampling design from which the benthic macrofauna was collected, Cassino beach, southernmost Brazil, June 2004 to May 2005.

Biological samples were obtained using a core of 20cm in diameter (0.03 m^2), sunk into the sediment to a depth of 20cm, as most of the macrofauna abundance is found in the first 15-20cm of depth in the sediment (Bally, 1983). Samples were sieved with a nylon mesh with a 0.5mm pore opening, and the material collected was fixed in a 10% formaldehyde solution. In the laboratory, the organisms were quantified and identified to the smallest possible taxonomic level under a stereomicroscope.

A monthly quantification was also performed on the number of burrows of the ghost crab, *Ocypode quadrata* (Fabricius, 1787), which were mainly located in the supralittoral zone. Starting from the bases of the primary dunes, 100m lines parallel to the beach were established. These lines were anchored in the area of occurrence of the *O. quadrata* burrows at a distance of 5m from one another. Through the continuous arrangement of 1x1m grid, the density of burrows along each line was recorded.

Samples belonging to each transect were totaled on a monthly basis for the analysis of the temporal variation of the benthic macrofauna and with the aim of avoiding disturbances to the spatial variation.

Regarding the bivalve *Mesodesma mactroides* Deshayes, 1854, individuals with a shell length between 1 and 10mm were defined as recruits; those with a shell length between 10.1 - 42.9mm were defined as juveniles; the ones with a shell length greater than 43mm were defined as adults, according to Masello & Defeo (1986) and Defeo *et al*. (1992b). Recruits, juveniles and adults of the bivalve *Donax hanleyanus* Philippi, 1847 were defined respectively as individuals of 1-5mm, 5.5-15mm and >15mm in length, following Defeo & de Alava (1995).

Seasonal sediment samples were taken at each of the levels of the three sites. The proportions of sand, silt and clay in the sediment were determined through sieving (> 0.062mm in diameter) and pipetting (< 0.062mm in diameter), following procedures described by Suguio (1973). During the monthly sampling, wave height (visual observations), average wave period (digital chronometer) and salinity (optical refractometer) were recorded, along with air and water temperatures (mercury thermometer). Hourly data on wind speed and direction were provided by the Barra de Rio Grande Pilotage Authority.

To characterize the seasonal morphodynamics state of the beach, the dimensionless Dean’s parameter $\Omega = Hb/WsT$ was employed, where Hb is the wave height of the surf, Ws is the rate of sediment decantation and T is the wave period. The Ω values < 1 represent reflective beaches; intermediate beaches are classified within the 1 to 6 interval; and dissipative beaches present Ω values > 6 (SHORT & WRIGHT, 1983).

In order to analyze the temporal variation of the benthic macrofauna throughout the year, statistical analyses were performed on the PRIMER v5 program (Plymouth Routines In Multi Ecological Research) using quantitative data (CLARKE & WARWICK, 1994). From the sum of the samples of each transect, a similarity spreadsheet was drawn up (Q mode) using the Bray-Curtis dissimilarity index. Multi-Dimensional Scaling (MDS) analysis was then performed and the groups determined by grouping of the samples and analysis of the graphics that showed the temporal variability of the populations abundance. The difference between groups was tested through the analysis of similarity (ANOSIM), at a significance level of $p<5\%$ and R statistic >0.5. Similarity percentage analysis (SIMPER) was used to determine the contribution of the principal species in the formation of the groups.

The monthly variability of the abundance of the eleven most important taxa was compared. The Shannon-Weaver diversity index (H') and the Pielou evenness index (J') were also determined for each month.

RESULTS

Minimum salinity was recorded during July (29) and maximums were recorded in January (36) and March (36). Water temperature of the inner surf zone following the same tendency as air temperature, with minimums recorded in July (water=14º C; air=15º C) and May (water=13.5º C; air=15º C), and the maximum recorded in January (water=26º C; air=30º C). Wave height presented higher values in November (1.5m) and July (1m), whereas the average wave period ranged from 8 to 11.9 seconds. Average declivity of the beach was 1.7º throughout the sampling period.

From the Ω values, it was determined that the beach studied presented an intermediate stage throughout the four seasons of the year (Tab. I). The sediment type for most of the area was classified as fine sand, but in some occasions medium sand predominated on the lower part of the beach (Tab. I).

The NE wind was the most frequent among the sampling periods. The S wind was not very frequent, but reached high velocities, especially among the sampling periods of October – November and February – March (Tab. II).

