

ZONATION OF BENTHIC MACROFAUNA ON CASSINO BEACH, SOUTHERNMOST BRAZIL

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ABSTRACT

Benthic macrofauna zonation was studied for one year (June 2004 to May 2005) with monthly sampling on Cassino Beach, Rio Grande do Sul, Brazil. Three sites (spaced 50 m apart) were selected. Three transects were anchored at each site, spaced equidistantly 2 m apart. 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. Monthly, with a 20 cm diameter core, one biological sample was collected per transect at each level, a total of nine samples per level. Within transects, the distance between the levels was 20 m until the upper swash zone, from which the distance was 10 m until the 1-meter isobath. Zonation proved to be variable throughout the year. Variability was mainly a reflection of the greater instability of the lower part of the beach, which comprised the lower mesolittoral zone and the inner surf zone. This was evidenced seasonally with the formation of distinct groups of fauna in accordance with the peculiarity of each season of the year. The formation of these groups was strongly influenced by fluctuations in densities stemming from recruitments and the migration of juvenile and adult infauna, as well as superimposing of the distribution of organisms as a result of rises in sea level due to storms.

RESUMO

A zonação da macrofauna bentônica na praia do Cassino, Rio Grande do Sul, Brasil, foi estudada durante um ano (junho 2004 a maio de 2005) com base em coletas mensais. Para isso escolheu-se 3 locais, com 50 m de distância um do outro, sendo que em cada local foram fundeadas 3 transversais 2 m equidistantes. Cada transversal se estendeu desde a base das dunas primárias até aproximadamente 1m de profundidade no infralitoral, sendo 7 a 8 níveis de coleta distribuídos em cada uma das transversais. Mensalmente, utilizando-se um tubo extrator de 20 cm de diâmetro, coletou-se uma amostra biológica por transversal em cada nível, totalizando nove amostras por nível. A distância dos níveis de coleta em cada transversal foi de 20 m até o limite superior da zona de varrido, a partir da qual a distância foi de 10 m. A zonação mostrou-se variável ao longo do ano, sendo que esta variabilidade refletiu, principalmente, a maior instabilidade da zona inferior da praia, que compreendeu o mesolitoral inferior e a zona de arebentação interna. Isto ficou evidenciado sazonalmente, com a formação de distintos grupos faunísticos de acordo com a peculiaridade de cada estação do ano. A formação destes grupos foi fortemente influenciada pelas flutuações das densidades, decorrentes dos recrutamentos e migrações de juvenis e adultos da infauna, e da sobreposição da distribuição dos organismos, em função da elevação do nível da água devido às ressacas.

Descriptors: Sandy beaches; Benthic macrofauna; Zonation; Cassino Beach.

Descritores: Praias arenosas; Macrofauna bentônica; Zonação; Praia do Cassino.

INTRODUCTION

Beaches are dynamic environments where elements such as wind, water and sand interact, resulting in complex hydrodynamic and depositional processes (BROWN; MCLACHLAN, 1990). The peculiar demands or tolerations of each species to different ecological factors result in a vertical distribution of organisms in characteristic zones, which is known as zonation.

Despite the difficulty in identifying zonation on sandy beaches, some schemes have been proposed. Based on the distribution of crustaceans, Dahl (1952) proposed a universal division into three zones. Salvat (1964) proposed a zonation scheme that divides beaches into four zones (dry sand, retention, resurgence and saturation zones) based on physical factors. In spite of these and other proposals, controversy remains regarding the validity of zonation definition schemes on sandy beaches (RAFFAELLI et al., 1991).

It has been verified that the zonation pattern of macrofauna changes according to the type of beach, and the number of zones increases from reflective beaches to dissipative beaches (DEFEO et al., 1992a; JARAMILLO et al., 1993).

An analysis of macrofauna in the mesolittoral zone of 15 beaches in the state of Rio de Janeiro (Brazil) indicated more than one zonation scheme. There was the recognition of two or three biological zones, and reflective beaches presented a more stable pattern of two zones (VELOSO et al., 2003).

In a study carried out on a sandy beach in the state of Paraná (Brazil), a persistent pattern of four fauna zones was recorded throughout the year (SOUZA; GIANUCA, 1995). Also in Paraná, a study analyzing the influence of morphodynamics on the benthic community of 10 beaches recognized 4 fauna zones following the scheme proposed by Salvat (1964) (BORZONE et al., 1996). Borzone and Souza (1997) verified that macrofauna zonation adjusted to the Salvat (1964) scheme, but evidenced temporal variations in zonation patterns, which were more related to the stability of the sediment than tide levels. Based on data from six beaches, Barros et al. (2001) demonstrated that the macrofauna zonation pattern was better adjusted to the Salvat (1964) scheme, with a small difference between the winter and summer results.

The Uruguayan coast on the border of the state of Rio Grande do Sul (Brazil) biogeographically constitutes what is known as the Riogrande-Uruguayan Sector, due to the similarity in the fauna composition of sandy beaches (ESCOFET et al., 1979). A one-year accompaniment of macrofauna zonation at Barra del Chuy (Uruguay) indicated the existence of three zones between the supralittoral zone and the lower levels of the swash zone (BRAZEIRO; DEFEO, 1996). However, the authors identified an important variation in the zonation of organisms throughout the seasons of the year, which reinforces the need for temporal follow-ups of the benthic macrofauna in the Riogrande-Uruguayan Sector.

On the northern coast of the state of Rio Grande do Sul (Brazil), daily accompaniment (for five days) of benthic macrofauna zonation between the mid mesolittoral zone and the beginning of the surf zone on three sandy beaches, distinguished only two fauna zones (NEVES; BEMVENUTI, 2006). Despite work carried out regarding the composition and distribution of benthic macrofauna on beaches along the southern coast of Rio Grande do Sul (GIANUCA, 1983, 1987; BORZONE; GIANUCA, 1990), there is a lack of approaches regarding quantitative sampling with replication between the supralittoral zone and the lower bounds of the swash zone. The aim of the present study was to determine the vertical distribution

of benthic macrofauna during the four seasons of the year on a sandy beach on the southern coast of Rio Grande do Sul.

MATERIALS AND METHODS

Study Area

The sandy beaches of southernmost Brazil are exposed, with a slight decline, fine sand, moderate to strong wave action and well-developed surf zone, presenting dissipative to intermediate morphodynamic states (GIANUCA, 1988; GARCIA; GIANUCA, 1998; BORZONE; GIANUCA, 1990). The astronomical tides are insignificant, and meteorological factors are the main cause of variations in water level (CALLIARI; KLEIN, 1993).

Cassino Beach, Rio Grande (RS) presents dissipative characteristics in the area near the jetties of Barra de Rio Grande, whereas 17.2 km southwards of the western jetty (052° 14' 040 W and 32° 15' 554 S) (Fig. 1), intermediate characteristics were observed (CALLIARI; KLEIN, 1993; PEREIRA, 2005).

For the zonation denomination, the nomenclature proposed by Gianuca (1998) for Cassino beach was used. The supralittoral level is a zone under the effect of sea spray, which is only inundated by the ocean during extreme events, such as tides of storms. The mesolittoral corresponds to the zone inundated by the tides, with the swash zone in its lower bounds, which is subjected to the swash and backwash of waves. The upper bounds of the infralittoral was denominated the inner surf zone, which is characterized by shallow sandy bottoms and turbulent between the lower swash zone and approximately 2 m in depth.

Sampling

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 50 m from each other. At each site, 3 transects were demarked, 2 m equidistant from one another. Each transect extended from the base of the primary dunes to the inner surf zone at approximately 1 m depth, with between 7 and 8 collection levels. Monthly one biological sample was collected per transect at each level, a total of nine samples per level. Within transects, the distance between the levels was 20 m until the upper swash zone, from which distance was 10 m 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).

