Abundance and diversity of the sublittoral meiofauna on two sand beaches under different hydrodynamic conditions at Ilha do Mel (PR, Brazil)

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Abstract
The meiofaunal community of two hydrodynamically different sand beaches was studied at Ilha do Mel, Paraná state (25°29’ S and 48°17’ W), Brazil. The sediment at a sheltered site and at a site exposed to open ocean was dominated mainly by fine sand. At the sheltered site the sediment was less sorted, with some clay, silt and organic matter. Sea water salinity and temperature did not differ between the two sites. Total meiofauna and Nematoda densities were greater at the exposed site. The high vertical migratory capacity of Nematoda in comparison with other meiofaunal taxa, and the almost complete absence of other interstitial meiofaunal groups could explain this pattern. High resistance to environmental impacts (i.e. turbidity) could be another possible explanation for the high Nematoda densities at the exposed site. On this basis, the low Nematoda/Copepoda ratio at the sheltered site could be an indication of moderate hydrodynamic stress at this place, since Copepoda are more sensitive to environmental disturbances than Nematoda. Copepoda densities, Shannon diversity (log 2), and evenness indices were higher at the more eutrophic (sheltered) site. Cluster analysis showed that replicated samples were more similar within each site (sheltered or exposed) than between them (sheltered x exposed), thus illustrating a possible response of meiofaunal taxa to environmental differences imposed by different hydrodynamic regimes.

Keywords: Meiofauna, sublittoral, Paranaguá Bay, hydrodynamic impact.

Introduction
Patterns of meiofaunal distribution depend on physical and chemical environmental conditions such as temperature, salinity, desiccation, mean grain size of sediment and biotic interactions, such as competition and predation (Coull & Bell, 1979; Bell, 1980). For a long time, granulometric properties have been considered to be the more important variable that structure the distribution of benthic organisms (i.e. Ford, 1923; Davis, 1925 apud Snelgrove & Butman, 1994).

Besides grain size, the importance of factors related to infaunal species distribution should also be considered, such as the water bottom currents, which deposit fines particles (silt and organic matter) on the sediment, and cause the proliferation and deposition of algae sources and microbial flora (Snelgrove & Butman, 1994).

It has been shown that natural episodic events such as the action of currents and waves may cause a range of responses in macrobenthic populations and communities inhabiting intertidal soft sediments (Schoeman et al., 2000) and probably shallow sublittoral areas. The severity of impact is apparently related to the scale and duration of the event (Bender et al., 1984), the nature of its periodicity (cyclic or stochastic), the characteristics of the environment and the initial community structure (Saloman & Naughton, 1977; Santos & Simon, 1980; Jamarillo et al., 1987; Dos Santos, 1991).

It is common belief that the meiofauna is closely associated with, and responsive to, environmental change, due to its high abundance and diversity, short life cycle with only a benthic phase (permanent meiofauna only), a relatively low dispersal capacity (being frequently resuspended by hydrodynamic forces (i.e. Palmer & Brandt, 1981), and a close affinity for sediments (by living under or above them) (Coull & Chandler, 1992). Despite the great abundance and ubiquitous presence of meiofauna in marine sediments, factors that control the distribution and abundance of meiofaunal taxa are poorly known. In Brazil, until the 1970 decade, reports on the meiofauna were centred basically on taxonomic descriptions (Lana et al., 1996). The last decade, however, has shown an important increase in the information about the meiofauna ecology (i.e. Souza et al., 1993; Corbisier et al., 1997 [Flamengo Inlet, Ubatuba, SP, Brazil]; Netto et al., 1999a, b [macro and meiofauna at Rocas Atoll, RN, Brazil]; Dalto & Albuquerque, 2000 [Jacuacanga’s Bay, RJ, Brazil]; Ozorio, 2001 [Lagoa dos Patos, RS, Brazil] and Corgosinho, 2002).
In this study, we compared meiofauna communities at the level of less inclusive taxonomic subdivisions (i.e. Nematoda, Copepoda, and Tardigrada), at two sites with distinct physical characteristics (waves and currents) in order to test for differences in community composition, abundance and diversity between them.

**Material and Methods**

**Study area**

The study area is located at Ilha do Mel (25°29’ S and 48°17’ W), Paraná, southeast Brazil (Fig. 1). Samples were collected in March 2001 (summer) in the sublittoral zone of two hydrodynamically different beaches.

In this area, a typical rainy season initiates in late spring and lasts during most of the summer while the dry season lasts from late autumn to late winter but is usually interrupted by a short and weak rainy period in early winter (Lana et al., 2000). The mean precipitation during the rainy season is more than three times higher than that during the dry season (Lana et al., 2000). The hydrodynamics are driven by tidal forces and river runoff (Knoppers et al., 1987; Brandini et al., 1988; Rebello & Brandini 1990; Machado et al., 2000 apud Lana et al., 2000). Waves, mainly from the southeast, are only important in the bay mouth and tides are semi-diurnal with diurnal inequalities, being amplified towards the head of the bay (Lana et al., 2000). Seasonal variation of freshwater input corresponds to about 30% of the mean annual values during the dry period (May/October) and to 170% during the rainy period (November/April) (Lana et al., 2000).