A total of 28 taxa were collected. January had the highest number of taxa and July had the lowest, but the latter presented a higher diversity index (H'). The class Crustacea presented the highest number of taxa, followed by the class Polychaeta (Tab. III).

The MDS analysis indicated the tendency to formation of three sample groups: the first formed by samples obtained in June, July, August, September and May (6, 7, 8, 9 and 5); the second by samples of March

Table I. Average grain size (phi), sediment classification and seasonal value of Ω, Cassino beach, southernmost Brazil, June 2004 to May 2005.

		Winter		Spring		Summer		Fall	
Site	Level	Average (phi)	Classification	Average (phi)	Classification	Average (phi)	Classification	Average (phi)	Classification
1	1	2.564	Fine sand	2.568	Fine sand	2.764	Fine sand	2.747	Fine sand
	2	2.753	Fine sand	2.562	Fine sand	2.723	Fine sand	2.521	Fine sand
	3	2.499	Fine sand	2.358	Fine sand	2.508	Fine sand	2.77	Fine sand
	4	2.27	Fine sand	2.541	Fine sand	2.546	Fine sand	2.766	Fine sand
	5	2.154	Fine sand	2.332	Fine sand	2.383	Fine sand	2.753	Fine sand
	6	1.889	Medium sand	2.188	Fine sand	2.502	Fine sand	2.465	Fine sand
	7	1.774	Medium sand	2.214	Fine sand	2.394	Fine sand	2.501	Fine sand
	8	***	***	***	***	2.403	Fine sand	2.375	Fine sand
2	1	2.609	Fine sand	2.499	Fine sand	2.565	Fine sand	2.747	Fine sand
	2	2.621	Fine sand	2.691	Fine sand	2.574	Fine sand	2.533	Fine sand
	3	2.342	Fine sand	2.765	Fine sand	2.429	Fine sand	2.723	Fine sand
	4	2.282	Fine sand	2.53	Fine sand	2.423	Fine sand	2.638	Fine sand
	5	2.373	Fine sand	2.363	Fine sand	2.597	Fine sand	2.415	Fine sand
	6	1.733	Medium sand	2.467	Fine sand	2.198	Fine sand	2.483	Fine sand
	7	1.987	Medium sand	2.513	Fine sand	2.163	Fine sand	2.098	Fine sand
	8	***	***	***	***	1.991	Medium sand	2.441	Fine sand
3	1	2.523	Fine sand	2.755	Fine sand	2.585	Fine sand	2.576	Fine sand
	2	2.479	Fine sand	2.748	Fine sand	2.719	Fine sand	2.571	Fine sand
	3	2.406	Fine sand	2.787	Fine sand	2.385	Fine sand	2.776	Fine sand
	4	2.293	Fine sand	2.774	Fine sand	2.409	Fine sand	2.75	Fine sand
	5	2.264	Fine sand	2.766	Fine sand	2.508	Fine sand	2.242	Fine sand
	6	1.895	Medium sand	2.511	Fine sand	2.37	Fine sand	2.394	Fine sand
	7	1.491	Medium sand	2.518	Fine sand	2.346	Fine sand	2.442	Fine sand
	8	***	***	***	***	1.877	Medium sand	2.466	Fine sand
	Ω	4.956		4.097		3.269		3.131	

and April (3 and 4); and the third by samples of December and February (12 and 2). The remaining sampling periods were not grouped (Fig. 2).

ANOSIM analysis revealed significant differences between all the groups and remaining periods (Tab. IV).

The polychaeta *Scolelepis gaucha* (Orensanz & Gianuca, 1974) characterized the December/February group, as well as the November and January periods. The difference in abundance of this species was the main reason for the separation of this group from the other months. The May-September and March/April groups were respectively formed mostly by the amphipod Platyischnopidae indet. and the bivalve *D. hanleyanus*. The amphipod *Bathyporeiapus* sp. strongly influenced the samples grouping of the October period (Tab. V).

Scolelepis gaucha was the most abundant taxon throughout the study period, followed by *M. mactroides*, *Bathyporeiapus* sp., and *D. hanleyanus* (Tab. III).