Biological samples were collected using a core of 20 cm diameter (0.031416 m²), sunk into the sediment to a depth of 20 cm, as most of the

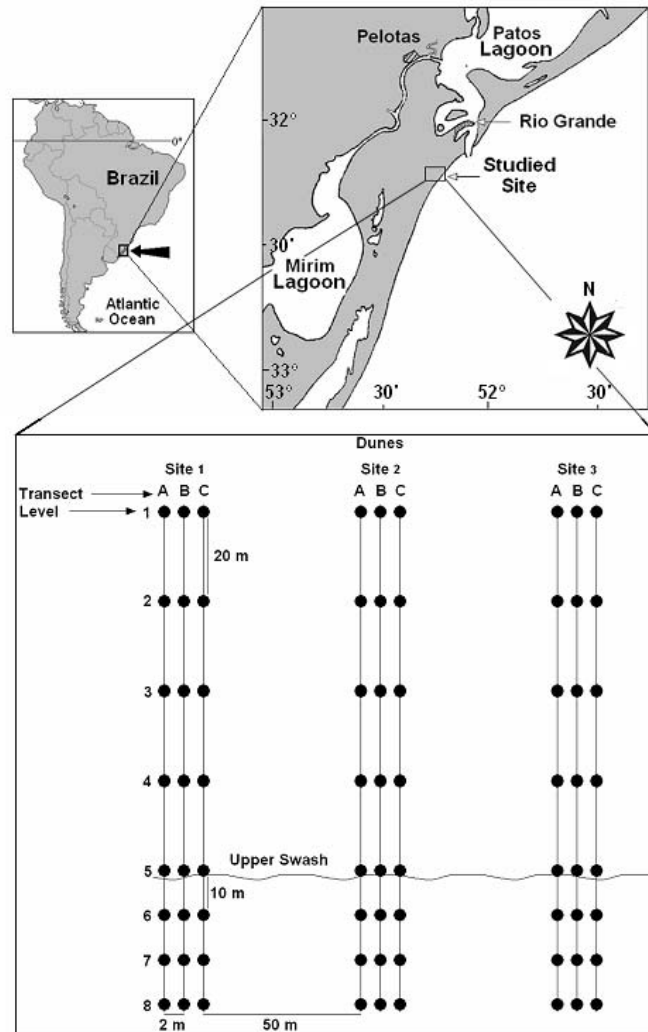


Fig. 1. Location of study area and sampling design from which the benthic macrofauna was collected.

macrofauna abundance is found in the first 15-20 cm of depth in the sediment (BALLY, 1983). Samples were sieved with a nylon mesh with a 0.5 mm pore opening, and the material collected was fixed in a 10 % formaldehyde solution. In the laboratory, organisms were quantified and identified to the smallest possible taxonomic level under a stereoscopic microscope.

A monthly quantification was also performed on the number of Ghost Crab burrows (*Ocypode quadrata*), which were mainly located in the supralittoral zone. The method utilized to quantify the density of *O. quadrata* through the number of burrows was also used by Neves and Bemvenuti (2006) and Alberto and Fontoura (1999) in works carried out on

the coast of the state of Rio Grande do Sul. Starting from the bases of the primary dunes, 100 m 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 5 m from one another. Through the continuous arrangement of 1x1m grid, the density of burrows along each line was recorded.

Regarding the bivalve *Mesodesma mactroides*, organisms with a shell length between 1 and 10 mm were defined as recruits; those with 10.1 – 42.9 mm were defined as juveniles; and as adults, those with a shell length greater than 43 mm,

according to the procedure proposed by Masello and Defeo (1986) and Defeo et al. (1992b). Recruits, juveniles and adults of the bivalve *Donax hanleyanus* were defined respectively as organisms of 1-5 mm, 5.5-15 mm and >15 mm in length, following Defeo and de Alava (1995).

For the analysis of the spatial variation of the benthic macrofauna, samples pertaining to each level at each site were totaled on a monthly basis.

Environmental Data

Seasonal sediment samples were taken at each of the levels of the 3 sites. The grain size analysis of sediment were performed through the proportions of sand, silt and clay in the sediment were determined through sieving (> 0.062 mm in diameter) and pipetting (< 0.062 mm 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. Using a fixed reference, the monthly topographic profile of the beach was obtained for the central transversal at Site 2. For such, a dumpy level was used. 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 Dean's dimensionless parameter ($\Omega = H_b / W_s \cdot T$) was employed, where H_b is the wave height of the surf, W_s is the rate of sediment decantation and T is the wave period. The Ω values less than 1 represent reflective beaches; intermediate beaches are classified within the 1 to 6 interval; and dissipative beaches present Ω values greater than 6 (SHORT; WRIGHT, 1983).

Statistical Analyses

In order to analyze the zonation and possible variations of the benthic macrofauna distribution throughout the year, statistical analyses were performed on the PRIMER v5 program (Plymouth Routines in Multi Ecological Research) using quantitative data (CLARKE; WARWICK, 1994). For the multivariate analyses, the sum of the samples of each level, for site, was used to draw up a similarity spreadsheet (Q mode) using the Bray-Curtis dissimilarity index. The spring and summer data and the annual total were transformed into $\sqrt{\sqrt{\quad}}$ due to the considerable difference in the density of individuals (CLARKE; GREEN, 1988). Multi-Dimensional Scaling (MDS) analysis was then performed to find the groups. This analysis is considered the most robust to verify the benthic macrofauna zonation on sandy beaches (KENKEL; ORLOCI, 1986; RAFFAELLI et al., 1991). 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 for the determination of dissimilarity between the groups formed and to verify the contribution of the principal species in the groups formation. Levels 1 and 2 (supralittoral) were not considered in the multivariate analyses, as they presented only benthic macro-invertebrates originating from the stranding, i.e. organisms that were flung to these levels by storms. The vast majority of them were dead at the time of sampling.

The Shannon-Weaver diversity index (H') and the Peilou evenness index (J') were also determined for each level.

RESULTS

Environmental Variables

Minimum salinity was recorded during the July sampling (29 ‰) and maximums in January (36 ‰) and March (36 ‰). Water temperature of the inner surf zone followed the same tendency as air temperature, with minimums recorded in July (water = 14°C and air = 15°C) and May (water = 13.5°C and air = 15°C), and the maximum in January (water = 26°C and air = 30°C). Wave height presented higher values in November (1.5 m) and July (1 m), whereas the average wave period ranged from 8 to 11.9 sec. Average declivity of the beach was 1.7° 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 (Table 1). The sediment type for most of the area was classified as fine sand, but on some occasions medium sand predominated on the lower part of the beach (Table 1). The beach presented constant erosion and accretion throughout the year, but the profiles that composed the summer were more stable (Fig. 2).

During the 7 days prior to sampling of the benthic macrofauna, NE wind was the most frequent, with a maximum velocity of 26.4 m.s⁻¹ in October. The SW wind was more frequent in periods of lower temperature, but its maximum velocity of 25.1 m.s⁻¹ occurred in March (Table 2).

Benthic Macrofauna

A total of 18 taxa were collected in winter (June, July and August). Crustacea was the most diverse, followed by polychaeta, which also occurred in the other seasons. At Level 4, there was a greater average index of diversity ($H' = 1.29$) and greater average density of macrofauna, but the highest number of taxa occurred at Level 6 (Table 3).

MDS and ANOSIM analyses determined the formation of 3 groups: Level 3, Level 4 and Levels 5 to 8 (ANOSIM 3x4 R=0.9 and $p=0.1\%$; 3x5-8 R=0.8

Table 1. Average grain size (phi), sediment classification and seasonal value of Ω .

