MEIOFAUNA COMMUNITY STRUCTURE VARIABILITY IN A BRAZILIAN TROPICAL SANDY BEACH

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RESUMO

Estrutura da comunidade de meiofauna de praia arenosa numa região tropical do Brasil

O objetivo do presente trabalho é verificar a influência de parâmetros ambientais na estruturação da comunidade de meiofauna, considerando as escalas temporal e espacial. As amostras foram coletadas em dois períodos do ano caracterizados por estiagem e chuva e em locais ao longo do banco de areia Coroa do Avião diferindo entre si em termos de composição das frações de areia e presença ou ausência de vegetação. Os grandes grupos registrados foram: Nematoda, Copepoda, Rotifera, Turbellaria, Tardigrada, Gastrotricha, Ostracoda, Polychaeta, Oligochaeta, Acari, Bivalvia, Kinorhyncha e larvas de crustáceo no estágio Nauplius. A densidade média da meiofauna total variou de 542 a 4354 e de 1203 a 5095 ind.10 cm^{-2} durante período seco e chuvoso, respectivamente. Os valores da concentração de clorofila-*a* variaram de 0,76 a 26,80 $\mu g.cm^{-2}$ e o tamanho médio dos grãos de sedimento de 1,673 a 3,028 ϕ. Os resultados das análises permitiram verificar variações nos padrões de distribuição espacial dos grandes grupos da meiofauna e que parâmetros ambientais, tais como: concentração de clorofila-*a*, profundidade da camada de oxi-redução e grau de selecionamento dos sedimentos, são os que apresentaram maior influência sobre a estrutura da comunidade de meiofauna do banco de areia Coroa do Avião.

PALAVRAS-CHAVE: meiofauna, praia arenosa, microfitobentos, sedimento, distribuição espacial.

ABSTRACT

This work was designed to verify the influence of different environmental factors on the meiofauna higher taxa community structure, considering spatial and temporal variations. Samples were taken in two different periods of the year characterized by dryness and rain. Meiofauna community was studied in different sedimentary habitats differing in sand fractions composition and presence/absence of vegetation. Meiofauna was composed by: Nematoda, Copepoda, Rotifera, Turbellaria, Tardigrada, Gastrotricha, Ostracoda, Polychaeta, Oligochaeta, Acari, Bivalvia, Kinorhyncha and larval stages of crustaceans (Nauplius). Total average meiofauna density ranged from 542 to 4354 and from 1203 to 5095 ind.10 cm^{-2} during dry and wet periods respectively. Chlorophyll-*a* values ranged from 0.76 to 26.80 $\mu g.cm^{-2}$ and sediment grain size from 1.673 to 3.028 ϕ. Multivariate analysis (multidimensional scaling MDS) and similarity analysis (ANOSIM) suggested significant differences in spatial distribution patterns of meiofauna higher taxa. Chlorophyll-*a* concentration, RPD layer and grain size sorting were the main factors structuring meiofauna community according to BIOENV analysis.

KEY WORDS: meiofauna, sandy beach, microphytobenthos, grain size, spatial heterogeneity.

1 – INTRODUCTION

The physical characteristics of the sediments are recognized as important factors structuring the benthic communities (McLachlan 1996). Sand granulometry, which is defined by parameters like grain size, porosity, permeability and content of water, is very important to the interstitial system characteristics (McLachan & Turner 1994). Several authors (Coull 1988, Giere 1993, McLachlan & Turner 1994, Fenchel 1996) agree that size of the sediment particles is an important factor regarding both structural and spatial conditions and also that chemical and physical characteristics of the sediment are strongly related to the habitat of the meiofauna. However, other factors like hydrodynamics and macrofauna animal activity can act in an indirect way on meiofauna since they could change sediment characteristics (Giere 1993)

Sand meiofauna tends to be slender to move through the narrow interstitial pores, while the fauna found in muddy sediments does not have a particular morphology, but it is generally larger-sized than sandy animals (Coull & Bell 1979). The importance of the grain size is not only related to the mobility of the organisms, but also to the capacity of the sediment for both circulation and retention of water, mainly because the water circulation is responsible for the renewal of oxygen supply. Coarser grains have smaller retention capacity than fine ones but, in the other hand, they have larger capacity of circulation (Nybakken 1996). Therefore, any major change in the sedimentary structure results in a change in the community structure (Somerfield *et al.* 1995, McLachlan 1996). Many authors suggest that microphytobenthos also influence the spatial distribution of the benthic organisms (Montagna *et al.* 1983, Decho 1988, Blanchard 1991, Giere 1993, Santos *et al.* 1995).