Temporal variability of the abundance of populations indicated that *S. gaucha*, *M. mactroides*, *Bathyporeiapus*

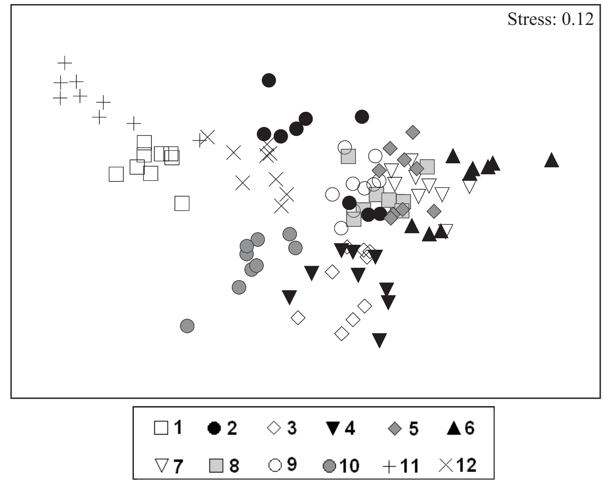

Fig. 2. Temporal MDS of benthic macrofauna, June 2004 to May 2005, Cassino beach, southernmost Brazil. The numbers from 1 to 12 refer respectively to the months of January, February, March, April, May, June, July, August, September, October, November and December.

Table II. Frequency, average and maximum speed of winds in the periods between the sampling of benthic macrofauna, Cassino beach, southernmost Brazil, June 2004 to May 2005.

		N	NE	E	SE	S	SW	W	NW
Jun - Jul	Frequency (%)	7.1	34.6	0.5	4.4	3.7	29.0	8.6	12.0
	Average Speed ($m.s^{-1}$)	4.3	6.1	2.1	3.3	4.1	5.4	4.5	3.7
	Maximum Speed ($m.s^{-1}$)	12.5	16.1	4.5	6.7	12.5	19.7	19.7	18.4
Jul - Aug	Frequency (%)	2.2	60.5	3.9	3.9	2.2	20.3	3.9	3.1
	Average Speed ($m.s^{-1}$)	4.9	8.4	6.0	7.2	3.6	6.1	4.0	2.6
	Maximum Speed ($m.s^{-1}$)	13.0	22.4	13.9	3.8	13.0	15.6	10.3	11.6
Aug - Sep	Frequency (%)	3.8	36.5	3.3	14.8	10.5	14.2	6.5	10.4
	Average Speed ($m.s^{-1}$)	4.4	8.6	7.6	6.9	6.6	5.2	5.6	4.6
	Maximum Speed ($m.s^{-1}$)	17.0	21.9	17.4	17.4	17.4	16.1	20.1	19.2
Sep - Oct	Frequency (%)	2.3	34.7	6.6	13.6	7.4	27.2	5.6	2.7
	Average Speed ($m.s^{-1}$)	3.7	8.6	7.3	5.9	6.2	5.9	4.3	3.0
	Maximum Speed ($m.s^{-1}$)	14.8	26.4	17.0	13.9	15.2	19.2	10.3	8.5
Oct - Nov	Frequency (%)	3.5	45.6	5.7	11.4	7.4	3.8	4.4	18.2
	Average Speed ($m.s^{-1}$)	4.6	9.1	6.8	4.6	6.8	3.2	5.1	6.7
	Maximum Speed ($m.s^{-1}$)	16.6	21.5	15.2	15.6	23.7	18.4	15.6	24.6
Nov - Dec	Frequency (%)	0.3	35.0	18.4	24.3	6.0	11.4	3.2	1.3
	Average Speed ($m.s^{-1}$)	4.5	9.7	8.3	7.4	6.9	6.8	6.0	4.6
	Maximum Speed ($m.s^{-1}$)	9.0	21.9	15.6	15.2	13.9	16.6	15.6	11.6
Dec - Jan	Frequency (%)	1.7	50.6	11.2	17.2	3.8	8.9	1.5	5.0
	Average Speed ($m.s^{-1}$)	4.8	8.7	6.6	5.8	7.2	6.3	5.2	5.0
	Maximum Speed ($m.s^{-1}$)	16.1	21.5	14.3	15.6	15.2	19.7	17.0	17.0
Jan - Feb	Frequency (%)	2.2	46.1	10.0	15.6	5.8	15.5	2.4	2.4
	Average Speed ($m.s^{-1}$)	4.6	10.2	9.2	6.6	7.9	7.8	4.1	3.0
	Maximum Speed ($m.s^{-1}$)	13.4	21.5	17.0	13.9	17.0	18.4	10.8	12.5
Feb - Mar	Frequency (%)	1.4	35.7	13.1	30.1	7.2	6.4	3.6	2.5
	Average Speed ($m.s^{-1}$)	4.6	8.2	7.6	6.4	7.7	6.2	3.0	3.2
	Maximum Speed ($m.s^{-1}$)	11.6	22.8	21.9	18.8	25.5	25.1	10.3	8.5
Mar - April	Frequency (%)	5.3	35.4	7.7	16.8	9.8	13.5	4.6	6.9
	Average Speed ($m.s^{-1}$)	3.9	7.9	7.1	5.8	7.1	6.2	4.0	5.0
	Maximum Speed ($m.s^{-1}$)	15.6	20.6	17.9	17.0	17.6	22.4	13.4	17.0
April - May	Frequency (%)	6.7	31.6	4.0	10.1	9.6	17.8	10.5	9.7
	Average Speed ($m.s^{-1}$)	3.7	6.7	4.7	4.9	6.6	5.8	4.2	3.0
	Maximum Speed ($m.s^{-1}$)	19.7	19.2	12.1	14.8	19.2	21.9	18.8	15.6