Site	Level	Winter		Spring		Summer		Fall	
		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	2,777	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	

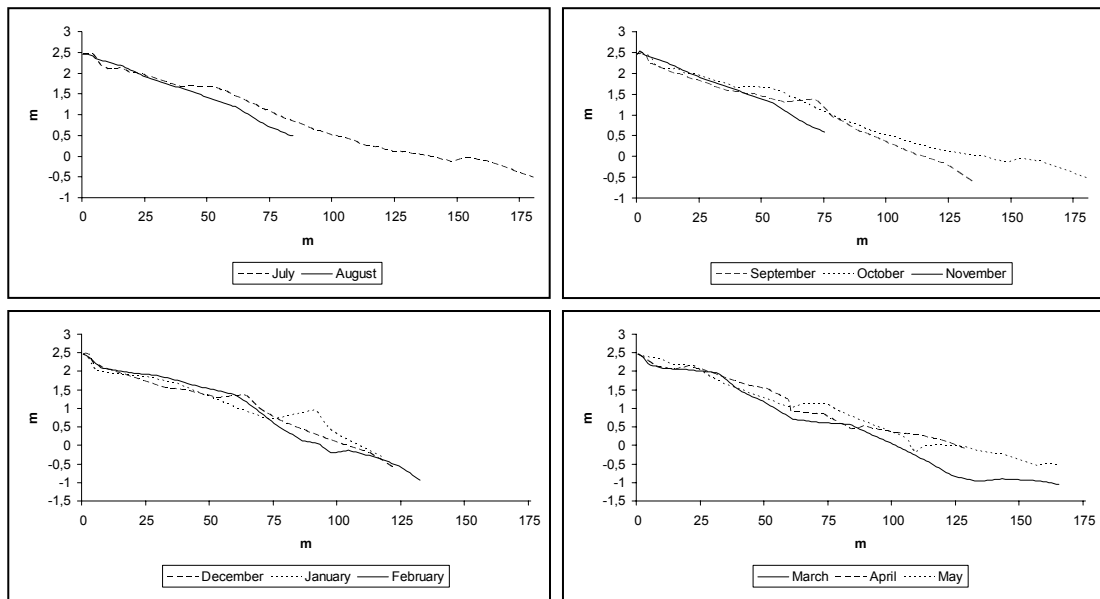


Fig. 2. Profiles of the beach between July 2004 and May 2005, grouped according to the months that make up each season of the year.

Table 2. Wind characteristics during the 7 days before the benthic macrofauna sampling (June 2004 to May 2005).

		N	NE	E	SE	S	SW	W	NW
June	Frequency (%)	7,1	32,7	0,0	0,0	0,0	9,5	29,2	21,4
	Average Speed (m.s ⁻¹)	3,6	5,4	0,0	0,0	0,0	6,1	5,9	3,9
	Maximum Speed (m.s ⁻¹)	9,8	15,6	0,0	0,0	0,0	16,1	16,6	11,2
July	Frequency (%)	0,6	28,6	0,0	10,6	7,5	45,3	3,1	4,3
	Average Speed (m.s ⁻¹)	2,2	7,1	0,0	4,0	6,2	6,2	3,0	2,9
	Maximum Speed (m.s ⁻¹)	4,9	16,1	0,0	6,7	12,5	13,4	8,1	5,8
August	Frequency (%)	1,2	26,8	4,2	10,1	2,4	41,1	10,1	4,2
	Average Speed (m.s ⁻¹)	2,9	7,8	6,4	3,5	3,0	6,6	3,9	2,4
	Maximum Speed (m.s ⁻¹)	6,3	19,7	9,0	7,2	6,3	15,6	9,0	4,9
September	Frequency (%)	0,6	14,9	6,0	37,5	26,8	14,3	0,0	0,0
	Average Speed (m.s ⁻¹)	5,8	8,9	7,5	8,9	8,4	8,3	0,0	0,0
	Maximum Speed (m.s ⁻¹)	12,1	16,1	12,1	17,4	17,4	16,1	0,0	0,0
October	Frequency (%)	1,2	42,9	5,4	5,4	1,8	28,0	14,3	1,2
	Average Speed (m.s ⁻¹)	7,4	11,3	10,8	6,3	6,3	5,5	4,9	4,5
	Maximum Speed (m.s ⁻¹)	14,8	26,4	17,0	12,5	9,4	13,0	9,4	8,1
November	Frequency (%)	3,0	41,7	9,5	4,8	11,3	14,3	12,5	3,0
	Average Speed (m.s ⁻¹)	2,5	10,4	9,9	3,7	8,2	7,1	5,2	1,4
	Maximum Speed (m.s ⁻¹)	7,2	21,5	15,2	7,6	23,7	24,6	13,9	4,5
December	Frequency (%)	0,0	18,8	37,1	44,1	0,0	0,0	0,0	0,0
	Average Speed (m.s ⁻¹)	0,0	9,4	9,7	9,4	0,0	0,0	0,0	0,0
	Maximum Speed (m.s ⁻¹)	0,0	16,6	15,6	15,2	0,0	0,0	0,0	0,0
January	Frequency (%)	3,6	48,8	11,9	16,1	3,0	10,7	1,8	4,2
	Average Speed (m.s ⁻¹)	4,2	8,0	7,4	5,0	5,6	8,6	5,4	3,9
	Maximum Speed (m.s ⁻¹)	11,2	15,2	12,1	12,1	11,6	17,4	11,2	16,1
February	Frequency (%)	4,8	28,6	18,5	20,8	6,0	17,9	1,8	1,8
	Average Speed (m.s ⁻¹)	4,1	10,4	11,2	7,5	6,9	6,3	4,0	3,1
	Maximum Speed (m.s ⁻¹)	11,6	19,2	17,0	13,9	13,4	15,6	7,6	7,2
March	Frequency (%)	4,8	18,5	12,5	35,7	10,1	4,2	4,8	8,9
	Average Speed (m.s ⁻¹)	5,3	8,5	9,6	7,0	9,2	8,1	4,2	3,5
	Maximum Speed (m.s ⁻¹)	11,6	22,8	21,9	18,8	25,5	25,1	10,3	8,5
April	Frequency (%)	6,0	23,8	5,4	11,9	10,7	20,2	6,5	15,5
	Average Speed (m.s ⁻¹)	2,6	9,1	8,2	9,3	7,7	5,4	3,6	5,9
	Maximum Speed (m.s ⁻¹)	12,1	20,6	16,6	17,0	17,6	15,6	13,4	17,0
May	Frequency (%)	3,0	16,7	4,8	5,4	1,8	28,6	24,4	15,5
	Average Speed (m.s ⁻¹)	4,0	4,7	2,1	5,9	6,6	6,0	5,8	4,6
	Maximum Speed (m.s ⁻¹)	10,3	9,4	5,8	9,4	13,0	17,9	18,8	15,6

Table 3. Organisms mean density (ind. m⁻²) and standard deviation (SD) in winter at each level. The average index of diversity (H'), evenness (J'), average total densities and number of species at each level are also presented.

Levels	Winter 2004															
	1		2		3		4		5		6		7		8	
	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD
Bivalvia																
<i>Donax hanleyanus</i>	0	0	0	0	0	0	4,72	14,52	201,60	343,74	473,93	878,60	224,00	306,65	244,04	387,24
<i>Mesodesma mactroides</i>	0	0	0	0	1,18	6,13	49,51	55,37	269,97	476,02	172,12	277,95	78,99	129,56	120,25	171,99
Polychaeta																
<i>Euzonus furciferus</i>	0	0	24,76	42,64	235,78	273,86	156,80	466,64	2,36	8,50	1,18	6,13	0	0	0	0
<i>Scolecopsis gaucha</i>	0	0	1,18	6,13	3,54	10,19	350,14	834,73	10,61	24,97	2,36	8,50	0	0	0	0
<i>Hemipodus olivieri</i>	0	0	0	0	1,18	6,13	3,54	10,19	3,54	13,49	2,36	8,50	11,79	26,70	14,15	16,78
<i>Sigalion cirriferum</i>	0	0	0	0	0	0	0	0	5,89	15,39	3,54	10,19	5,89	12,60	3,54	10,61
Crustacea																
Platyschnopidae	5,89	15,39	4,72	14,52	27,12	40,17	682,60	441,62	239,32	348,84	63,66	130,65	3,54	10,19	3,54	10,61
<i>Phoxocephalopsis</i> sp.	0	0	0	0	1,18	6,13	463,32	506,40	47,16	83,46	35,37	65,07	60,13	57,44	99,03	99,96
<i>Bathyporeiapus</i> sp.	9,43	35,11	12,97	28,28	5,89	12,60	18,86	42,58	93,13	143,69	200,42	228,48	108,46	149,89	56,59	44,39
<i>Excirolana armata</i>	0	0	0	0	35,37	41,72	106,10	61,16	17,68	31,00	1,18	6,13	0	0	0	0
<i>Emerita brasiliensis</i>	0	0	0	0	0	0	0	0	3,54	10,19	42,44	56,53	5,89	12,60	7,07	21,22
<i>Macrochiridothea</i> sp.	0	0	0	0	0	0	0	0	10,61	17,66	16,50	34,61	11,79	23,60	3,54	10,61
<i>Pinnixa patagoniensis</i>	0	0	0	0	0	0	0	0	0	0	2,36	12,25	0	0	0	0
<i>Excirolana brasiliensis</i>	0	0	2,36	8,50	0	0	0	0	0	0	0	0	0	0	0	0
<i>Puelche</i> sp.	0	0	0	0	0	0	1,18	6,13	0	0	0	0	0	0	0	0
<i>Balloniscus sellowii</i>	0	0	0	0	1,18	6,13	0	0	0	0	0	0	0	0	0	0
Gastropoda																
<i>Olivancillaria auricularia</i>	0	0	0	0	0	0	0	0	0	0	0	0	1,18	6,13	0	0
Nemertea																
Nemertea	0	0	0	0	0	0	8,25	18,92	7,07	22,22	5,89	15,39	4,72	14,52	3,54	10,61
Average Total Densities	15,33	39,85	45,98	51,73	312,41	261,45	1845,01	1292,69	912,49	673,21	1023,30	1373,52	516,37	387,98	555,27	458,55
Number of Taxas	2	3	5	9	11	13	14	11	14	11	10	10	11	10	10	10
J'	***	***	***	***	0,62	0,31	0,66	0,10	0,57	0,16	0,76	0,16	0,70	0,22	0,70	0,12
H'(loge)	0,07	0,20	0,31	0,42	0,76	0,44	1,29	0,22	1,05	0,40	1,25	0,30	1,19	0,40	1,28	0,19