The Coroa do Avião sandbank is an ebb-tidal delta located at the south part of the Santa Cruz Channel, Itamaracá Island, Pernambuco. By it’s dimensions, about 560 m length and 80m width, some authors consider it as a small island (Silva 1994). It is considered a recent geological formation, which was originated around 1978, and presents evident erosional and depositional processes, which generate great sedimentological diversity, and hence habitats diversity, in a relatively small geographical area. Thus, the Coroa do Avião sandbank provides an excellent opportunity for ecological studies, in particular for the study of meiofauna relationship with the sedimentological environment.

In this context, this study was designed to test the following hypothesis: the meiofauna community structure in the Coroa do Avião sandbank has spatial and temporal variations, regarded to composition and density of higher taxa. Once accepted that hypothesis, a second one has been tested: spatial and temporal variations of the meiofauna community structure are closely related to variations in some measured physical and biological characteristics of the sediment.

2 – MATERIAL AND METHODS

The region of the Santa Cruz Channel is characterized by two periods related to pluviometry: the dry period, which occurs between September and February generally presenting monthly rainfall below 100 mm and higher salinity values, around 30, and the wet period, which occurs between March and August and presents monthly rainfall ranging from 100 mm to 400 mm; during this period salinity values of 25 are characteristic (Macêdo *et al.* 2000). The region has a mesotidal regime with tidal range varying from 0.3 to 2.5 m.

In this work, surveys were done in January and July, 1997, characterizing dry and wet periods respectively.

Sampling was carried out in 12 sampling points located in the intertidal or shallow subtidal area of Coroa do Avião sandbank (07º 49' S 034° 50' W), Northeastern Brazil (Fig.01). The position of these points was chosen based on previous samplings data on the occurrence and density of the meiofauna taxa as well as on the sediment granulometry near the bank (Pinto and Santos, unpublished data). These data allowed an *a priori* clustering of the points into 4 groups due to sedimentary habitat characteristics (A, B, C and D), Group A points (A1, A2 and A3) were submerged in both sampling periods and presented coarse sand grain characteristics. Groups B (B1, B2 and B3) and C (C1, C2 and C3) points presented medium to fine granulometry characteristics respectively and Group D points (D1, D2 and D3) presented characteristics of very fine sand granulometry with the presence of a seagrass bed *Halodule wrightii* (Fig. 01).

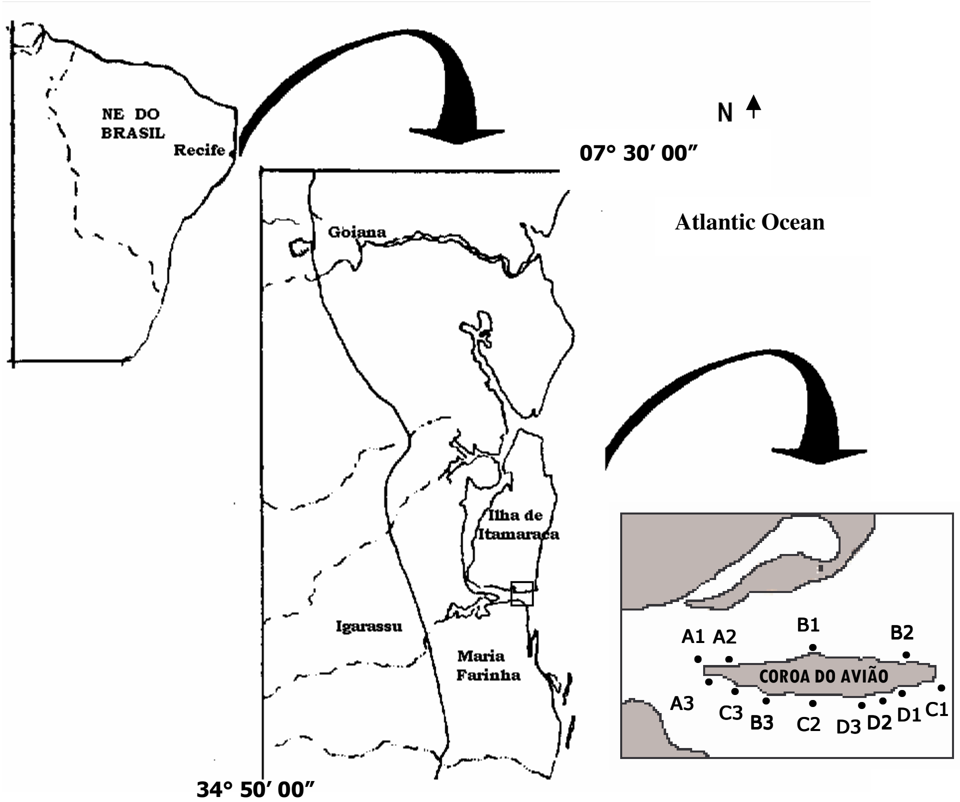

FIGURE 01 – Map showing the studied area and schematic position of sampling points.