The physical, chemical, and biological properties at Paranaguá bay are controlled mainly by tidal fluctuations, waves and seasonal input of continental drainage (Lana et al., 2000). Spatial variability of these properties occurs mainly due to environmental energetic gradients maintained by transport and remobilization of sediments, by mixture of fresh and salt water and by current dynamics, winds and waves (Lana et al., 2000). The sheltered site located at “Saco do Limoer” (bay side of Ilha do Mel) is characterised by low exposure to waves. The exposed site, called “Enseada das Conchas” (open ocean side of Ilha do Mel, hereafter called “exposed site”), is characterised by high wave exposure.

**Sampling**

At each site 10 corers (35.34 cm³ for each sample) for analysis of the meiofauna were randomly sampled along an area of approximately 5 m² and 1.50 m depth. Three samples were collected for analysis of chlorophyll a and pheopigments (3.14 cm³ for each sample) at each sampling site. The bottom water salinity and temperature were measured using a manual refractometer and a thermometer, respectively. Both data were obtained by a single measurement. For analysis of organic matter and granulometric patterns, a single 70.68 cm³ sediment sample was collected at each site.

Chlorophyll a analysis was performed by the method of Parsons et al. (1984). The granulometric analysis of the sediment collected was carried out using the routine sieving and pipetting techniques described by Suguio (1973) (mesh size of 0.5 φ). The statistical parameters were obtained using the formulations of the Moments Method (Tanner, 1995) and the results were expressed as φ values (φ = -Log diameter in mm). Organic matter was measured by the method of Dean (1974). The hydrodynamic conditions of the sites studied were inferred from the contribution of the different classes of sediment and by kurtosis and selection. In the laboratory, the meiofauna samples were fixed with 4% formol, stained with Bengal Rose and centrifuged and washed through a 40 mm mesh sieve. Biological samples were analysed under light and stereoscopic microscopes. Taxa were quantified and identified at the level of major taxonomic groups.

**Data Analysis**

Total and individual (between different taxa) meiofauna abundance was compared between the two sites with Student’s t test. Only the more abundant groups were considered in this analysis. Shannon diversity (log2) and evenness indices were calculated for each replicated sample. The same procedure was applied for the calculation of the Nematoda/Copepoda ratio. Diversity indices and Nematoda/Copepoda ratio were compared by Student’s t test between the two environments. Classification of the 10 randomly replicated samples at each site was obtained by Cluster analysis using the WPGMA (Weighted pair group median) as an amalgamation method. Abundance data were log10 transformed, and the Bray-Curtis dissimilarity index was used to construct the dissimilarity matrix.

**Results**

**Sediment characteristics and chlorophyll values**

The two sites were primarily composed of sand (90%), with fine sand predominating at both locations. Silt was only present at the sheltered site (Tab. 1). The sheltered site was also
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### Table 1 – Values of sediment physico-chemical and biological properties for the sampled sites. VCS= Very coarse sand; CS= Coarse sand; MS= Medium sand; FS= Fine sand; VFS= Very fine sand; OM= Organic mater; Chl= Chlorophyll; Php= Pheopigment; S (°/oo) = Salinity (parts per thousand); T°C= Temperature (centigrade degrees); X ± SE = Mean ± Standard Error.

<table>
<thead>
<tr>
<th></th>
<th>VCS</th>
<th>CS</th>
<th>MS</th>
<th>FS</th>
<th>VFS</th>
<th>Silt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed</td>
<td>0.49</td>
<td>0.58</td>
<td>4.15</td>
<td>37.05</td>
<td>3.83</td>
<td>3.50</td>
</tr>
<tr>
<td>Sheltered</td>
<td>0.00</td>
<td>0.00</td>
<td>0.62</td>
<td>42.62</td>
<td>6.76</td>
<td>0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Clay</th>
<th>OM</th>
<th>S (°/oo)</th>
<th>T°C</th>
<th>Chl (X±SE)</th>
<th>Php (X±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed</td>
<td>0.25</td>
<td>1.68</td>
<td>31.00</td>
<td>28.00</td>
<td>0.21 ± 0.20</td>
<td>0.55 ± 0.96</td>
</tr>
<tr>
<td>Sheltered</td>
<td>0.00</td>
<td>0.51</td>
<td>31.00</td>
<td>28.00</td>
<td>5.02 ± 1.91</td>
<td>1.93 ± 0.84</td>
</tr>
</tbody>
</table>

### Table 2 – Statistical granulometric properties (moment measure method) for the different studied sites. FS = Fine sand; PS = Poor sorted; VWS = Very well sorted; LPT = Leptokurtic; ELPT = Extremely leptokurtic.