sp., *Phoxocephalpsis* sp., Platyischnopidae indet., and *Emerita brasiliensis* Schmitt, 1935 presented higher values between spring and summer (Fig. 3). *Euzonus furciferus* (Ehlers, 1897), *Donax gemmula* Morrison, 1971, and *D. hanleyanus* presented higher abundances in fall. The occurrence of *Excirolana armata* (Dana, 1852) was more erratic, presenting several peaks throughout the study period (Fig. 3).

During the study, populations of *M. mactroides* and *D. hanleyanus* were characterized mostly by recruits and, to a lesser degree, juveniles (Tabs. VI, VII).

The crab *O. quadrata* presented the highest average density of burrows in March (0.2125 burrows.m^{-2}), whereas in July, August, September, October, December and May, no burrows were found.

Table III. Total abundance of organisms caught monthly on the beach, and monthly diversity index (H') and evenness index (J'), Cassino beach, southernmost Brazil, June 2004 to May 2005. (P, Polychaeta; B, Bivalvia; C, Crustacea; G, Gastropoda).

Code		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Total Abundance
P	*Scolelepis gaucha* (Orensanz & Gianuca, 1974)	2	67	243	418	590	65145	4461	22217	2278	53	7	62	95543
P	*Euzonus furciferus* (Ehlers, 1897)	52	143	162	99	81	348	32	38	57	35	109	681	1837
P	*Hemipodus olivieri* Orensanz & Gianuca, 1974	3	12	8	21	27	132	3	1	5	11	15	11	249
P	*Sigalion cirriferum* Orensanz & Gianuca, 1974	5	3	6	5	5	5	4	6	2	4	3	2	50
P	Capitellidae indet.	0	0	0	0	0	0	2	0	0	0	0	0	2
P	*Capitella* sp.	0	0	0	1	0	0	0	0	0	0	0	0	1
P	*Hyalinoecia* sp.	0	0	0	0	0	0	0	0	0	1	0	0	1
P	Hesionidae indet.	0	0	0	0	0	1	0	0	0	0	0	0	1
P	*Grubeulepis bracteata* Nonato,1981	0	0	0	0	1	0	0	0	0	0	0	0	1
B	*Mesodesma mactroides* Deshayes, 1854	33	239	247	764	1970	748	2097	9573	596	660	923	103	17953
B	*Donax hanleyanus* Philippi, 1847	223	134	479	305	637	492	458	1339	135	2472	2592	433	9699
B	*Donax gemmula* Morrison, 1971	0	0	0	0	1	0	28	27	4	895	109	4	1068
C	*Bathyporeiapus* sp.	33	104	260	321	8100	724	63	106	133	72	129	60	10105
C	*Phoxocephalopsis* sp.	96	179	268	139	586	426	986	452	159	91	131	425	3938
C	Platyischnopidae indet.	250	272	350	325	788	314	281	392	112	272	290	224	3870
C	*Emerita brasiliensis* Schmitt, 1935	4	14	28	9	9	2	48	736	225	242	2	18	1337
C	*Excirolana armata* (Dana, 1852)	33	48	55	68	30	18	81	93	118	37	47	92	720
C	*Macrochiridothea* sp.	5	18	11	13	6	16	9	76	15	76	20	26	291
C	*Puelche orensanzi* Barnard & Clark, 1982	0	0	1	0	5	3	0	4	5	33	4	3	58
C	*Excirolana braziliensis* Richardson, 1912	1	0	1	1	1	0	0	0	0	0	0	1	5
C	*Pinnixa patagoniensis* Rathbun, 1918	0	2	0	0	0	0	2	3	0	0	0	0	7
C	*Balloniscus sellowii* (Brandt, 1833)	0	0	1	0	0	0	0	0	0	0	0	0	1
C	*Arenaeus cribarius* (Lamarck, 1818)	0	0	0	0	0	0	0	1	0	0	1	0	2
C	Megalopa of *Ocypode quadrata* (Fabricius, 1787)	0	0	0	0	0	0	0	0	0	0	1	0	1
G	*Buccinanops duartei* Klappenbach, 1965	0	0	0	0	0	0	0	7	1	1	0	0	9
G	*Olivancillaria auricularia* (Lamarck, 1810)	1	0	0	1	0	0	0	1	1	1	0	0	5
	Nemertea indet.	6	15	2	5	29	40	44	36	18	13	13	10	231
	Oligochaeta indet.	0	0	0	0	0	21	48	22	1	1	1	1	95
	Total monthly abundance	747	1250	2122	2495	12866	68435	8647	35130	3865	4970	4397	2156	
	Number of taxa	15	14	16	16	17	16	17	20	18	19	18	17	28
	H'(loge)	1.78	2.14	2.08	1.96	1.27	0.29	1.42	1.03	1.48	1.62	1.35	1.90	1.30
	J'	0.66	0.81	0.75	0.71	0.45	0.10	0.50	0.35	0.51	0.55	0.47	0.67	0.39