and $p=0.1\%$; 4x5-8 $R=0.5$ and $p=0.1\%$) (Fig. 3a). Through the SIMPER analysis, the dissimilarity between groups 3x4, 3x5-8 and 4x5-8 was 87%, 96% and 86%, respectively. Table 4 displays the contribution percentages of the main taxa in the formation of the distinct groups.

A total of 21 taxa were collected in spring (September, October and November). Level 4 had the greater average index of diversity ($H'=1.02$), whereas Level 5 presented the greatest average density and Level 7 contained the highest number of taxa (Table 5).

The formation of 2 groups was verified: one formed by Level 3 and the other by Levels 4 to 7 (ANOSIM $R=0.8$ and $p=0.1\%$) (Fig. 3b). The difference between these groups was 76%. Table 4 displays the percentages of the main taxa that formed each group.

A total of 21 taxa were found in summer (December, January and February). For the period, Level 6 presented the greater average index of diversity ($H'=1.35$) and highest number of taxa,

whereas Level 5 presented the greatest average density (Table 6).

Four groups were identified: Level 3, Levels 4-5, Levels 6-7 and Level 8 (ANOSIM 3x4-5 $R=0.5$ and $p=0.1\%$; 3x6-7 $R=0.8$ and $p=0.1\%$; 3x8 $R=0.3$ and $p=7.7\%$; 4-5x6-7 $R=0.5$ and $p=0.1\%$; 4-5x8 $R=0.8$ and $p=0.4\%$; 6-7x8 $R=0.6$ and $p=0.5\%$) (Fig. 3c). There was no significant difference between Levels 3 and 8. The likely cause for this was the abrupt reduction in the density of *Euzonus furciferus* at Level 3, which was the characteristic species of the level. The difference between groups 3x4-5, 3x6-7, 4-5x6-7, 4-5x8 and 6-7x8 were 70%, 83%, 55%, 69% and 49%, respectively. Table 4 displays the percentages of the main taxa in the formation of each group.

A total of 22 taxa were collected in fall (March, April and May). Level 4 presented the greatest average index of diversity ($H'=1.43$), whereas Level 6 showed the greatest average density. Level 5 and 6 contained the highest number of taxa for the season (Table 7).

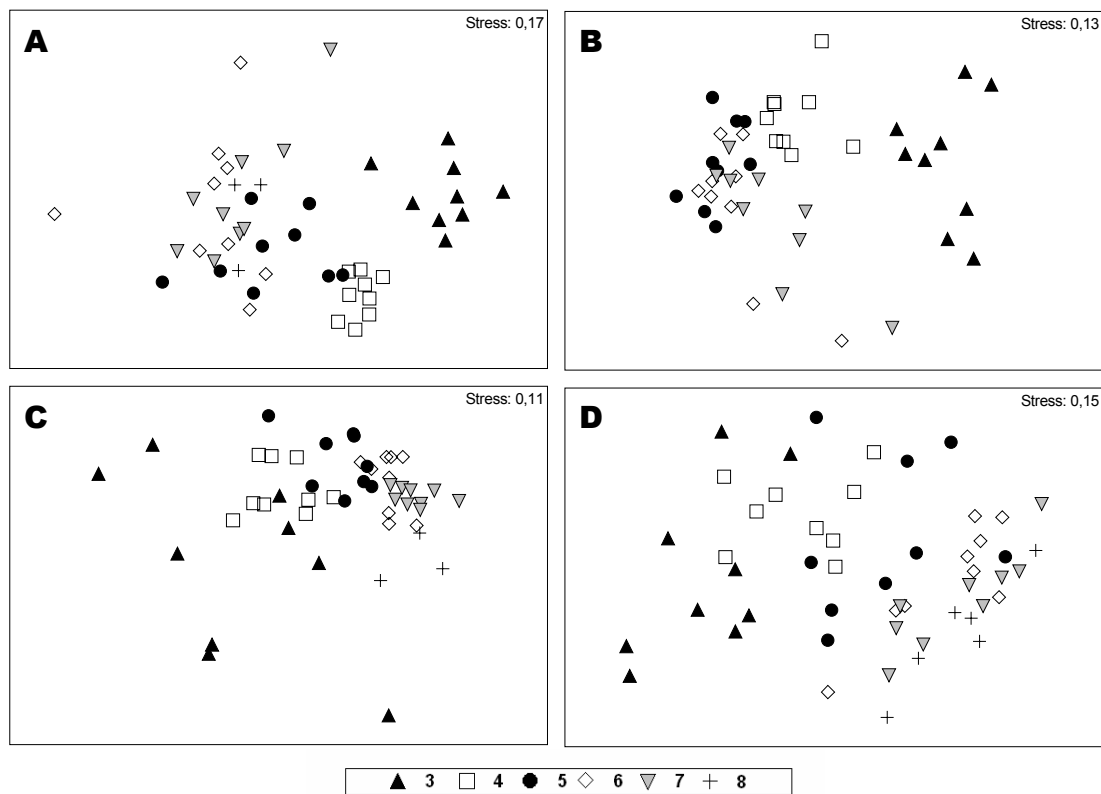


Fig. 3. Seasonal MDS analysis of the sampling levels along transects. Each analysis contains the referent months that formed each season of the year. The letters A, B, C and D refer to winter, spring, summer and fall, respectively.

Table 4. Contribution percentage of principal taxa on the groups formed during winter, spring, summer, fall and the entire year (June 2004 to May 2005).

Groups	Winter			Spring		Summer				Fall		Annual	
	3	4	5-8	3	4-7	3	4-5	6-7	8	3-4	5-8	3	4-8
Bivalvia													
<i>Donax hanleyanus</i>			34%						15%		73%		16%
<i>Mesodesma mactroides</i>			23%		14%		21%	25%	33%	22%			19%
Polychaeta													
<i>Euzonus furciferus</i>	65%			57%						26%			42%
<i>Scolelepis gaucha</i>					17%	53%	30%						
Crustacea													
Platyschnopidae		53%											
<i>Bathyporeiapus</i> sp.					19%			12%					
<i>Excirrolana armata</i>													29%
<i>Emerita brasiliensis</i>									17%				
<i>Phoxocephalopsis</i> sp.													14%

Table 5. Organisms mean density (ind. m⁻²) and standard deviation (SD) in spring at each level. The average index of diversity (H'), evenness (J'), average total densities and number of species at each level are also presented.

