

Meiofauna in the soft-bottom habitats of the Patos Lagoon estuary (south Brazil).

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ABSTRACT: Meiofauna in the soft-bottom habitats of the Patos Lagoon Estuary (south Brazil). This study aims to compare the composition and the density of the meiofauna among three soft-bottom habitats over an emersion gradient during a prolonged tidal exposure period (summer 2000). The selected habitats were (1) a *Spartina alterniflora*-marsh, (2) an intertidal mudflat (both exposed at ca. 25 days), and (3) a subtidal bottom. The meiofauna composition was similar among habitats, where nematodes, ostracods and harpacticoid copepods were the organisms numerically dominant. Mean meiofaunal density ranged from 2,908 to 896 individuals 10cm². The higher densities values were achieved at subtidal bottom and significantly decrease in salt marsh direction. The meiofauna density was negatively correlated with increase of fine fractions and organic matter content as well as decrease of grain size, sorting and pH values of sediment. The presence of marsh roots and the prolonged tidal exposure time also contributed for observed differences.

Key-words: meiofauna, soft-bottom, salt-marsh, controlling factors, Patos Lagoon Estuary.

RESUMO: Meiofauna nos planos inconsolidados do estuário da Lagoa dos Patos (sul do Brasil). A composição e a densidade da meiofauna foram comparadas entre três ambientes de fundos inconsolidados ao longo de gradiente de emersão durante um período de prolongada exposição mareal (verão de 2000). Os ambientes selecionados foram: (1) uma marisma dominada por *Spartina alterniflora*, (2) um plano de lama intermareal (ambos emersos por 25 dias) e (3) um plano sublitoral. A composição da meiofauna foi similar entre os ambientes, onde nematódeos, ostrácodos e copépodes harpacticóides foram os organismos numericamente dominantes. A densidade da meiofauna variou entre 2.908 e 896 indivíduos 10cm². Os maiores valores de densidade foram obtidos no plano sublitoral e diminuíram significativamente em direção a marisma. A redução na densidade foi negativamente correlacionada com o aumento das frações finas do sedimento e do teor de matéria orgânica, bem como com a redução do tamanho do grão, do grau de seleção e do pH do sedimento. A presença das raízes da marisma e o prolongado período de exposição também contribuíram para as diferenças observadas.

Palavras-chave: meiofauna, fundos inconsolidados; marisma; fatores controladores; Lagoa dos Patos.

Introduction

Meiofauna is defined as benthic metazoans passing a 500µm sieve but retained on meshes of 42µm (Higgins & Thiel, 1988). In estuarine sediments, meiofauna facilitates biomineralization of organic matter and enhances nutrient regeneration, serves as food for a variety of higher trophic levels, and exhibit high sensitivity to anthropogenic inputs, making them excellent sentinels of estuarine pollution (Coull, 1999).

Distribution and abundance of the meiofauna are mainly controlled by physical-chemical factors such as grain size, potential redox and tidal exposure (Alongi, 1987; Coull, 1988). However, the presence of the biogenic structure (e.g., animal tubes or

burrow, system root) may also to affect the meiofauna distribution and abundance (Bell et al., 1978).

The Patos Lagoon is the largest choked lagoon in the world (Kjerfve, 1986) and is mostly composed by extensive shallow body water, where island and embayment margins are colonized by *Spartina alterniflora*-marshes (Capitoli et al., 1978). The choked lagoon characteristics and the negligible tidal amplitude make physical-chemical parameters in the Patos Lagoon Estuary largely dependent on wind and rainfall (Costa et al., 1998). The high variability and low previsibility of regional environmental conditions (mainly wind and precipitation intensities) originate irregularly flooded intertidal habitats, which may stay either submerged or emerged by prolonged times (Costa, 1997).

Previous study compared the meiofauna community among a salt marsh and a subtidal bottom during permanent intertidal flooding period (Ozorio et al., 1999). Although physical-chemical parameters were unmeasured during at study, the lower meiofauna density observed in salt marsh suggested that physical-chemical characteristics of habitats may be an important factor affecting meiofauna community structure. This study aims to compare the composition and the density of the meiofauna among three soft bottom habitats during a prolonged tidal exposure time and to evaluate its relationship with physical-chemical proprieties of substratum.