For both samplings periods a single corer with an inner area of 6.15 cm^2 was used to collect sediments, in order to analyze granulometry, microphytobenthic and meiofauna. The first ten centimeters on each point were sampled for granulometric analysis without replication. About 50 grams of each sediment sample were dried in a 80° C stove during 8 hours (Suguio, 1973), then sieved through a set of six sieves of 2.0, 1.0, 0.5, 0.250, 0.125 and <0.062 mm separating the sediment in fractions of gravel, sand (very coarse, coarse, medium, fine and very fine sand) and silt+clay (Wenthworth 1922). Sediment was analyzed according to Folk & Ward (1957).

In order to calculate both chlorophyll-*a* and phaeopigments concentrations, samples were collected at each point, without replication, in the first two centimeters of sediment, since most microphytobenthic algae are concentrated in the uppermost surface (Souza & David 1996). Pigments were extracted during 12 hours in the dark with 10 ml of pure acetone and measured in two wave lengths: 665 and 750 nm before and after acidification with 50 µl of HCl 0.1 N. Chlorophyll-*a* and phaeopigments concentrations were calculated using Lorenzen's formulae (Lorenzen 1967). The active chlorophyll index (chlorophyll-*a*/phaeopigments) (Lamontagne *et al.* 1986, Santos *et al.* 1996) was used.

Five samples, 10 cm deep, were collected at each point for meiofauna. Samples were fixed with 4% saline formaldehyde. Fixed animals were separated from the sediment by elutriation, where the supernatant was sieved through 1.0 and 0.044 mm meshes. This procedure was repeated ten times and the material retained in 0.044 mm sieve was analyzed. The residual sediment was always analyzed for the presence of meiofauna. The animals were stained with Bengal Rose, identified to higher taxonomic level and quantified under a stereoscopic microscope.

At each point, the depth where changes in sediment coloration from light brown to black occur was observed and considered the beginning of the redox potential discontinuity layer (RPD). The depth of the water table was also registered. Both measurements were done with a common ruler. The temperature of the sediment was also measured using a mercury thermometer.

An Analysis of Variance (2-way ANOVA) was applied to environmental data utilizing Levene's test to verify the homogeneity of variances. The *a posteriori* Tukey test for means comparisons was also used. A 5% significance level was used.

The Plymouth Routine in Multivariate Ecological Research (PRIMER), version 5.2.4, was also used for data analysis. MDS and One and 2-Way ANOSIM for individual periods and for both periods together, respectively, were done looking for patterns of clustering and statistical differences among sampling groups and periods respectively. Fourth root transformed data and Bray-Curtis similarity index were used. BIOENV was used to elucidate which of the measured abiotic factors were closer related to those differences.

Some groups (Acari, Kinorhyncha and Bivalvia) were excluded from the statistical analysis due to very low density and/or frequency of occurrence.

3 – RESULTS

Environmental factors

Sediment samples showed that mean grain size ranged from 1.799 to 2.884 ϕ and from 1.673 to 3.028 ϕ in the dry and wet periods, respectively, thereby classifying the sediments in medium to very fine sands (Tables 01 and 02).

TABLE 1 – Granulometric parameters in each point during the dry period.

Points	Mean (phi)	Mean (mm)	Classification (sand)	Median (phi)	Standard deviation	Skewness	Kurtosis
A1	2.128	0.229	FINE	2.234	0.661	-0.241	0.822
A2	2.182	0.220	FINE	2.289	0.636	-0.26	0.882
A3	1.848	0.278	MEDIUM	1.802	0.743	-0.009	0.934
B1	2.002	0.249	FINE	2.127	0.816	-0.322	0.977
B2	1.948	0.259	MEDIUM	1.996	1	-0.069	1.006
B3	2.254	0.209	FINE	2.362	1.108	-0.149	1.057
C1	2.566	0.169	FINE	2.538	0.768	-0.019	1.373
C2	1.799	0.287	MEDIUM	1.731	0.809	0.023	0.962
C3	1.949	0.259	MEDIUM	2.01	0.834	-0.209	0.947
D1	2.795	0.144	FINE	3.105	1.112	-0.435	0.978
D2	2.884	0.135	FINE	3.163	1.113	-0.396	1.103
D3	2.772	0.146	FINE	3.121	1.213	-0.404	0.991

TABLE 2 – Granulometic parameters in each point during the wet period.