Levels	Spring 2004															
	1		2		3		4		5		6		7			
	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD		
Bivalvia																
<i>Mesodesma mactroides</i>	3,54	18,38	0	0	2,36	8,50	76,63	98,41	1183,64	1194,89	2540,58	3312,00	298,27	367,74		
<i>Donax hanleyanus</i>	0	0	0	0	0	0	40,08	60,90	1307,43	830,70	321,85	508,48	21,22	40,46		
<i>Donax gemmula</i>	0	0	0	0	0	0	0	0	0	0	0	0	1,18	6,13		
Polychaeta																
<i>Scolelepis gaucha</i>	20,04	59,32	28,29	75,08	22,40	38,29	31187,22	46173,01	37770,33	61418,21	6936,78	17581,52	2024,21	5215,19		
<i>Euzonus furciferus</i>	1,18	6,13	8,25	22,67	318,31	260,55	274,69	325,35	20,04	30,77	0	0	0	0		
<i>Hemipodus olivieri</i>	0	0	0	0	0	0	23,58	34,86	11,79	20,03	95,49	177,23	81,35	106,43		
<i>Sigalion cirriferum</i>	0	0	0	0	0	0	1,18	6,13	3,54	10,19	5,89	12,60	7,07	16,12		
<i>Grubeulepis bracteata</i>	0	0	0	0	0	0	0	0	0	0	0	0	1,18	6,13		
<i>Capitella</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	1,18	6,13		
Hesionidae	0	0	0	0	0	0	0	0	0	0	0	0	1,18	6,13		
Crustacea																
<i>Bathyporeiapus</i> sp.	101,39	270,53	145,01	294,44	50,69	102,67	598,89	1231,48	4725,12	14985,79	2738,64	3824,43	2421,51	4674,16		
Platyschnopidae	3,54	10,19	0	0	1,18	6,13	352,50	418,85	754,51	842,02	468,03	474,42	102,57	150,17		
<i>Phoxocephalopsis</i> sp.	2,36	8,50	0	0	9,43	27,66	720,32	792,89	281,76	352,22	176,84	189,00	166,23	245,51		
<i>Macrochiridothea</i> sp.	0	0	0	0	0	0	0	0	2,36	8,50	16,50	29,77	22,40	43,08		
<i>Emerita brasiliensis</i>	0	0	0	0	0	0	0	0	11,79	21,89	11,79	20,03	0	0		
<i>Excirrolana armata</i>	0	0	1,18	6,13	25,94	42,37	106,10	109,91	2,36	12,25	1,18	6,13	0	0		
<i>Puelche</i> sp.	0	0	0	0	0	0	1,18	6,13	4,72	19,15	1,18	6,13	2,36	8,50		
<i>Excirrolana brasiliensis</i>	1,18	6,13	1,18	6,13	0	0	0	0	0	0	0	0	0	0		
Gastropoda																
<i>Olivancillaria auricularia</i>	0	0	0	0	0	0	0	0	0	0	0	0	1,18	6,13		
Nemertea																
Nemertea	0	0	0	0	0	0	17,68	23,91	17,68	35,68	24,76	36,76	27,12	39,19		
Oligochaeta																
Oligochaeta	24,76	101,56	0	0	0	0	0	0	0	0	0	0	0	0		
Average Total Densities	157,98	294,99	183,91	319,33	430,31	323,58	33400,06	46611,94	46097,06	59816,95	13339,51	18044,72	5180,19	7301,227		
Number of Taxas	8		5		7		12		14		13		16			
J'	***	***	***	***	0,66	0,20	0,49	0,32	0,37	0,26	0,49	0,23	0,51	0,21		
H'(loge)	0,29	0,33	0,29	0,39	0,72	0,24	1,02	0,64	0,79	0,54	0,97	0,44	1,01	0,48		

Only 2 groups were identified in the period: one was formed by Levels 3-4, and the other by Levels 5 to 8 (ANOSIM R=0.6 and $p=0.1\%$) (Fig. 3d). The dissimilarity between these groups was 87%. Table 4 displays the contribution percentages of the main taxa in the formation of each group.

Based on the analyses of data throughout the sampling period, the formation of 2 groups was distinguished: one formed by Level 3 and the other by Levels 4 to 8 (ANOSIM R=0.6 and $p=0.1\%$) (Fig. 4). These groups presented a dissimilarity of 76%. Table

4 displays the contribution percentages of the main taxa in the formation of each group.

The zonation of the 10 taxa that presented the greatest densities throughout the seasons of the year indicated a clear spatial/temporal pattern in the benthic macrofauna abundance. The greatest densities of benthic macrofauna were concentrated in the wash zone (Figs 5a, 5b, 5c, 5d). With regard to seasonality, the months of spring and, especially, summer presented greater benthic macrofauna densities, reflecting the recruitments recorded in these warmer seasons.

Table 6. Organisms mean density (ind. m⁻²) and standard deviation (SD) in summer at each level. The average index of diversity (H'), evenness (J'), average total densities and number of species at each level are also presented.

Levels	Summer 2004 - 2005															
	1		2		3		4		5		6		7		8	
	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD
Bivalvia																
<i>Donax gemmula</i>	0	0	0	0	1,18	6,13	0	0	0	0	3,54	10,19	56,59	75,60	24,76	21,22
<i>Mesodesma mactroides</i>	23,58	69,29	1,18	6,13	53,05	111,67	282,94	366,70	5761,40	12224,50	5614,03	8758,62	2416,79	2171,48	923,10	1129,55
<i>Donax hanleyanus</i>	2,36	8,50	0	0	15,33	33,47	156,80	495,72	643,69	796,57	949,03	1444,80	471,57	698,44	116,71	222,82
Polychaeta																
<i>Hemipodus olivieri</i>	0	0	0	0	0	0	1,18	6,13	2,36	8,50	2,36	8,50	4,72	11,52	0	0
<i>Scolelepis gaucha</i>	12,97	44,37	17,68	50,97	109,64	206,92	3697,10	5663,47	29184,23	38207,78	1055,14	1836,98	57,77	110,98	7,07	14,04
<i>Sigalion cirriferum</i>	0	0	0	0	0	0	0	0	1,18	6,13	4,72	14,52	4,72	14,52	10,61	15,92
Capitellidae	0	0	2,36	8,50	0	0	0	0	0	0	0	0	0	0	0	0
<i>Euzonus furciferus</i>	1,18	6,13	0	0	23,58	103,93	97,85	143,69	25,94	51,51	1,18	6,13	0	0	0	0
Crustacea																
<i>Phoxocephalopsis</i> sp.	0	0	0	0	2,36	8,50	51,87	104,89	475,11	852,33	1279,13	1673,80	74,27	155,94	0	0
<i>Emerita brasiliensis</i>	1,18	6,13	1,18	6,13	0	0	0	0	462,14	624,34	677,88	744,92	24,76	55,37	67,20	80,28
Platyschnopidae	1,18	6,13	0	0	0	0	17,68	41,72	245,22	345,75	557,63	869,24	103,75	215,27	0	0
<i>Bathyporeiapus</i> sp.	1,18	6,13	0	0	1,18	6,13	2,36	8,50	121,43	327,37	123,79	119,86	101,39	122,66	14,15	28,07
<i>Excirrolana armata</i>	2,36	8,50	0	0	17,68	35,68	200,42	141,48	91,96	116,56	31,83	81,39	0	0	0	0
<i>Macrochirodothea</i> sp.	0	0	0	0	0	0	0	0	5,89	25,03	28,29	39,81	67,20	115,89	49,51	71,37
<i>Pinnixa patagoniensis</i>	0	0	0	0	0	0	0	0	0	0	1,18	6,13	1,18	6,13	10,61	31,83
<i>Puelche</i> sp.	0	0	0	0	0	0	0	0	0	0	3,54	13,49	7,07	20,39	0	0
<i>Arenaeus cribarius</i>	0	0	0	0	0	0	0	0	0	0	1,18	6,13	0	0	0	0
Gastropoda																
<i>Buccinanops duartei</i>	0	0	0	0	0	0	0	0	0	0	0	0	2,36	8,50	21,22	35,59
<i>Olivancillaria auricularia</i>	0	0	0	0	0	0	0	0	0	0	1,18	6,13	0	0	3,54	10,61
Oligochaeta																
Oligochaeta	83,70	307,49	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea																
Nemertea	0	0	0	0	0	0	0	0	27,12	42,07	54,23	50,57	29,47	44,08	14,15	16,78
AverageTotal Densities	129,68	313,12	22,40	50,57	224,00	282,85	4508,20	5886,90	37047,65	46896,91	10389,85	11077,75	3423,59	2655,20	1262,63	1292,68
Number of Taxas	9	4	4	8	8	9	13	13	13	18	15	15	12	12	12	12
J'	***	***	***	***	***	***	0,57	0,31	0,49	0,33	0,59	0,17	0,46	0,18	0,47	0,19
H'(loge)	0,26	0,39	0,06	0,19	0,43	0,45	0,89	0,46	1,06	0,70	1,35	0,36	1,05	0,42	0,96	0,31

Table 7. Organisms mean density (ind. m⁻²) and standard deviation (SD) in fall at each level. The average index of diversity (H'), evenness (J'), average total densities and number of species at each level are also presented.

