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Daily Variation of Macrobenthic Fauna on an Exposed Sandy Beach of Rio Grande do Sul, Brazil

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ABSTRACT

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This work aims to verify the daily zonation of benthic macrofauna in Harmonia beach, north coast of Rio Grande do Sul state, for five consecutive days. Biological data was collected with a PVC core (20 cm diameter) along three transects distant 50 m each other, with four levels and three samples in each level. First level was always 8 m above the superior limit of swash zone and the last one was 1 m depth. There were also daily data collection of beach topographical profiles, which indicated a pronounced erosion process in the fifth day. Benthic macrofauna organisms showed a regular pattern of zonation along all days, with intertidal zone marked by the presence of the isopod *Excirolana armata* and the polychaeta *Euzonus furciferus*. Swash zone was represented by a high abundance of the hippid crab *Emerita brasiliensi*s, the pelecypod *Donax hanleyanus* and the polychaeta *Scolelepsis gaucha*. Surf zone and breaker zone didn't show differences in species composition, being dominated by juvenile of *D. hanleyanus, Mesodesma mactroides*, the amphipode *Phoxocephalopsis zimmeri* and the polychaeta *Hemipodus olivieri*. Results indicated that benthic macrofauna zonation pattern was regular, although some changes in species position along the transect was observed, mainly due to swash zone variation.

ADDITIONAL INDEX WORDS: *Zonation pattern, beach macrofauna, beach profile.*

INTRODUCTION

The variation in distribution, composition and structure of benthic communities on sandy beaches has been related to changes in environmental parameters such as precipitation and temperature (LEBER, 1982), and morphodynamic parameters (MCLACHLAN, 1990, 1996; MCLACHLAN *et al.*, 1993; JARAMILLO *et al.*, 1993; MCLACHLAN and JARAMILLO, 1995). The geomorphology of a sandy beach is a result of action by factors such as wind, waves and tides, which when associated determine sediment granulometry (BROWN and MCLACHLAN, 1990). As a general rule, it can be said that the bigger the sediment grain, the steeper the beach profile (VILLWOCK, 1994), being biological diversity and abundance inversely proportional to grain size (MCLACHLAN, 1983).

Besides those aspects, biological factors also structure sandy-beach benthic communities. Such structuring is a result of features such as food availability and foraging activity, reproductive effects upon dispersion and settling, effects due to movement and aggregation, intra- and inter-specific competition, and predation effects (KNOX, 2000).

Those factors in association, especially passive selection by waves and localized food concentration, can lead the macrofauna to present such features as a pattern of zonation, and distribution as patches and fluctuations (MCLACHLAN and HESP, 1984). Patch scale may range from 10 m at reflexive beaches to 100 m at high-energy dissipative beaches (Bally, 1981).

BRAZEIRO and DEFEO (1996) found the existence of three zones between the dunes and the lowest levels of the swash zone at beaches on the Uruguayan coast. At Southern Brazilian sandy beaches, GIANUCA (1998) describes that the benthic macrofauna species vertical distribution follows a typical zonation pattern, with a supralittoral zone being only flooded during storm tides; a midlittoral zone that is constantly flooded by the tide; and a surf zone, extending from the lower limit of the swash zone to about 10 m of depth. This zone is divided in inner surf zone, between the beach and 2 m of depth, and outer surf zone (2 10 m), which is subject to strong current and wave action.

However, in a review of zonation patterns, MCLACHLAN and JARAMILLO (1995) emphasized that there is no relation between beach faunistic zones and mean or long-term tide levels. They conclude that the zones adjust on a daily basis to beach limits, defined by swash zone variation, and distinguish the existence of three zones as: 1- supralittoral; 2- littoral; and 3- sublittoral. Additionally, other authors such as RAFFAELLI *et al.* (1991) consider that except at the highest zones on the beach, it becomes hard to define biological zones on sandy beaches.