Points	Mean (phi)	Mean (mm)	Classification (sand)	Median (phi)	Standard deviation	Skewness	Kurtosis
A1	2.321	0.200	FINE	2.408	0.831	-0.117	1.189
A2	2.108	0.232	FINE	2.221	0.735	-0.290	0.932
A3	2.008	0.249	FINE	2.053	0.647	-0.095	0.741
B1	2.118	0.230	FINE	2.239	0.707	-0.305	0.929
B2	1.823	0.283	MEDIUM	1.862	1.021	-0.035	0.978
B3	2.136	0.227	FINE	2.299	0.894	-0.291	1.235
C1	2.724	0.151	FINE	3.064	1.211	-0.390	0.958
C2	1.673	0.314	MEDIUM	1.704	0.910	-0.090	0.899
C3	2.041	0.243	FINE	2.162	0.897	-0.0257	1.067
D1	2.190	0.219	FINE	2.179	0.986	0.012	1
D2	3.028	0.122	VERY FINE	3.263	0.998	-0.413	1.197
D3	2.069	0.238	FINE	2.262	1.068	-0.220	0.970

Points D1, D2 and D3 had smaller grain diameters when compared to the other points. Most samples presented asymmetric tendency to the coarse grades. Sediment sorting index generally classify sediments as moderately sorted and in some cases, like points B2, B3, C1 and D3 for the dry period and D1, D2 and D3 for the wet period, as weakly sorted with standard deviations around 1 (Tables 01 and 02).

The depth of the RPD layer was higher for group A points, around 20 cm deep. For the other points the maximum depth registered was 5 cm. The water table was at the surface in points, such as group A, which were always submerged. The higher depth of the water table values were registered at points B1 (both sampling periods) and B2 (dry period) (Table 03).

TABLE 3 – Environmental parameters measured in each point during the dry (D) and wet (W) periods. (Temp=temperature, WT=water table, RPD=redox potential discontinuity layer, Chla=chlorophyll-*a* concentration, Phaeop=phaeopigments concentration, Chlactive=active chlorophyll (Chla/pheop.)).

Points	Temp (°C)		WT (cm)		RPD (cm)		Chla (μg/cm²)		Phaeo (μg/cm²)		Chlactive	
	D	W	D	W	D	W	D	W	D	W	D	W
A1	31.5	29	0	0	20	20	3.9	0.9	0	0.8	-	1.2
A2	31.5	30	0	0	20	20	0.7	2.7	1.3	1.4	0.5	3.7
A3	31.5	28	0	0	20	20	1.9	3.0	0	0.7	-	4.2
B1	31	29	10	10.5	1.5	3.5	-	10.9	-	3.4	-	3.2
B2	32	28	10	1	4	5	16.0	10.4	3.0	5.6	5.2	1.8
B3	33	29	1.5	1	4	0.5	3.8	3.9	0	1.9	-	2.0
C1	32	28	7.0	5	0.5	3	9.8	5.1	12.2	1.6	0.8	3.1
C2	32	28	11	4	0.3	2	16.3	7.4	10.3	2.9	1.5	2.5
C3	32	27	0	0	1	-	17.1	5.8	0.2	3.5	82.5	1.6
D1	32	29	0	0	1.5	2	16.4	22.0	11.0	39.6	1.4	0.5
D2	31.5	28	2.5	7.5	1	2	17.8	26.8	16.6	28.3	1.0	0.9
D3	32.5	28	5.5	0	1	0.5	13.0	14.6	7.6	12.3	1.7	1.1

Chlorophyll-*a* concentration (Fig. 02a) ranged from 0.76 to 17.85 $\mu g.cm^{-2}$ and from 0.96 to 26.8 $\mu g.cm^{-2}$ for dry and wet periods, respectively. Phaeopigments concentration (Fig. 02b) was generally lower than that of chlorophyll-*a*. The highest value for both factors was registered for group D points. The active chlorophyll index values, except for station C3 during the dry period, were generally close to one.

Significant differences ($p<0.05$) were found among groups of points through 2-Way ANOVA for standard deviation (or sorting index), RPD layer depth and for both chlorophyll-*a* and phaeopigments concentrations (Table 04).