	Fall 2005															
	1		2		3		4		5		6		7		8	
	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD	Av	SD
Bivalvia																
<i>Donax hanleyanus</i>	4,72	14,52	0	0	33,01	63,34	225,17	331,14	966,72	1463,53	2429,76	2224,40	2193,98	2812,84	940,78	795,75
<i>Mesodesma mactroides</i>	0	0	1,18	6,13	252,29	461,94	534,05	824,69	1020,95	2503,57	114,36	173,96	47,16	56,09	26,53	52,64
<i>Donax gemmula</i>	0	0	0	0	0	0	0	0	9,43	21,29	120,25	251,15	374,90	765,13	1025,66	2753,08
Polychaeta																
<i>Euzonus furciferus</i>	2,36	8,50	2,36	8,50	478,64	647,09	475,11	1123,69	11,79	30,77	2,36	8,50	0	0	0	0
<i>Scolelepis gaucha</i>	0	0	0	0	38,90	98,83	99,03	211,20	3,54	13,49	1,18	6,13	1,18	6,13	0	0
<i>Hemipodus olivieri</i>	0	0	0	0	0	0	1,18	6,13	7,07	18,38	14,15	29,72	8,25	14,21	19,45	29,17
<i>Sigalion cirriferum</i>	0	0	0	0	0	0	0	0	1,18	6,13	2,36	8,50	4,72	11,52	3,54	10,29
<i>Hyalinoecia</i> sp.	0	0	0	0	0	0	0	0	0	0	0	0	1,18	6,13	0	0
Crustacea																
Platyschnopidae	2,36	8,50	0	0	25,94	50,74	460,96	365,64	406,73	540,50	27,12	32,68	3,54	10,19	0	0
<i>Phoxocephalopsis</i> sp.	0	0	0	0	69,56	130,96	418,52	521,15	127,32	199,18	83,70	99,16	41,26	59,76	33,60	63,17
<i>Bathyporeiapus</i> sp.	1,18	6,13	3,54	10,19	2,36	8,50	21,22	63,05	43,62	80,50	108,46	109,65	74,27	75,94	79,58	93,44
<i>Emerita brasiliensis</i>	0	0	0	0	10,61	43,25	8,25	20,88	268,79	709,86	14,15	28,38	5,89	12,60	1,77	7,50
<i>Excirrolana armata</i>	0	0	7,07	20,39	119,07	123,15	75,45	91,81	5,89	17,74	0	0	0	0	0	0
<i>Macrochirodothea</i> sp.	0	0	0	0	0	0	0	0	21,22	35,31	42,44	44,14	44,80	61,33	53,05	82,43
<i>Puelche</i> sp.	0	0	0	0	0	0	3,54	10,19	2,36	12,25	9,43	21,29	23,58	51,17	12,38	38,04
<i>Excirrolana brasiliensis</i>	0	0	1,18	6,13	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arenaeus cribarius</i>	0	0	0	0	0	0	0	0	0	0	1,18	6,13	0	0	0	0
<i>Ocyrode quadrata</i>	1,18	6,13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropoda																
<i>Buccinanops duartei</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,77	7,50
<i>Olivancillaria auricularia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,77	7,50
Nemertea																
Nemertea	0	0	0	0	1,18	6,13	3,54	10,19	11,79	23,60	16,50	23,97	5,89	12,60	5,31	12,21
Oligochaeta																
Oligochaeta	3,54	10,19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AverageTotal Densities	15,33	23,97	15,33	29,77	1031,56	908,68	2326,01	1840,93	2908,40	3715,27	2987,39	2490,41	2829,41	3530,84	2205,175	3167,565
Number of Taxas	6	5	5	10	10	12	12	15	15	15	15	14	14	13	13	13
J'	***	***	***	***	0,61	0,19	0,71	0,07	0,59	0,21	0,43	0,22	0,43	0,19	0,58	0,14
H'(loge)	0,26	0,41	0,32	0,39	0,96	0,36	1,43	0,21	1,24	0,49	0,97	0,50	0,90	0,43	1,17	0,33

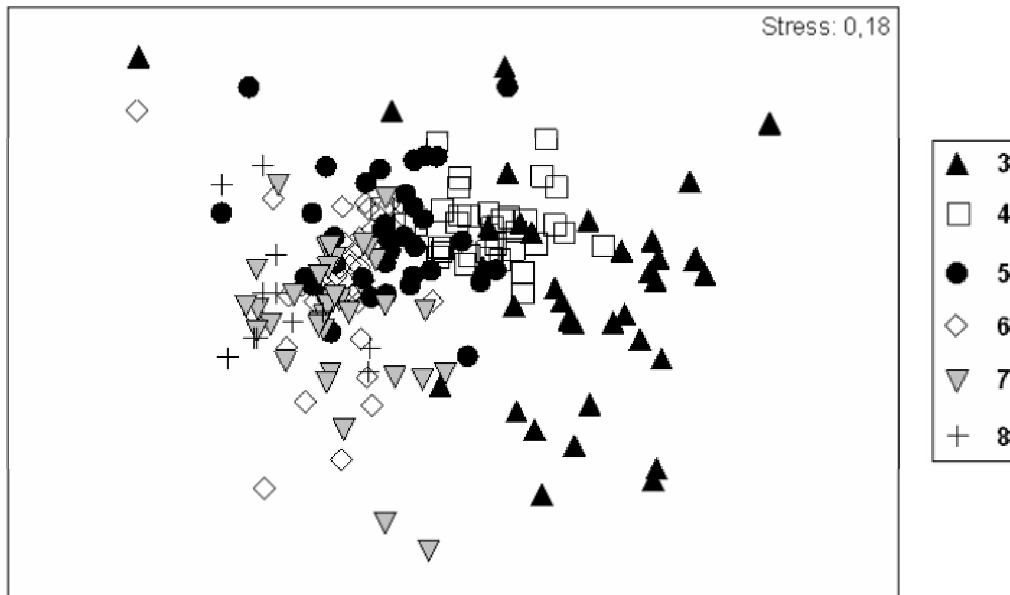


Fig. 4. MDS analysis of the sampling levels along transects with the data for the entire sampling period (June 2004 to May 2005).

The greatest average density of *Ocypode quadrata* burrows was found in March (0.2125 dens m^{-2}), while no burrows were encountered in July, August, September, October, December and May. For all months in which burrows were found, there was a greater concentration in dune proximities, with a reduction in number of burrows toward the lower parts of the beach.

DISCUSSION

A 3-zone pattern was found based on data recorded throughout the year: the supralittoral, where the Ghost Crab *Ocypode quadrata* occurred; the upper mesolittoral, characterized by polychaeta *Euzonus furciferus* and the isopod *Excirolana armata*; and the final zone including the lower mesolittoral and inner surf zone, which was characterized by the tidal migrants clams *Donax hanleyanus* and *Mesodesma mactroides*, together with the amphipod *Phoxocephalopsis* sp. The fauna of the supralittoral zone may be related to the subterrestrial zone described by Dahl (1952) and the dry sand zone described by Salvat (1964). In the scheme proposed by Dahl (1952), the mesolittoral, which corresponds to the retention zone proposed by Salvat (1964), is characterized by cirrolanid isopods. In the present study, *Excirolana armata* was found in this zone, along with *Euzonus furciferus*, similarly to what was

observed on Uruguayan beaches (DEFEO et al., 1992a; GIMÉNEZ; YANNICCELLI, 1997). The third fauna zone corresponds to the infralittoral zone of Dahl (1952), that includes the resurgence and saturation zones of Salvat (1964) (MCLACHLAN, 1990).