Studies have been conducted at the Southern region of Brazil about distribution, population dynamics, and secondary production of the benthic fauna species from sandy beaches (GIANUCA, 1983, 1985, 1987; BORZONE and GIANUCA, 1990; BORZONE, 1991; SOUZA and GIANUCA, 1995; BORZONE *et al.,* 1996). Still, due to a lack of knowledge about the daily variation of macrofauna distribution, the present work aims at verifying and comparing the macrofauna daily zonation pattern along 5 days and its relation to geomorphologic parameters.

STUDY AREA

Harmonia beach is located on the North shore of Rio Grande do Sul state (29 54´ 857 S and 05005´ 421 W), presenting along with Southern Brazilian (29°S) and Argentinean beaches (43° S) a gradient of the transitional faunistic composition from temperate-to-warm to temperate-to-cold, with the Prata River working as an effective ecological barrier (ESCOFET, *et al.*, 1979). This beach is characterized as exposed-dissipative with fine sand and low declivity (DEFEO *et al*., 1992), presenting a narrow dune strip (~15 m) and distance between those and the upper swash limit of about 40 m.

MATERIAL AND METHODS

Benthic macrofauna sampling was daily performed in the Autumn of 2003, between April 7th and the 11th. This season is marked by the incoming of cold fronts from the South, which cause storm tides on the coast of Rio Grande do Sul.

In order to characterize benthic macroinvertebrate zonation, three transects were chosen from the primary dunes, crossing the supralittoral, midlittoral, swash zone (still on midlittoral) and reaching about 1-m deep into the inner surf zone. The transects were located 50 m apart from one another.

Limits of supralittoral and the upper midlittoral level were registered and the presence of benthic macroinvertebrates in those levels was noted through organism and burrow observation and counting, as in the case of the crab *Ocypode quadrata*. For *O. quadrata* burrow density estimate, 12 1-m^2 squares were randomly positioned. From the lower midlittoral level on, four sampling stations were established, where macrozoobenthos quantitative samplings were performed, being three samples collected from each station. Station 1 was positioned 8 meters above the upper swash zone limit, based on measures performed at the time of sampling. Station 2 was always located within the swash zone. Station 3 was situated at the limit between the swash zone and the beginning of the inner surf zone, whereas Station 4 was positioned 1-m deep into the inner surf zone.

In order to determine the distance among all 4 quantitative sampling stations, a tapeline was used for measuring the distance between Station 1 (8 meters above the swash zone limit) and Station 4 (1-m deep). The intermediate stations were then positioned in an equitable fashion.

180 samples were collected by using a 20-cm-diameter (0.031 m^2) PVC extractor tube buried 20-cm deep. Biological samples were sieved in the field with a 0.5-mm-pore nylon screen. Retained material was fixed in 10% formalin.

At the laboratory, organism screening was conducted from the sediment as well as their identification to the least possible taxon, with the help of stereoscopic microscopes. Then, the benthic macroinvertebrates were quantified and their densities extrapolated to number of individuals per m^2.

Topographical profiles were traced on a daily basis, perpendicularly to the beach with the use of a topographic level and geologist's compass according to method by BIRKEMEIER (1981). The obtained data were ploted on Cartesian plans for beach behavior (declivity) verification along the 5 days. The beach was characterized on a daily basis according to 3 stages: dissipative, intermediate (longshore bar and trough) and intermediate (rhythmic bar and beach) (SHORT and WRIGHT, 1984).

Sediment samples were collected (on the second-to-last day) from the 3 profiles, with the use of a PVC tube (with 20-cm diameter) at each beach level, totaling 12 samples. Granulometry analysis was performed by passing dry sediment through a different-sized sieve sequence and the later weighing of the fraction retained by each sieve size. The weighed sediment fractions as well as the calculated simple frequencies were analyzed through the software SysGran 2.4, producing sediment classification (FOLK and WARD, 1957), mean grain size and composition data.