TABLE 4 – Results of Analysis of Variance (2-Way ANOVA) and Tukey Test applied to environmental factors (SD=standard deviation, RPD=redox potential discontinuity layer depth, A, B, C, D=groups of points, ns=not significant).

POINTS	RPD			SD			Chlorophyll-*a*			Phaepigments		
	F=426, p=0.000			F=11,63, p=0.000			F=11,48, p=0.000			F=14,5, p=0.000		
A	-	-	-	-	-	-	-	-	-	-	-	-
B	0.000	-	-	ns	-	-	ns	-	-	ns	-	-
C	0.000	ns	-	0.030	ns	-	ns	ns	-	ns	ns	-
D	0.000	ns	ns	0.002	ns	0.020	0.006	0.030	ns	0.000	0.000	0.007
	A	B	C	A	B	C	A	B	C	A	B	C

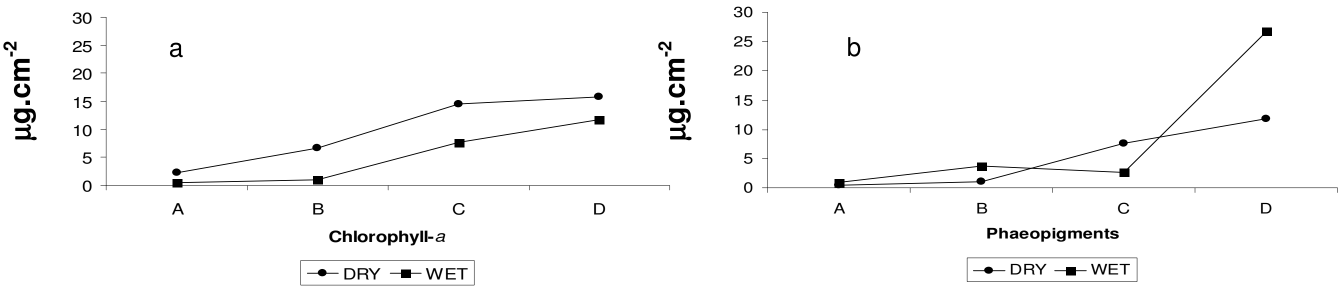

FIGURE 2 – Chlorophyll-*a* (a) and Phaeopigments (b) mean concentration for groups of points (A, B, C,and D) in dry (circle) and wet (square) periods.

Meiofauna

Ten permanent meiofauna higher taxa were found: Nematoda, Copepoda, Rotifera, Turbellaria, Tardigrada, Gastrotricha, Ostracoda, Oligochaeta, Acari, and Kinorhyncha. Two temporary meiofauna taxa (macrofauna juveniles) were also found: Polychaeta and Bivalvia. Crustacea larvae in the nauplius stage were counted separately. The total mean density ranged from 542 to 4354 ind.10 cm^{-2} during the dry period and from 1203 to 5095 ind.10 cm^{-2} during the wet period (Figure 03). Total meiofauna density for each point group was slightly higher during the wet period. Group A points had always lower densities compared to the other point groups.

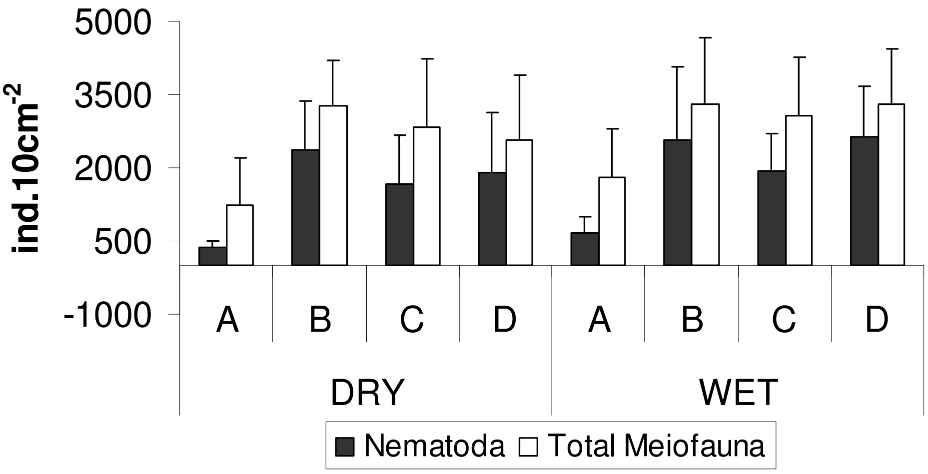

FIGURE 3 – Mean density (± std) of Total Meiofauna (white bars) and Nematoda (black bars) for groups of points in dry and wet periods.