Material and methods

The study was carried out in January/2000 (summer) in an area located near the east margin of Pólvora Island, Patos Lagoon, South Brazil (Fig. 1). Three habitats were selected along an exposure gradient: (1) a *Spartina alterniflora*-marsh, (2) an intertidal mudflat (both exposed at approximately 25 days), and (3) a subtidal bottom. These habitats were hereafter referred to as "salt marsh", "intertidal" and "subtidal", respectively.

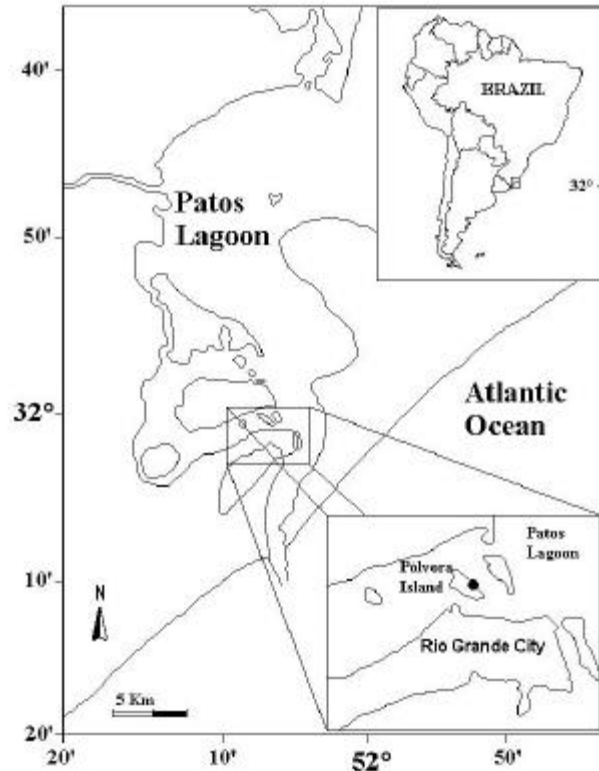


Figure 1: Map of the estuarine region of Patos Lagoon indicating the study area (●).

Three sampling sites were established at same tidal level for each habitat. At these sites, three meiofauna samples were taken using a corer tube (5.31 cm² area and 2 cm depth). Biological samples were fixed in 4% buffered formalin and stained with Bengal Rose (0.5 g l⁻¹). Simultaneously, the pH and Eh values of the sediment were measured with digital pHmeter (DIGIMED, DM2). Surface sediment samples (from first 2cm) were collected in order to determine the granulometric characteristics and the proportion of organic matter.

In the laboratory, meiofauna was extracted from sediment by manually elutriations with the help of flowing water and a becker. Supernatant was passed through a set of 500 and 42 μ m sieves. Only the material retained in the second sieve was sorted and quantified. Meiofaunal organisms were identified to the higher taxonomic level. Granulometric data were obtained through sieving and pipetting analysis and, dried sub-samples were then combusted at 550°C for 60 min in order to determine organic content through weight loss (Suguio, 1973).

One-way ANOVA was used to compare biotic and abiotic data between habitats. When necessary, data were log (x+1) transformed to assure variance homogeneity and distribution normality. In cases in which ANOVA results were significant ($p < 0.05$), the post-hoc Scheffé test (Zar, 1984) was applied.

Similarity of meiofauna among habitats was determined by non-metric multidimensional scaling ordination (MDS) on log (x+1) transformed data, using the Bray-Curtis similarity index (Clarke, 1993). Formal significance tests for differences in meiofauna community structure between habitats were performed using the one-way ANOSIM test (Clarke, 1993).

Environmental data were ordinated using a correlation-based principal component analysis (PCA). In order to examine the relationship between meiofaunal community patterns and environmental structure of the habitats, a Spearman rank correlation (r) was computed between the Bray-Curtis similarity faunal matrix and the Euclidean distance matrix derived from abiotic data. The significance of the correlation was determined using a permutation procedure (RELATE analysis; Clarke & Warwick, 1994). The relationships between multivariate community structure and combinations of environmental variables were then analyzed using the BIO-ENV procedure (Clarke & Ainsworth, 1993) to define sets of variables that best explain the faunistic structure.