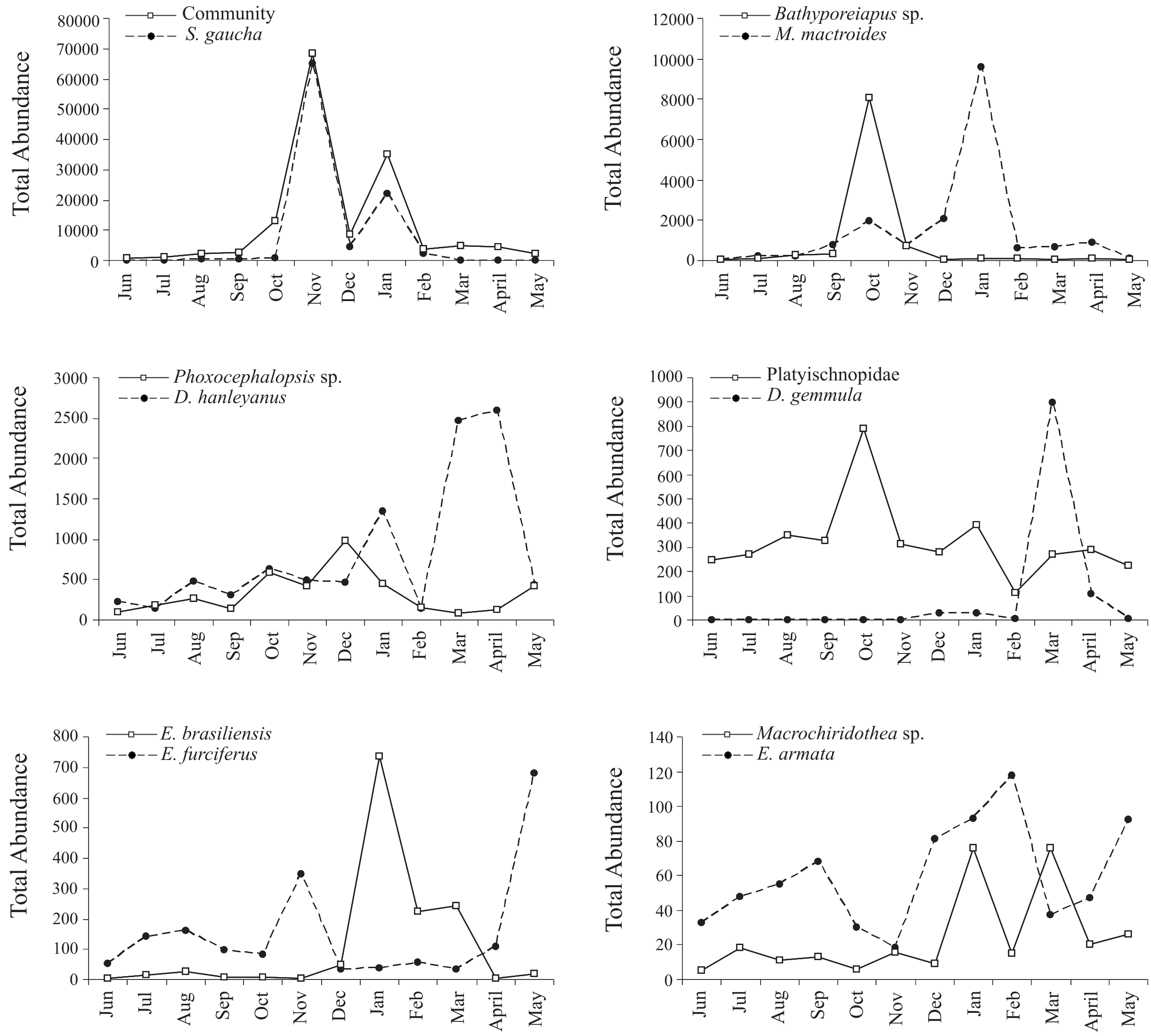

Fig. 3. Total abundance of main organisms collected on the beach in the different months, Cassino beach, southernmost Brazil, June 2004 to May 2005.

Table IV. Analysis of similarity (ANOSIM) between the groups and the other periods (p<5% and R statistic >0.5). The numbers from 1 to 12 refer respectively to the months of January, February, March, April, May, June, July, August, September, October, November and December (Cassino Beach, southernmost Brazil, June 2004 to May 2005).

	R	*p*
5 - 9 *vs* 10	0,89	0,1%
5 - 9 *vs* 11	0,998	0,1%
5 - 9 *vs* 12 and 2	0,729	0,1%
5 - 9 *vs* 1	0,998	0,1%
5 - 9 *vs* 3 - 4	0,668	0,1%
10 *vs* 11	1	0,1%
10 *vs* 12 and 2	0,765	0,1%
10 *vs* 1	1	0,1%
10 *vs* 3 - 4	0,973	0,1%
11 *vs* 12 and 2	0,91	0,1%
11 *vs* 1	0,752	0,1%
11 *vs* 3 - 4	1	0,1%
12 and 2 *vs* 1	0,721	0,1%
12 and 2 *vs* 3 - 4	0,854	0,1%
1 *vs* 3 - 4	1	0,1%

DISCUSSION

Fluctuations in the total abundance of organisms throughout the twelve months of sampling were strongly influenced by periods of recruitment. The two main occurrence peaks, however, were due to the high number of adults and juveniles of the polychaeta *S. gaucha* in the mesolittoral zone.

Scolelepis gaucha was the most abundant species, being numerically dominant between November and February and with abundance peaks in November and January. Santos (1991) verified that *S. gaucha* was the most abundant polychaeta in the mesolittoral zone of Cassino Beach, reaching a density of up to 100,000m^{-2} in spring and early summer. Barros *et