Ostracoda were particularly abundant at points with smaller grain diameter, located close to the seagrass *Halodule wrightii* area. Gastrotricha appeared mainly in B and C points in both studied periods. Epsilonematidae were more abundant in points A1, A2 and A3 (submerged and without redox potential descontinuity layer) and B3 (Figure 04a and b). Juveniles of a single species of Polychaeta (*Laeonereis acuta*), considered temporary meiofauna, appeared only in one replicate in the wet period and present very high density (up to 9750 ind.$10cm^{-2}$). The mean densities and standard deviations for both total meiofauna and higher taxa in each point group for sampling periods are showed in figures 03 and 04 (a and b).

Patterns among the four groups of points (A, B, C and D) could be evidenced when applying the MDS for all data in set and for each period separately, mainly among A and B and C plus D (Fig. 05 a,b,c). ANOSIM analysis pointed to differences only considering the spatial scale (groups of points) (p<0.05, Table 05), allowing the observation of significant differences among groups of points, except between C and D, with the greatest difference occurring between A and D. These results are quite similar for both periods (separately and in set).

TABLE 5 – ANOSIM applied to meiofauna groups density in each point for both sample periods.

POINTS	WET PERIOD		DRY PERIOD		BOTH PERIODS	
	R	*P*	R	*p*	R	*p*
A-D	0.874	0.001	0.822	0.001	0.841	0.001
A-C	0.701	0.001	0.776	0.001	0.728	0.001
A-B	0.635	0.001	0.763	0.001	0.676	0.001
B-D	0.733	0.001	0.663	0.001	0.707	0.001
B-C	0.568	0.001	0.547	0.001	0.503	0.001

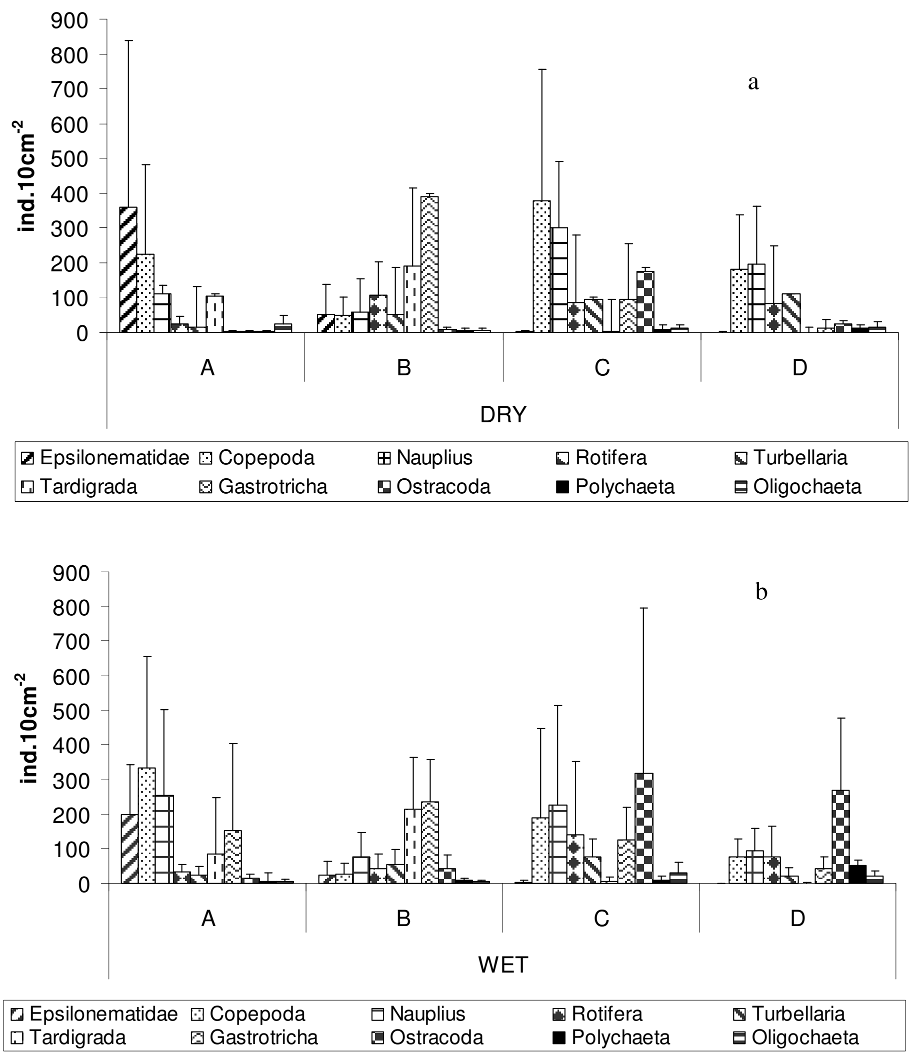

FIGURE 4 – Mean density (± std) of other Meiofauna taxa for groups of points in dry (a) and wet (b) periods.