Results

All environmental variables varied significantly between the habitats. However, Scheffé post-hoc comparison only showed differences between the subtidal and the other two exposed habitats (Tab. I). Subtidal sediments were composed by moderately sorted fine sand, while both intertidal mudflat and salt marsh sediments by very poorly sorted fine sand. Fine fractions and organic matter content increase from the subtidal to the salt marsh sediments, while redox potential (Eh) and pH decreased (Tab. I).

Ordination by PCA (Fig. 2) of environmental data showed a clear distinction between the subtidal habitat and other two exposed habitats (i.e., salt marsh and intertidal mudflat). The first two components explained 90% of the data variance (PC1 = 74% and PC2 = 16%). On component 1, high negative values were associated with sand percentage and pH, while high positive values were due to organic matter, mean grain size and sediment sorting. High negative values along principal component 2 were a result of kurtosis, and positive ones were due to redox potential (Eh).

Eight meiobenthic taxa were recorded (Tab. II). Nematodes and ostracods were numerically dominant in all habitats, accounting for more than 90% of total meiofauna. Densities of the meiofaunal organisms, except Kinorhyncha, were higher at subtidal than at exposed habitats. The ANOVA results showed that the densities of the three

Table I: Mean values and standard deviation (in parenthesis) and results of a one-way ANOVA evaluating the differences in environmental variables between habitats. Differences between habitats determined by Scheffé comparison test.

Variables	Habitats			F- value	p	Comparison
	Subtidal (Sb)	Intertidal (In)	Salt marsh (Sm)			
Mean grain size (f)	2.87 (0.01)	3.42 (0.23)	3.47 (0.42)	10.2	0.002	Sb < (In = Sm)
Sorting	0.67 (0.04)	1.62 (0.37)	1.35 (0.6)	11.56	0.001	Sb < (Sm = In)
Skewness	0.19 (0.02)	0.55 (0.07)	0.46 (0.17)	21.97	< 0.001	Sb < (Sm = In)
Kurtosis	1.31 (0.08)	2.89 (0.79)	2.28 (0.52)	17.69	< 0.001	Sb < (Sm = In)
Sand (%)	92.88 (0.69)	79.11 (5.61)	77.58 (12.53)	5.42	0.017	(Sm = In) < Sb
Fines (%)	7.1 (0.67)	20.89 (5.62)	22.42 (12.53)	18	< 0.001	Sb < (In = Sm)
Organic Matter (%)	0.29 (0.07)	0.6 (0.25)	0.83 (0.28)	11.02	0.001	Sb < (In = Sm)
Eh (mV)	-78 (34.32)	-203 (9.98)	-211 (47.07)	22.03	< 0.001	Sb < (In = Sm)
pH	7.03 (0.09)	5.53 (0.32)	5.05 (0.28)	81.82	< 0.001	(Sm = In) < Sb

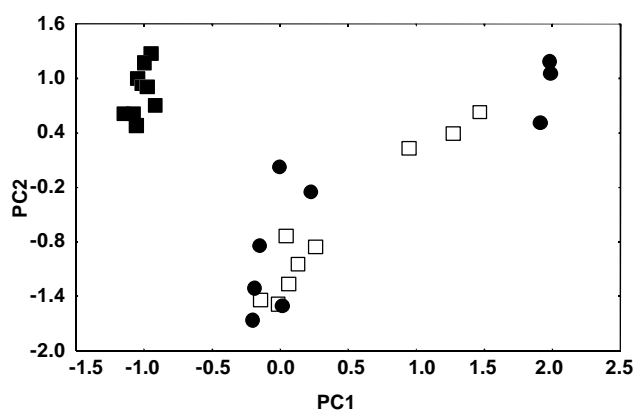


Figure 2: PCA ordination of environmental variables from subtidal (■), intertidal (□) and salt marsh (●) habitats.

Table II: Mean density (inds.10cm²) and standard deviation (in parentheses) of meiofauna higher taxa, ranked in order of percentage of total meiofauna.

