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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 (25º29' 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).

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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 (25º29' 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 Limoeiro" (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 cm^3 for each sample) for analysis of the meiofauna were randomly sampled along an area of approximately 5 m^2 and 1.50 m depth. Three samples were collected for analysis of chlorophyll *a* and pheopigments (3.14 cm^3 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 cm^3 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

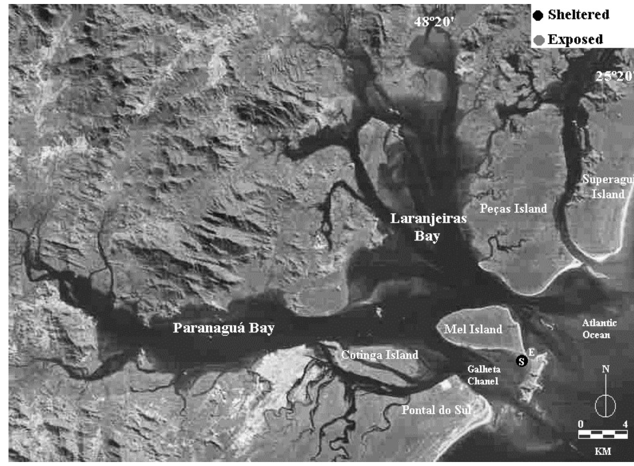

Figure 1 – General location of the studied area at Ilha do Mel, Paraná, BR. Sheltered site = Black dot located at the bay side of Ilha do Mel; Exposed= Gray dot located at the ocean side of Ilha do Mel.

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_2 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 trough 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

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 ($^{o}/_{oo}$) = Salinity (parts per thousand); T°C= Temperature (centigrade degrees); X ± SE = Mean ± Standard Error.

	VCS	CS	MS	FS	VFS	Silt
Exposed	0.49	0.58	4.15	37.05	3.83	3.50
Sheltered	0.00	0.00	0.62	42.62	6.76	0.00
	Clay	**OM**	**S ($^{o}/_{oo}$)**	**TºC**	**Chl (X±SE)**	**Php (X±SE)**
Exposed	0.25	1.68	31.00	28.00	0.21 ± 0.20	0.55 ± 0.96
Sheltered	0.00	0.51	31.00	28.00	5.02 ± 1.91	1.93 ± 0.84

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.

	PSA	Classification	Selection	Classification	Kurtosis	Classification
Exposed	2.73	FS	0.29	VWS	5.10	LPT
Sheltered	2.70	FS	1.18	PS	11.36	ELPT

Table 3 – Mean density of organisms/10cm^2 at the different sampled sites. X ± SE = Mean ± Standard Error.

	Nematoda	Gastrotricha	Polychaeta	Oligochaeta	Copepoda
Exposed	550,18±422,73	0,71±1,49	0,00±0,00	0,00±0,00	26,50±18,34
Sheltered	210,60±104,17	1,06±11,02	1,77±3,43	13,43±11,02	85,16±58,99

Table 4 – Student's *t* test for the more representative *taxa* collected at the exposed and sheltered environment. Values Log_{10} transformed. X ± SE = Mean ± Standard Error; DF = Degrees of Freedom; p = probability; N/C = Nematoda/Copepoda relation.

	Exposed	Sheltered	DF	t	p
Nematoda	2.09 ± 0.09	1.71 ± 0.09	18	-2.97	< 0.05
Copepoda	0.79 ± 0.09	1.23 ± 0.14	18	2.61	< 0.05
Total abundance	2.12 ± 0.08	1.89 ± 0.08	18	-1.97	> 0.05
N/C relation	17.23 ± 9.49	48.69 ± 10.00	18	-2.28	< 0.05

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

	Exposed	Sheltered	DF	t	P
Diversity	0.10 ± 0.06	0.32 ± 0.05	18	-8.01	< 0.05
Evenness	0.32 ± 0.20	0.62 ± 0.18	18	-3.49	< 0.05

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).

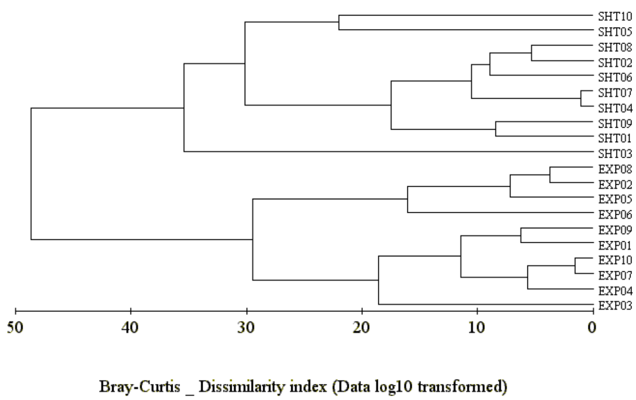

Figure-2 – Cluster diagram between replicated samples of the sheltered and exposed areas. SHT= Sheltered; EXP= Exposed.

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, Netto et al. (1999 *b*) found that both meiofauna and macrofauna were clearly affected by local sediment instability, showing low abundance and richness in tidal flats where hydrodynamic impacts were more severe than at deeper sublittoral sites.

Thus, the high incidence of Copepoda Harpacticoida at the sheltered site may be related to sediment stability, the granulometric characteristics of this environment (less selected sediment and consequently a greater variety of microhabitats) and the high concentration of organic matter and microalgae (not measured) induced by the relatively low hydrodynamic forces at this place. Many studies all over the world have correlated the high incidence and diversity of meiofaunal taxa with the quantity of organic mater in the sediment (i.e. McIntyre, 1961; Tietjen, 1971; McLachlan et al., 1977b; Amjad & Gray, 1983; Gómez Noguera & Hendrickx, 1997; Coull, 1999; Soltwedel, 2000). In Brazil similar results were obtained by Souza et al., (1993), Corbisier et al., (1997), Netto et al., (1999a), and Corgosinho (2002).

At the exposed site, the Nematoda/Copepoda ratio (Rafaelli & Mason, 1981) was higher, possibly reflecting the negative impact imposed by the action of the waves on the exposed sediment. Thus, an alternative explanation for the low density of Copepoda at the exposed site is the higher sensitivity of these taxa to environmental stresses compared to Nematoda (Coull et al., 1981), in view of their high mobility due to suspension in the overlying water by currents or following any process that disturbs the sediment (Palmer & Brandt, 1981). Thus, they disappear or diminish in numbers and species at sites with less environmental stability, such as the exposed site in this study.

Nematoda are more abundant in places where sediments rich in silt, clay, and organic matter dominate (Rafaelli & Mason, 1981; Heip et al., 1985). However, these organisms were more abundant at the exposed site, where their interstitial habit and high vertical migratory capacity may favour their presence (Heip et al., 1985; Warwick & Gee, 1984; Kennish, 1990). Another explanation for their abundance at the exposed site is the lack of other interstitial meiofaunal taxa, which could compete for local resources. We found higher diversity and evenness values at the sheltered site. A similar pattern was observed at sheltered sites ("sediment inflow zone") 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. (1994b), we also think that sediment stability acts as a very important variable in controlling meiofauna diversity and abundance at the studied sites.

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