Neither MDS analysis nor Anosim indicated patterns or differences between periods of sampling,

BIOENV results for the wet period show that the highest value of correlation (p = 0.559) was found between meiofauna structure and two of the measured parameters: sediment sorting index and chlorophyll-*a*. Considering the dry period, the highest correlation with meiofauna community structure was found for three parameters together: sediment sorting index, kurtosis and RPD layer (p =0.658).

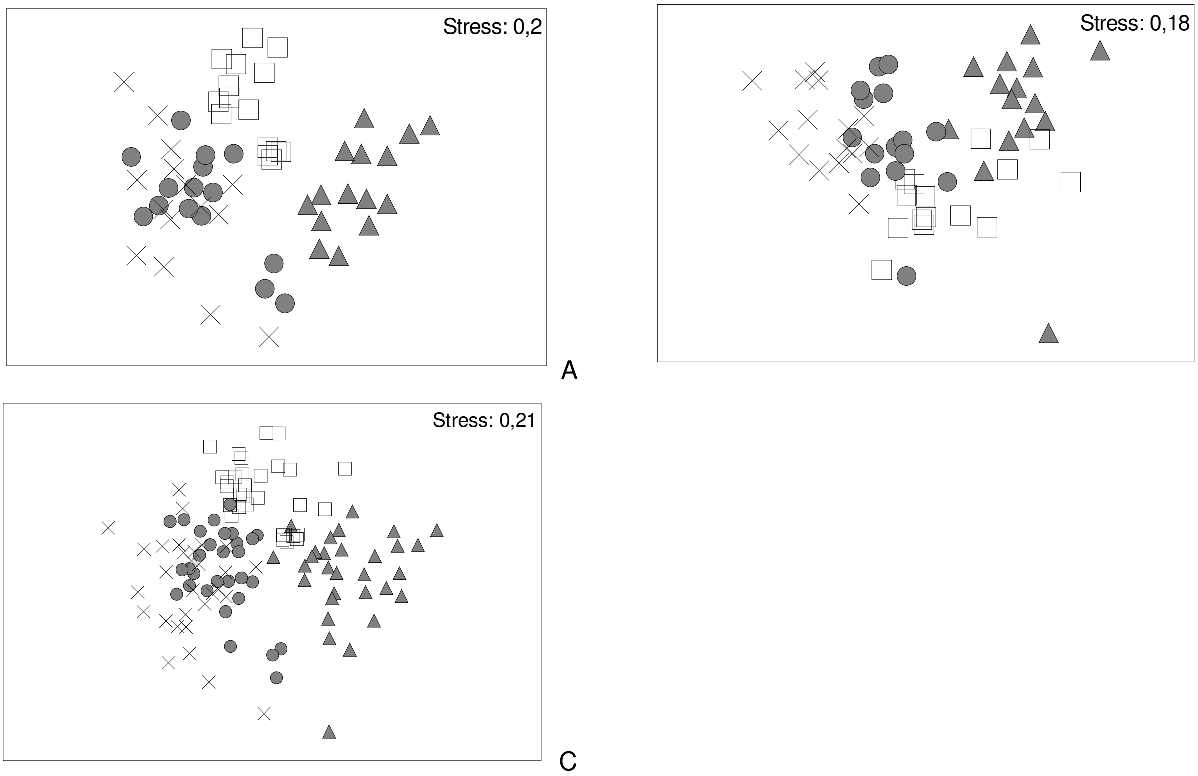

FIGURE 5 – MDS applied to meiofauna higher taxa density for groups of points (A = ▲,B=□ C= ● and D=**x**) for: dry period (stress=0.20) (a); wet period (stress=0,18) (b); and both periods (stress 0.21) (c).

4 – DISCUSSION

The Coroa do Avião sandbank meiofauna community structure presents significant differences in distribution patterns along the different sedimentary habitats sampled and these differences were related to some measured environmental parameters. Significant differences were not found for temporal scale.