In a one-year accompaniment of a Uruguayan beach with similar characteristics of the beach studied in the present work, 3 zones were also observed based on the annual average abundance of each species. In the study, however, the occurrence of the talitrid amphipod *Pseudorchestoidea brasiliensis* was recorded in the supralittoral zone (BRAZEIRO; DEFEO, 1996). An earlier study on Cassino Beach reports the occurrence of this amphipod in the supralittoral zone (GIANUCA, 1983). As recorded for other amphipods in the estuary region of Patos Lagoon, this species presents an aggregated distribution, which is reflected in its absence from the sampling of the present study.

In winter, there was the formation of 4 biological zones: the supralittoral, where the Ghost Crab *Ocypode quadrata* occurred; the upper mesolittoral, characterized by *Euzonus furciferus* and, to a lesser degree, *Excirolana armata*; the mid mesolittoral, represented by the amphipod *Platyschnopidae*; and the lower mesolittoral together with the inner surf zone, inhabited by the tidal migrants *Donax hanleyanus* and *Mesodesma mactroides*.

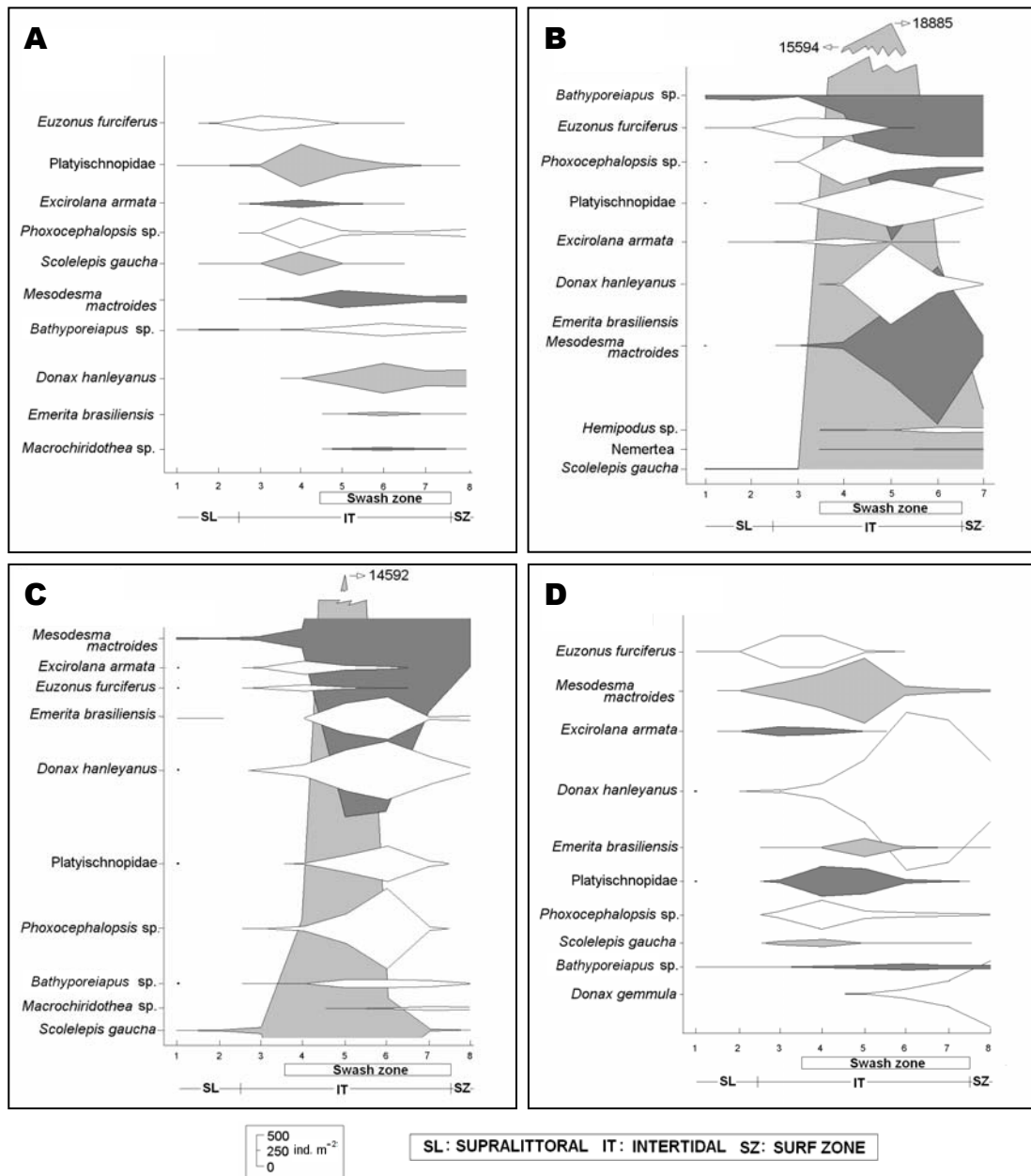


Fig. 5. Average densities per level of the organisms with greater densities during the seasons of the year. The letters A, B, C and D refer to winter, spring, summer and fall, respectively (June 2004 to May 2005).

The winter zonation pattern presented a division of the mesolittoral zone, similar to that found by James and Fairweather (1996). Raffaelli et al. (1991) concluded that up to 3 zones based on macrofauna assemblages could be identified within the

mesolittoral zone defined by Dahl (1952). The division of the mesolittoral zone was mainly due to the occurrence of the amphipod *Platyschnopidae*. The low temperatures of the season may determine the distribution of the amphipod in this zone. Charvat et

al. (1990) observed that amphipods were more important in the infralittoral than in the mesolittoral zone, suggesting that higher temperatures exclude amphipods from the upper parts of the beach.

Another factor that may have influenced the division of the mesolittoral zone was the low density of organisms found in winter, mainly stemming from the absence of recruitments. Even if meteorological factors are the main cause of variations in water level on the beach studied (CALLIARI; KLEIN, 1993), where winds from the south can raise the sea level by as much as 2 m (BARLETTA; CALLIARI, 2003), the greater frequency of southwestern winds, which reached as much as 16.1 m.s^{-1} in the 7 days prior to the sampling, did not cause a significant superimposing of organisms, probably due to the low density of benthic macrofauna in the period.

In spring, a 3-zone pattern was found, with the supralittoral composed basically of *Ocypode quadrata*, the upper mesolittoral dominated by *Euzonus furciferus* and the lower mesolittoral together with the inner surf zone characterized by amphipod *Bathyporeiapus* sp., polychaeta *Scolecopsis gaucha* and *Mesodesma mactroides*. The spring zonation pattern fits into Dahl proposal (1952), but, similar to what occurred in the upper mesolittoral in winter, the cirrolanid isopod zone was inhabited mostly by *Euzonus furciferus*. On a dissipative beach in Uruguay, Defeo et al. (1992a) observed that *Excirolana armata* and *Euzonus furciferus* were dominant organisms in the mesolittoral zone, the latter being responsible for 44% of the overall benthic macrofauna on the beach.

The high densities of *Bathyporeiapus* sp. and *Scolecopsis gaucha* in spring were probably the cause of the junction of levels located from the upper swash zone to the last level, located in the inner surf zone, thereby forming a single broad band that corresponded to the infralittoral zone of Dahl (1952).

On a beach in the state of Paraná (Brazil), *Bathyporeiapus ruffoi* was normally well represented in the lower zones of the beach, extending its distribution with high abundance into the infralittoral zone, especially in the spring months (BORZONE; SOUZA, 1997). In the present study area, the action of the south, southwest and southeast winds, which occurred in the 7 days prior to the sampling, reaching velocities of up to 24.6 m.s^{-1} , raised the sea level and should have collaborated to the increased density of *Bathyporeiapus* sp. in the mid mesolittoral zone. In this zone, the amphipod significantly superimposed its distribution with *Scolecopsis gaucha*, the latter of which a species that present greater density in the mesolittoral zone, with values reaching $100\,000 \text{ m}^{-2}$ in spring and early summer (SANTOS, 1991).