Taxa	Subtidal	Intertidal	Salt marsh	% Total
Nematoda	1697.84 (555.97)	1373.51 (244.59)	841.18 (398.82)	72.8
Ostracoda	906.88 (202.12)	147.31 (65.17)	37.25 (16.84)	20.3
Copepoda	166.98 (107.76)	12.35 (7.77)	7.74 (4.66)	3.5
Acari	47.08 (32.08)	14.86 (6.88)	2.72 (2.99)	1.2
Turbellaria	49.17 (22.88)	7.11 (5.86)	0.63 (1.33)	1
Nauplii	37.66 (22.97)	8.37 (5.58)	6.91 (6.39)	1
Kinorhyncha	1.88 (2.49)	5.44 (8.07)	0	0.1
Total meiofauna	2908.98 (488.21)	1569.16 (307.27)	896.63 (404.50)	

more abundant taxa (i.e., Nematoda, Ostracoda and Copepoda) and total meiofauna were significantly different ($p < 0.001$) between habitats (Fig. 3). Both total meiofauna and ostracods showed distinct densities in each habitat. Nematodes densities were only significantly lower in the salt marsh, whilst copepods densities were significantly lower in both exposed intertidal levels.

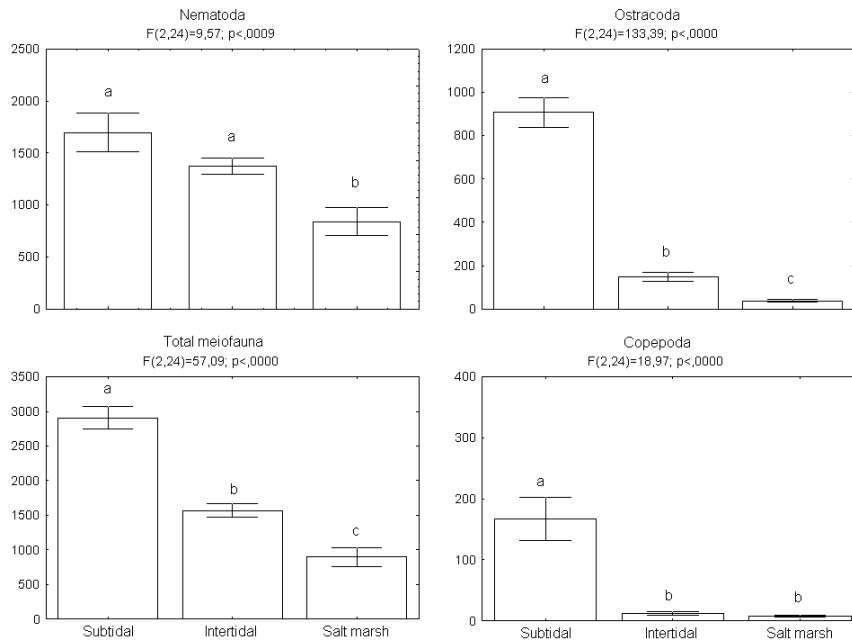


Figure 3: Mean density (inds.10 cm⁻²) of the more numerically abundant organisms and of the total meiofauna in the habitats. Results of the one-way ANOVA evaluating the differences in meiofaunal data between habitats. Bars with the same letters above them are not significantly different (Scheffé test).

The MDS ordination (Fig. 4) of meiofaunal data revealed a clear difference between the habitats distributing then across a gradient of the meiofauna distribution. The habitat with high meiofauna density (subtidal) was plotted on the left of this gradient while habitat with low density (salt marsh) was plotted on the right. Results of the both global ($R = 0.804$; $p = 0.001$) and pair-wise (Tab. III) ANOSIM tests confirmed that the structure of meiofauna were different between habitats.

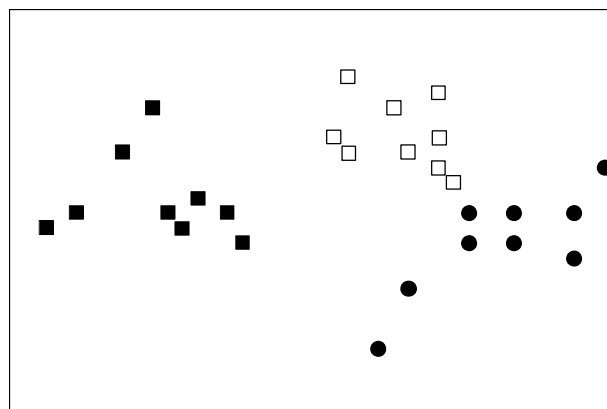


Figure 4: MDS ordination of log (x + 1) transformed meiofauna data from subtidal (■), intertidal (□) and salt marsh (●) habitats.

Table III: Results of the ANOSIM pair-wise tests for difference on meiofauna community structure between habitats. Analyses performed on log (x+1) transformed data.