<table>
<thead>
<tr>
<th></th>
<th>PSA</th>
<th>Classification</th>
<th>Selection</th>
<th>Kurtosis</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed</td>
<td>2.73</td>
<td>FS</td>
<td>0.29</td>
<td>5.10</td>
<td>LPT</td>
</tr>
<tr>
<td>Sheltered</td>
<td>2.70</td>
<td>FS</td>
<td>1.18</td>
<td>11.36</td>
<td>ELPT</td>
</tr>
</tbody>
</table>

### Table 3 – Mean density of organisms/10cm² at the different sampled sites. X ± SE = Mean ± Standard Error.

<table>
<thead>
<tr>
<th></th>
<th>Nematoda</th>
<th>Gastrotricha</th>
<th>Polychaeta</th>
<th>Oligochaeta</th>
<th>Copepoda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed</td>
<td>550.18±422.73</td>
<td>0.71±1.49</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>26.50±18.34</td>
</tr>
<tr>
<td>Sheltered</td>
<td>210.60±104.17</td>
<td>1.06±11.02</td>
<td>1.77±3.43</td>
<td>13.43±11.02</td>
<td>85.16±58.99</td>
</tr>
</tbody>
</table>

### Table 4 – Student’s t test for the more representative taxa collected at the exposed and sheltered environment. Values Log₁₀ transformed. X ± SE = Mean ± Standard Error; DF = Degrees of Freedom; p = probability; N/C = Nematoda/Copepoda relation.

<table>
<thead>
<tr>
<th></th>
<th>Exposed</th>
<th>Sheltered</th>
<th>DF</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nematoda</td>
<td>2.09 ± 0.09</td>
<td>1.71 ± 0.09</td>
<td>18</td>
<td>-2.97</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Copepoda</td>
<td>0.79 ± 0.09</td>
<td>1.23 ± 0.14</td>
<td>18</td>
<td>2.61</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Total abundance</td>
<td>2.12 ± 0.08</td>
<td>1.89 ± 0.08</td>
<td>18</td>
<td>-1.97</td>
<td>&gt; 0.05</td>
</tr>
<tr>
<td>N/C relation</td>
<td>17.23 ± 9.49</td>
<td>48.69 ± 10.00</td>
<td>18</td>
<td>-2.28</td>
<td>&lt; 0.05</td>
</tr>
</tbody>
</table>

### Table 5 – Student’s t test for diversity and evenness indices. X ± SE = Mean ± Standard Error; DF = Degrees of Freedom; p = probability.

<table>
<thead>
<tr>
<th></th>
<th>Exposed</th>
<th>Sheltered</th>
<th>DF</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity</td>
<td>0.10 ± 0.06</td>
<td>0.32 ± 0.05</td>
<td>18</td>
<td>-8.01</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Evenness</td>
<td>0.32 ± 0.20</td>
<td>0.62 ± 0.18</td>
<td>18</td>
<td>-3.49</td>
<td>&lt; 0.05</td>
</tr>
</tbody>
</table>
more eutrophic than the exposed one, showing three times more organic matter than the exposed site and higher concentrations of chlorophyll-a and pheopigments (Tab. 1). The sediment at the sheltered site was poorly sorted and its distribution extremely leptokurtic, in contrast to the exposed site, where it was very well sorted and showed a leptokurtic distribution (Tab. 2).

Mean chlorophyll a and pheopigment values for the samples were 24 and 3.5 times higher, respectively, at the sheltered site than at the exposed one (Tab. 1).

**Meiofauna composition and abundance**

Nematoda and Copepoda was the dominant fauna (Tab. 2). Total abundance was similar between the studied sites (Tab. 3). However, Copepoda were more frequent at the sheltered site ($t_{18} = 2.61; p<0.05$), and Nematoda at the exposed one ($t_{18} = 2.95; p<0.05$).

The Nematoda/Copepoda ratio obtained was significantly higher at the sheltered site (Tab. 3). Diversity ($t_{18} = 8.01; p<0.05$) and evenness ($t_{18} = 3.49; p<0.05$) were also higher at the sheltered site (Tab. 4).

The cluster analysis indicated that the sites differed according to wave exposure. Two major “clusters” occurred with a dissimilarity of 36% (Bray Curtis dissimilarity index, log 10) (Fig. 2).

**Discussion**

In this study, we verified slight differences in the statistical granulometric properties between the two sites (Tab. 2). In our opinion, these small differences are mainly due to hydrodynamic differences between the two environments studied, since the exposed site suffers a continuous sediment reworking by waves, while the hydrodynamic impact at the sheltered site is mainly due to current forces that probably act only at ebb and flow tide.

Some studies have demonstrated that macroinfauna (e.g., amphipods), epifauna, and meiofauna are subject to sediment reworking by tidal currents and may react to tidal phenomena (Perkins, 1958; Vader, 1964; Boaden, 1968; McLachlan et al., 1977a; Grant, 1980), possibly responding negatively (with a decrease in diversity) when disturbances occur at frequency (i.e. due to constant wave action). Corroborating this idea, at Rocas Atoll (Northeast Brazil) by Netto et al. (1999b). These investigators correlated their findings with the structural complexity of the habitats, the increase of sediment stability and the fact that those sites acted as shelters from predation and as a place where organic matter accumulated more in comparison with exposed areas. In agreement with Netto et al. (1999b), we also think that sediment stability acts as a very important variable in controlling meiofaunal diversity and abundance at the studied sites.

**Acknowledgements**

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References