On flatter beaches, the lower zones can often be fused and divided (DEFEO; MCLACHLAN,

2005). In Chile, Jaramillo et al. (1993) observed that the lower zone of the beach was broader on most dissipative beaches in comparison to other types of beaches. Giménez and Yannicelli (1997) observed that seasonal changes in wind direction may cause a variation in the position of the swash zone, leading to the superimposing of species and broadening the lower zone of the beach. Furthermore, McLachlan (1990) verified that species inhabiting the lower zones of the beach can extend their distribution to the infralittoral zone, which may explain the greater amplitude of the lower zone of the beach.

A differentiated zonation pattern was found in summer, when up to 5 zones were identified: the supralittoral, composed of *Ocypode quadrata*; the upper mesolittoral, dominated by *Scolecopsis gaucha* and *Excirolana armata*; the mid mesolittoral, represented by *Scolecopsis gaucha* and *Mesodesma mactroides*; the lower mesolittoral, inhabited mostly by the tidal migrants *Mesodesma mactroides* and *Donax hanleyanus* together with *Bathyporeiapus* sp.; and the inner surf zone, characterized by *Mesodesma mactroides* and *Emerita brasiliensis* (Anomura, Hippidae).

The similarity between the groups that characterized the upper mesolittoral and inner surf zone was influenced by the low densities of benthic macrofauna at the two levels. A relevant factor for this similarity was the low density of *Euzonus furciferus* in the upper mesolittoral zone, a zone which was well characterized by this species in the other seasons of the year. In summer, *E. furciferus* presented greater abundance at a level below the upper mesolittoral zone, but even here its abundance was still not very high. The greater abundance at a lower level of the beach (mid mesolittoral) may be the result of a damper substrate, which would favor the survival of this species in summer, season when occur the higher incidence of sunlight and warmer temperatures.

During the summer months, a greater number of people visit Cassino Beach, with consequently greater vehicle traffic precisely in the zone where the polychaeta occur, which may have influenced the lower density of *Euzonus furciferus* for the period. Jaramillo et al. (1996) observed no evidence of human impact on the benthic macrofauna of a Chilean beach, but Gianuca (1983) pointed out that vehicles of all types, including trucks used by fishermen, affect the macrofauna of Cassino Beach.

Moreover, the low density of the inner surf zone reflects the turbulence of this zone, where hydrodynamic conditions are severe and cause instability in the substrate. In a study on Dutch beaches, Janssen and Mulder (2005) observed a low diversity of species together with lower abundance in the surf zone.

The possible segregation of the other two biological zones (mid and lower mesolittoral) was partially due to the greater occurrence of *Scolelepis gaucha* in the mid mesolittoral. Even with the superimposing of *Mesodesma mactroides* recruits in the lower part of this zone (the species has two recruitment periods – one between November and January, and another between February and April (DEFEO et al., 1992b), the low frequency of winds from the south, except the SE in December, may not have been sufficient enough to superimpose the species and thereby fuse these zones, as occurred in spring. Even with this separation, the 2 zones were not as distinct as the upper zones. McLachlan (1990) observed that the lower zones of the beach were less clearly defined than the upper levels, though the definition was still evident.

In general, we can compare the summer zonation pattern to that proposed by Salvat (1964). Thus, the supralittoral, upper mesolittoral, mid mesolittoral and lower mesolittoral respectively corresponded to the dry sand, retention, resurgence and saturation zones of Salvat (1964). The inner surf zone was much more evident in this season and was separated from the lower zones of the beach.

Similar to the summer zonation pattern found in the present study, Barros et al. (2001) and Borzone et al. (2003) observed that the resurgence zone was characterized by abundance peaks of *Scolelepis squamata*.

In fall, the 3-zone pattern repeated once again, with the supralittoral composed basically of *Ocypode quadrata*, the upper mesolittoral inhabited by *Euzonus furciferus* and *Mesodesma mactroides* and the final zone, including the lower mesolittoral and the inner surf zone, was largely characterized by *Donax hanleyanus*. This pattern can be related to that proposed by Dahl (1952), but it should be pointed out that the zonation scheme the author suggests is only based on crustacean distribution, whereas in the present study, other classes along with the Crustacea were found in the distinct zones of the beach in different seasons.

Euzonus furciferus once again characterized the upper mesolittoral in fall, significantly extending its distribution to a level below. This was especially due to the recruitment of the polychaeta, which occurred in this season. Kemp (1988) observed that *Euzonus mucronata* adults were restricted to the upper mesolittoral, whereas juveniles settled both within and below this zone. This can explain the significant expansion in the distribution of *Euzonus furciferus* at this time of year. Throughout the study, *E. furciferus* extended its distribution principally to Level 4, but this was only evident in fall, as a result of the recruitment of the species.

In the present study, the lower zone of the beach in fall encompassed nearly the entirety of the swash zone, and was inhabited largely by *Donax hanleyanus* recruits. Cardoso and Veloso (2003) found a similar result for a tropical beach, recording higher abundances of this species in winter and fall, when recruits were mainly found in the swash zone.

During the study, the levels 1 and 2 (supralittoral) were not considered in the multivariate analyses because there were many organisms originated from the stranding, i.e. organisms that were flung to these levels by storms, without the possibility of their returning to the lower parts of the beach, consequently interfering in the recognition of the zones. This phenomenon is commonly observed in sand beaches of Rio Grande do Sul, Uruguay and Argentina, where strong southern winds carry and deposit a large number of organisms on the upper parts of the beach (Ramírez et al., 2004).

In summary, zonation on Cassino Beach proved to be variable throughout the seasons of the year, however, based on the data for the entire year, the following general zonation pattern is suggested: the supralittoral, characterized by *Ocypode quadrata*; the upper mesolittoral, characterized by the polychaeta *Euzonus furciferus*; and a broad lower zone, more variable, including the lower mesolittoral and the inner surf zone, characterized by diverse species.

The two upper zones (supralittoral and upper mesolittoral) were more stable throughout the study period. Brazeiro and Defeo (1996) observed that the supralittoral was the zone that presented greater stability over time, which was corroborated in the present study. This stability was also recorded for the upper mesolittoral zone, principally due to the distribution and occurrence of *Euzonus furciferus*. Borzone et al. (1996) concluded that biological zones may be more evident in the presence of sedentary species than in the presence of migrant ones. *Euzonus furciferus* was found at depths greater than 10 cm in the sediment, which should have influenced the greater stability of this zone.

The greater variability of benthic macrofauna in the lower zone of the beach, which included the lower mesolittoral and the inner surf zone, was evident seasonally with the formation of distinct fauna groups according to the peculiarity of each season.

In winter, the formation of two groups in the lower zone of the beach was mainly due to the low density of organisms, reflecting the absence of recruitment. Even with the greater frequency of SW winds on the days preceding the sampling, with a consequent rise in sea level, the low density of benthic macrofauna may have impeded the significant superimposing of species, resulting in the formation of

two groups. In spring, the high density of individuals at the lower levels of the beach, together with strong winds that likely raised the sea level, caused the expressive superimposing of species resulting in the formation of a single large group.

In summer, recruitments and milder hydrodynamic conditions may have led to the formation of three groups in the lower zone of the beach. Even with the high densities of benthic macrofauna, the frequency of winds from south in the 7 days prior to sampling was probably not sufficient enough to cause the superimposing of species. In this season, the separation of the group corresponding to the inner surf zone became more evident as a result of greater densities in the swash zone, reflecting the recruitment of tidal migrants. In fall, there was once again the formation of a single group in the lower zone of the beach, reflecting the recruitment of one tidal migrant (*Donax hanleyanus*) in the swash zone.

In general, the spatial variability of the benthic macrofauna groupings in the lower zone of the beach during the distinct seasons of the year was strongly influenced by fluctuations in densities stemming from both recruitments and the migration of juvenile and adult infauna. Another factor that influenced the vertical distribution of benthic macrofauna was the superimposing of species distribution due to the rise in sea level during storms.

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