Habitats compared	R	p
Subtidal – Intertidal	0.974	0.002
Subtidal – Salt marsh	0.962	0.001
Intertidal – Salt marsh	0.496	0.001

Spearman rank correlation showed that meiofauna was significantly correlated with environmental data ($r = 0.51$ and $p = 0.001$). In a Pearson product-moment correlation analysis, none of the environmental variables were highly correlated (>0.85), and thus all variables were used in the BIO-ENV analysis. The highest resulting correlation achieved for meiofauna ($r_w = 0.67$) was with a combination of mean grain size (f), sorting, organic matter and pH.

Discussion

The meiofauna composition was quite similar among the three habitats, however, its densities varied significantly among them. The higher values were achieved at subtidal bottom and decrease in salt marsh direction. Following BIO-ENV results, the decrease of the meiofauna densities was correlated with an increase of the fine sediment proportions and organic matter content as well as a decrease of sediment sorting and pH values. This was coincident with an increase of the substratum exposure at intertidal habitats. In this way, our results agree with other authors who observed that meiofauna abundance is influenced by physical-chemical factors (Alongi, 1987; Santos et al., 1996).

The poorly sorted very fine sediments, like observed at intertidal flat and salt marsh, are less consistent and have low percolation rates, favoring the surface water retention and exposing it to evaporation before percolation. These sediment characteristics associated to a prolonged tidal exposure time result at a substratum much reduced, like observed by low Eh values in this bottoms. In this anaerobic conditions, the degradation of organic matter by sulfate-reducing bacteria produce H_2S resulting in lower pH values in the sediments. Consequently, the physical-chemical sediment characteristics of the both intertidal and salt marsh bottoms make these habitats less suitable for meiofauna, as showed by the low densities at which meiofauna occurs there.

Besides physical-chemical sediment differences, another important factor that influenced the meiofauna density in the salt marsh habitat is the presence of the macrophyte itself. Although sediment characteristics of the intertidal bottom and salt marsh do not differ, the multivariate analysis (i.e. MDS and ANOSIM) indicate significant differences in the meiofauna densities among them. The lower meiofauna density in the salt marsh is probably related to marsh root system, which could limit faunal development into sediment. Bell et al. (1978) observed negative correlation among meiofauna density and root biomass in a *Spartina alterniflora*-marsh of South Carolina (USA). Following these authors, high root biomass imposes limitation on locomotion activities of meiofauna, especially of the burrowing organisms such as nematodes.

Nematode densities were significantly lower only at salt marsh sediments suggesting that its abundance had been influenced mainly by root marsh system than by physical-chemical factors. Nematodes are considered the most resistant meiofauna taxa to low oxygen concentrations and sulfide exposure, even though, it seems to be species specific since nematodes diversity may decrease after a hypoxic event (Austen & Widbom, 1991). However, Modig & Ólafsson (1998) evaluated the responses of benthic invertebrates to hypoxic events through laboratory experiments. According with their findings, the numerically important nematodes species were grouping as "tolerant species" since did not significantly decrease in abundance after two months of hypoxic treatment.

In turn, copepods densities were significantly reduced in both emerged habitats confirming that these organisms are the more affected by physical-chemical alterations of the sediments. However, in Patos Lagoon during permanent intertidal flooding period were registered higher copepod densities in a salt marsh than in a subtidal bottom (Ozorio et al., 1999). This should be related to epibenthic behavior of copepods, which could make them less susceptible to physical-chemical conditions of the sediment. In this way, the lower copepods densities in emerged habitats may be more related to tidal exposure than physical-chemical characteristics of sediment. It was also observed an increase in the contribution of the meiofaunal temporary taxa, characterized by insects (Chironomidae) and oligochaetes, on the meiofaunal composition and density in the salt marsh during permanent intertidal flooding (Ozorio et al., 1999). Once those organisms were not found in an inverse condition (i.e., during prolonged intertidal exposure), there is suggestion that those groups are also dependent of a flooding condition, which allows their presence in the salt marsh.

In summary, our results indicate that meiofauna density of soft-bottom habitats of Patos Lagoon is influenced by a set of physical-chemical factors of the sediment as well as by presence of the biogenic structures. However, the organism responses seem to be specie-specific to a determinate factor.

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