al*. (2001) also observed the dominance of this genus in Paraná, where *Scolelepis squamata* (Müller,1806) reached around 70% of macrofauna abundance on two sandy beaches in winter and summer. Borzone *et al*. (1996), in summer, and Degraer *et al.* (2003), at the end of summer and early fall, observed that *S. squamata* was the most dominant species on several beaches.

Table V. Result of SIMPER analysis. The main organisms that contributed to the formation of the groups and other periods are presented. The numbers from 1 to 12 refer respectively to the months of January, February, March, April, May, June, July, August, September, October, November and December (Cassino beach, southernmost Brazil, June 2004 to May 2005).

	5 - 9	10	11	12 and 2	1	3 - 4
Platyischnopidae indet.	25,19%					
Donax hanleyanus	19,20%				67,96%	
Mesodesma mactroides		16,51%		22,60%	21,67%	12,19%
Bathyporeiapus sp.		57,18%				
Scolelepis gaucha			95,56%	51,48%	69,20%	
Phoxocephalopsis sp.	13,58%					

Table VI. Total abundance of recruits, juveniles and adults of *Mesodesma mactroides* Deshayes, 1854 in the different months, Cassino beach, southernmost Brazil, June 2004 to May 2005.

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	April	May
Recruits	18	236	221	706	1146	210	1742	9026	393	627	907	93
Juveniles	1	1	14	43	854	510	325	340	155	14	1	7
Adults	10	1	2	4	2	3	6	8	2	1	3	0

Table VII. Total abundance of recruits, juveniles and adults of *Donax hanleyanus* Philippi, 1857 in the different months, Cassino beach, southernmost Brazil, June 2004 to May 2005.