In order to finish obtaining the data, wind speed (anemometer), wave period and height (visual observations), water and air temperature (thermometer), and salinity (refractometer) data were collected every day.

Biological data were analyzed with the software PRIMER 5.0 (Plymouth Routines In Multivariate Ecological Research). A data matrix was created by using the number of individuals belonging to each species per sample. The similarity between samples (Q mode) was estimated by the Bray-Curtis index with a square root transformation of the original abundances. First, profile differences on each day were tested through similarity analysis (ANOSIM); as the profiles presented no significant differences on each day, they were combined. The next step was testing if there were differences between the zones within each day (ANOSIM and MDS Multi-Dimensional scaling). Differences between zones reflect the existence of a marked zonation pattern. Then, temporal variation was tested for each zone (ANOSIM), with the sequential selection of each one and their analysis for each day. In order to verify the contribution of each species in each zone and their contribution for differences among zones and days, similarity percentage analysis was used (SIMPER).

RESULTS

The environmental data show that the present work was conducted at a period between two storm phenomena, the first one ending on the first sampling day and the second beginning on the fourth sampling day. This phenomenon was confirmed by the observation of brownish spots of the diatom *Asterionellopsis glacialis* from the surf to the swash zone. Qualitative observations were also conducted of the presence of the Five-slotted Sand Dollar *Mellita quinquiesperforata,* a sublittoral species, at the swash zone.

Due to such meteorological tides, the upper limit of swash varied temporally, occupying the following distances from the dunes: 1st day- 31m; 2nd day- 41m; 3rd day- 43m; 4th day- 40m and 5th day- 37m. The distance between Station 1 and Station 4 (at 1m of depth) also changed due to the storm, presenting the following distances along the 5 days: 1st day- 54m; 2nd day- 54m; 3rd day- 63m; 4th day- 48m and 5th day- 45m.

The mean wind speed varied from 6 m/s SW on the first day, with a mean wave height of 2.5 m and period of 14 s. On the third day, the wind speed was 3 m/s NE, wave height 1.5 m and period 12.5 s. On the last day, wind speed reached 9 m/s W, with 2 m of wave height and period of 8.5 s. Salinity presented values around 31 and water temperature ranged from 19 to 25º C.

The topographic profiles presented stages of the dissipative kind on the first 3 days and longshore bar and trough, with a tendency to rhythmic bar and beach on the last 2 days (Figure 1).

Sediment granulometric analysis showed that all beach Stations presented a fine-sand composition (Phi ranged from 2 to 2.5).

The mean concentrations of burrows of the crab *Ocypode quadrata* ranged from 0.4 to 1.5 burrows/m^2 along the days. On the first day, burrows were only found by the dune's bottom, about 31 m from the maximum reach of the swash; on the second day, the burrows got scattered and distributed up to 28 m from the dune's bottom, reaching 39 m from the dune's bottom and 1 m from the maximum limit of the swash on the second-to-last day. On the last day, a narrowing occurred on the burrow distribution, reaching only 19 m from the dune's bottom.

The benthic macrofauna presented a marked zonation pattern on the first and second days (Figure 2 and Table 1), when all stations presented significant differences (ANOSIM; $R>0.5$; $p<0.05$), except stations 3 and 4. On the third, fourth and fifth days, only Station 1 presented a significant difference from the others ($R>0.5$; $p<0.05$). Each day, Stations 2 and 3, which represented the swash zone, showed the highest total abundance values, except on day 3 (Table 2). The number of species and diversity (Shannon index) were, in general, always higher at lower stations, comparing to Station 1.

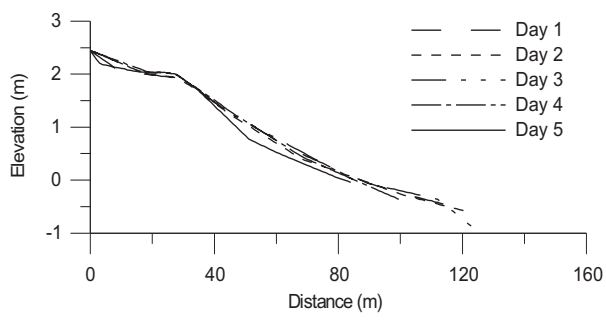

Figure 1. Harmonia beach profiles along the 5 days of study.