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	April	May
Recruits	175	129	344	187	312	34	98	1220	127	2449	2534	420
Juveniles	2	6	130	105	322	435	317	27	0	0	0	11
Adults	0	0	0	0	0	16	33	8	0	0	0	0

Mesodesma mactroides had its abundance peak in January, and also had a high number of organisms in October, December and April due to recruitment of this bivalve. DEFEO *et al.* (1992b) identified two recruitment periods for the species: one between November and January; and the other between February and April.

For the high abundance of *M. mactroides* in October, there was a contribution from juveniles, which up until then were practically absent from the beach. CASCARÓN (1959) stated that most *M. mactroides* juveniles and adults are concentrated in the infralittoral zone during winter, and in spring there is a migration to the mesolittoral zone, where they remain through summer and early fall. During research carried out with *M. mactroides* on the coast of Mar del Plata, Argentina, in the 1970s, it was also observed migratory movement of the species in this period (R. Capítoli, pers. comm.). Information obtained from fishermen who extract yellow clam from Cassino beach confirms an increase in the amount of juvenile and adult yellow clam between spring and summer in the swash zone (pers. comm.).

The expressive occurrence of *Bathyporeiapus* sp. strongly influenced the macrofauna abundance in October. In the state of Paraná, BORZONE & SOUZA (1997) observed that *Bathyporeiapus ruffoi* Escofet, 1971 presented high abundance in September and November, but October was not sampled in the study. This species was well represented in stations of the lower mesolittoral zone, extending its distribution to the infralittoral zone with high abundance (BORZONE & SOUZA, 1997). In the USA at 34º40'N of latitude, LEBER (1982) observed that two species of amphipods predominated in early winter at milder temperatures. In Florida, USA, CHARVAT *et al.* (1990) observed that amphipods were more important in the infralittoral than the mesolittoral zone, suggesting that higher temperatures exclude amphipods from the upper parts of the beach.

Donax haleyanus recruits were largely responsible for the formation of the March/April group. On Uruguayan beaches, DEFEO & DE ALAVA (1995) verified recruitment peaks between February and May, coinciding with the finding of the present study, whereas CARDOSO & VELOSO (2003), on a tropical beach, found greater abundances of this species in fall and winter. It is noteworthy that the recruitment peak for *D. hanleyanus* came after the recruitment peak for *M. mactroides*. In a study carried out in Uruguay, an inverse relationship was found between the recruitments of *D. hanleyanus* and the presence of *M. mactroides* juveniles and adults (de Alava, 1993 *apud* DEFEO, 1996b). Indications of competition between these species are reinforced by the fact that the distinct class sizes of *D. hanleyanus* and *M. mactoides* recruits and juveniles occur at similar depths in the sediment (DEFEO *et al.*, 1986), thereby increasing the chances of competition for space.

The formation of the group that encompassed the months of May, June, July, August and September was due to the frequency of Platyischnopidae and, especially, the low abundance of other taxa. There was an absence of recruitments in this period, as well as the migration of some species to deeper waters, contributing to the scarcity of benthic macrofauna. LEBER (1982) observed that *Donax parvula* Philippi, 1849 migrated to the infralittoral zone during winter and CASCARÓN (1959) verified the same tendency for *M. mactroides*.

Euzonus furciferus was the only species that recruited during the period in which the lowest abundance of benthic macrofauna occurred, with its peak abundance concentrated in May. On Matadeiro beach, in the state of Santa Catarina, Brazil, the population of *E. furciferus* showed the main recruitment period between May and August (pers. comm.), in agreement with the findings of the present study. In Oregon, USA, KEMP

(1988) verified that *Euzonus mucronata* (Treadwell, 1914) recruitment occurred in early summer. The difference of approximately 13º more in latitude of the site in Oregon in comparison to the studies carried out in southern Brazil allows us to infer that the recruitment period of both species occurs at times with quite similar temperatures.

One of the typical organisms from the supralittoral zone, the crab *O. quadrata*, presented oscillations in the density of burrows throughout the year, with no high densities verified during the 12-months study period. Furthermore, there were months in which no burrows were encountered. During the study it was observed that wind action could easily cover the burrows with sand, and the low density could be a reflection of such a process. NEVES & BEMVENUTI (2006) recorded this phenomenon studying the distribution and abundance of *O. quadrata* burrows on three beaches on the northern coast of state of Rio Grande do Sul. ALBERTO & FONTOURA (1999), in the same state, observed that variations in temperature, wind directions and intensity, and the reach of the waves directly interfered in the activities of *O. quadrata*, and in adverse conditions no sign of the species is observed on the beach.