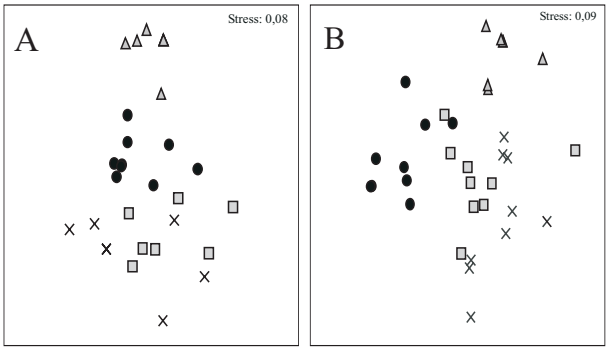

Figure 2. MDS showing zonation pattern on days 1 (A) and 2 (B). Triangles = station 1; circles = station 2; square = station 3 and cross = station 4.

The species that most characterized Station 1 everyday was the isopod *Excirolana armata* (SIMPER; contribution > 80%) and, to a lesser degree, but only for the fourth day, the polychaete *Euzonus furciferus* (17% contribution). Station 2 was marked by the daily presence of the hippid crab *Emerita brasiliensis*, the tidal migratory pelecipod *Donax hanleyanus* and the polychaete *Scolelepis gaucha*. On the second and fourth days, the polychaete *Scolelepis gaucha* had a high contribution (> 50%) at this station, and on days 3 and 4, juveniles of the white clam *Mesodesma mactroides* contributed with about 15%. On the last day, the polychaete *Euzonus furciferus* contributed with 23% of the composition at Station 2. At Station 3, a high percent contribution is observed of juveniles of the clam *Mesodesma mactroides* (>30%) everyday, except on the first day, when juveniles of *D. hanleyanus* (41%) and the polychaetes *Hemipodus olivieri* (35%) and *Scolelepis gaucha* (19%) dominated, besides the presence of *E. brasiliensis*. On the second and fifth days, along with *M. mactroides*, there was dominance of *D. hanleyanus* (42%). On the third and fourth days, there was also a significant contribution (16%) of the amphipod *Phoxocephalopsis zimmeri*. Station 4, which did not present significant difference from Station 3 (ANOSIM; R<0.5) on any day, was dominated by *D. hanleyanus* (42%) on the first day, and besides this species, the second day presented a high dominance of the amphipod *Phoxocephalopsis zimmeri* (40%) and the polychaete *Hemipodus olivieri* (15%). On days 3, 4, and 5, juveniles of *Mesodesma mactroides* dominated this station, contributing with more than 50% of the species abundance present at that region of the beach.

DISCUSSIONS

The faunal zones of Harmonia beach were identified by the present work and can be compared to the general scheme proposed by DAHL (1952). He identifies a sub-terrestrial zone, characterized by the presence of crabs of the genus Ocypode at tropical regions; a mid-littoral zone composed by cirolanid isopods and a sublittoral fringe characterized by a faunistic mix of hippid crabs, at tropical regions and haustoriid amphipods and others at temperate regions. Other authors, such as BRAZEIRO and DEFEO (1996), have identified the same scheme on beaches on the Uruguayan coast during a one-year study.

Some studies about beach benthic communities show that species richness, density and biomass are inversely proportional to sediment grain size and beach steepness (MCLACHLAN *et al*., 1993; DEFEO *et al.*, 1992). In the present work, the homogeneity of the sediment at the 4 sampling stations prevented this parameter to be related to community abundance, density or richness. Only on the last day, due to storm-caused erosion, it could be observed that the beach steepness had increased and the distance between the first and the last (1-m deep) macrofauna sampling stations had decreased. Such fact may account for the decrease in density of the clam *Mesodesma mactroides* and of *Donax gemmula* at Station 4 and the decrease in density of *Emerita brasiliensis* at Station 2 (swash) and their disappearance at the other stations.