It was generally verified that most of the recruitments of the several taxa mainly occurred in the periods of spring and fall, thereby altering the abundance of benthic macrofauna.

From a study carried out in the temperate region of Cape Paterson, Victoria, Australia, HAYNES & QUINN (1995) found a significant temporal variation in densities and number of species, relating this occurrence with changes in the densities of species common to the mesolittoral zone. On a subtropical sand beach in Paraná, SOUZA & GIANUCA (1995) observed that the overall abundance of macrofauna was significantly higher in summer than in winter. VELOSO *et al.* (2003), however, did not verify a significant difference in benthic macrofauna density and biomass between the periods of summer and winter on a tropical beach (state of Rio de Janeiro). It is likely that the difference in latitude of the beaches, with the subsequent variations in temperature, is the main non-biological determinant in the seasonal variation of benthic macrofauna.

The temporal variation revealed that there were abrupt reductions in the abundance of diverse species of benthic macrofauna generally 30 days after the occurrence of abundance peaks. *Donax hanleyanus* was the only species that maintained two consecutive abundance peaks (March and April), but one month later, a striking reduction in the number of individuals was verified.

There is a number of factors that may be responsible for the abrupt drop in the abundance of taxa. One of these factors is the predation pressure on the benthic macrofauna. In a study carried out in the USA, the most obvious predators on the beach were crabs, fish and birds. These predators fed on the tidal migrants and were more abundant during the summer months (LEBER, 1982). On Cassino Beach, many species of fish fed on the benthic macrofauna in the surf zone during the high tide, accompanied by crabs and gastropods. At low tide, birds were the main predators, some of which were residents and others were migrants (GIANUCA, 1983). The migration of some birds determines that the arrival of flocks coincides with peak benthic macrofauna abundance in southernmost Brazil (VOOREN, 1998).

The larger number of beach-goers and, consequently greater transit of vehicles on the beach, especially during the hotter months of the year, may also affect benthic macrofauna recruits and juveniles abundance. On the Chilean coast, JARAMILLO *et al.* (1996a) verified no significant effect of the presence of humans on benthic macrofauna. However, GIANUCA (1983) observed that a threat that affects the populations of the mesolittoral zone, especially juveniles and surface diggers, is the use of damp, compact sands by all types of vehicles, including the trucks of fishermen.

The decrease in *M. mactroides* density soon after the peak recorded in October may have been influenced by the imprisonment of individuals on the upper parts of the beach. Winds from the south, which occurred between the sampling of October and November, with velocities of up to $23.7 m/s^{-1}$, elevated the sea level, causing the imprisonment of a high number of *M. mactroides* specimens in the supralittoral zone. In the study area, the incidence of southern winds can raise the sea level by as much as 2m (BARLETTA & CALLIARI, 2003). In Argentina, strong southern winds carry and deposit a large number of organisms, without the possibility of their returning to the lower parts of the beach. This phenomenon commonly occurs with *M. mactroides*, making the return of the species to the water impossible (RAMÍREZ *et al.*, 2004).

DEFEO (1989) observed that *M. mactroides* is collected by fishermen with shovels on the Uruguayan coast. The collection of *M. mactroides* with the use of shovels causes collateral damage to non-exploited classes, breaking their shells and affecting the survival of juveniles due to disturbances in the sediment (DEFEO, 1996a; BRAZEIRO & DEFEO, 1999). This collection procedure is also used by fishermen in southernmost Brazil, and the mortality of individuals from all classes may be a consequence of this type of activity.

Temporal variations in the benthic macrofauna abundance on Cassino beach can be attributed to the positive effect of recruitment peaks and the migration of species to the swash zone, as well as the negative effects of the migration of some species to deeper waters, mortality by natural causes (stranding and action of predators) and human activity (extracting and traffic of vehicles). Among the positive effects, recruitment can be considered the main determinant in the expressive increases of benthic macrofauna abundance for most organisms. Stranding, that is, the trapping of organisms on the upper parts of the beach, is likely the main cause for the abrupt drops in benthic macrofauna abundance on sandy beaches in southernmost Brazil.

It was possible verify the monthly temporal variability in the present study. Perhaps other patterns could be observed depending on the samplings frequency.

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