Table 1. *List of macrofaunadominant species (80% of total species) occurrence per station per day.*

	1				2				3				4				5			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Excirolana armata	■	■				■	■			■							■	■	■	
Euzonus furciferus	■	■															■			
Mesodesma mactroides			■	■														■	■	■
Emerita brasiliensis	■	■	■	■																
Donax gemmula	■	■	■	■		■	■	■		■	■									
Donax hanleyanus	■	■	■			■	■							■	■	■		■	■	■
Hemipodus olivieri		■					■	■				■		■		■		■		■
Sigalion cirriferum			■	■		■	■	■		■	■	■								
Scolelepis gaucha	■	■	■			■	■			■	■			■	■	■		■	■	
Phoxocephalopsis zimmeri			■	■			■	■			■	■		■	■	■				■
Albunea paretii			■	■																
Mellita quinquiesperforata					■					■										■
Pitar rostratum						■								■						
Buccinanops duartei												■								
Olivancillaria auricularia																■				

The presence of the crab *Ocypode quadrata* at the supralittoral was only influenced by storms, being its distribution conditioned to the regions between the dunes and the maximum limit of the swash.

In spite of the existence of a general zonation pattern, some species varied along the days, mainly due to the variation of the swash zone caused by the meteorological tides. According to MCLACHLAN and JARAMILLO (1995), beach zones adjust each day to the swash limits. This can be seen for some migratory organisms, which present constant movement as they search for food and escape predation, as some species of the genus *Emerita* and *Donax* (ANSELL and TRUEMAN, 1973; BRAZEIRO and DEFEO, 1996). Still, low-moving or sedentary species may not follow the daily variations of the swash zone. It is observed on the first day of the present work that the polychaete *Euzonus furciferus* occurred at Station 2 (swash) and did not occur at Station 1; on the other hand, on the second, third and fourth days (lower tide), this species occurred at Station 1 and did not occur at Station 2. Such fact showed that this species did not migrate along with the swash variation, and presented a fixed strip on the beach, which is probably only altered during long periods of high or low tide. On the last day, this species reappeared at Station 2, as the limit of the swash had increased as a function of the storm.

Tide level variations must be considered as important describers of midlittoral gradients, as they influence the form and intensity of the patchy distribution as well as the relative position of the fauna on the beach zones (BRAZEIRO and DEFEO, 1996). On Harmonia beach, it was observed that the storm-caused swash zone variation is one of the main factors determining fauna distribution along the beach zones. The lower zones (sublittoral) are hard to define (RAFFAELLI *et al.*, 1991) due to greater hydrodynamics, especially during storm periods.

The present work shows that there is a daily adjustment of the fauna as a function of swash level variations. Some species are more rigid to such changes than others. In spite of the present work having been conducted during such a short period of time, it shows that the daily macrofauna variation is important for community structuring and that it shows peculiarities that long-term, monthly-sampling studies do not capture. It would be interesting to conduct new work with this same sampling scheme, though distributed along the seasons of the year.

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Table 2. *Community parameters. Number of species, total abundance and Shannon diversity (H') per station per day.*

	1				2				3				4				5			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
# species	2	5	8	7	4	4	10	7	4	6	7	6	4	7	4	7	4	6	5	6
Abund.	53,8	372,8	136,2	89,6	304,7	1931,9	358,4	100,4	272,4	279,6	261,7	272,4	136,2	365,6	878,1	139,8	157,0	322,6	218,6	157,7
H'	0,24	0,97	1,88	1,55	0,36	0,31	1,53	1,73	0,40	1,15	1,36	1,07	0,90	1,20	0,78	1,43	0,67	1,23	1,26	1,38

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