The Nematoda dominance in the present study, which reach 90% of organisms in samples, is a well documented event in the literature for medium to fine sand habitats (Giere, 1993). This dominance here, lead to a community where total meiofauna density patterns are mainly driven by Nematoda abundance fluctuations. The number of meiofauna groups recorded is similar to those found by another authors in similar environments (Medeiros 1992, Bezerra *et al.* 1997) and Polychaete and Bivalvia are common groups belonging to temporary meiofauna of sandy beaches (Brown & McLachlan 1990). Total meiofauna and Nematoda mean density found in this work are also similar to those of other sandy beach environments (Rodriguez *et al*. 2001).

The very high density of juvenile polychaete recorded in only one replicate in this work is probably due to a strongly clustered recruitment event. The fact that the multivariate analysis results pointed to differences in meiofauna community structure along the spatial scale, which means differences in groups of points with different physico-chemical characteristics, seems to be in agreement with Montagna (1991) e Soetaert *et al.* (1994). These authors verify that changes in physical gradients are in association with changes in meiofauna abundance patterns in scales of dm to km.

The higher Anosim R statistical values found between groups of points A and D (always > 0.8) means that the dissimilarities between them are high. This result is clearly related to the decrease in both total meiofauna and Nematoda abundances and the increasing in Epsilonematidae abundance in group A points for both sampling periods. Lower values found in point A group for some environmental factors such as: pigment concentration, standard deviation, assimetry and kurtosis are typical of a relatively high energy dynamic environment. In addition, these points were always submerged and show the higher values of RPD layer depth.

In group D points the occurrence of vegetation likely changed the local hidrodynamics (Decho *et al.* 1985) leading to an opposite set of characteristics as compared to A group of points. Thus, eventhough groups of points did not present significant differences regarding mean grain size (nor they correspond to previous data utilized to the preliminary choice of the sample points in terms of granulometry) the factors pigment concentration, standard deviation, assimetry and kurtosis cited above, which presented significant differences mainly among A and D points, pointed to significant differences of the sedimentary environment. That information allowed characterizing different habitats and these differences resulted in significant different meiofauna spatial distribution patterns.

In this work, the only meiofauna group that seems to benefit in terms of abundance in dynamics points, comparing among all points, was Epsilonematidae. This Nematode family is typical of sandy beach environments (Gourbaoult *et al.* 1995, Netto *et al.* 1999). According to Nicholas (2001) due to their small body size, the Epsilonematidae are easily pushed downward inside sediments when the tide retreats. In this work, the majority of points were emerged at the sample time, A was the only exception, and the depth of the water table was in general deeper than the depth of the sample core, probably explaining the higher abundance of this group at these points.

According to McLachlan & Turner (1994) the oxygenation of the interstitial system, and consequently the depth of RPD, depend primarily on the balance among the organic and oxygen inputs, suggesting the existence of a relationship with both chlorophyll-*a* concentration and the sediment sorting index. The lower chlorophyll-*a* concentration values in point A group are linked to low light incidence due to submersion and also to higher local energy. Colijn & Dijkema (1981) also found that the chlorophyll-*a* concentrations were more elevated in sheltered than in more exposed sandy areas. Moreover, they also found smaller concentrations of phaeopigments compared to those of chlorophyll-*a* in high energy stations and higher concentrations in lower energy stations. A similar situation occurred in the present study. Although Ólafsson *et al.* (1995) did not find a significant relationship between pigments concentration and density of meiofauna, other authors (Montagna 1984, Santos *et al.* 1995, Grant *et al.* 1986) report a close relation between these biotic components, assigning meiofauna aggregation to microphytobenthic food availability. Carman *et al.* (1997) registered that some meiofauna groups such as Ostracoda and Copepoda are particularly relevant microphytobenthos consumers. In agreement with that statement, in the present work the Ostracoda presented higher densities in points where chlorophyll-*a* values were higher (*i.e.*: C and D). This relationship with chlorophyll-*a* may also explain the lower densities of total meiofauna found in A.

McArthur *et al.* (2000) consider that meiofauna spatial distribution patterns are related to groups of environmental factors instead of being related to one or two isolated factors. Similar results were found here, where high correlation among meiofauna and associations of some factors such as: sediment sorting index, chlorophyll-*a* concentration, kurtosis values and RPD layer depth were registered.

The lack of differences between sampling periods, even when comparing single points, and the similarity of patterns found for periods apart, point to lower temporal variations in the meiofauna community structure or at least that in the specific situation spatial variations outweigh temporal ones. Some authors record that tropical regions have the influence of seasonal differences in precipitation, presenting increased abundances in the wet season (Alongi 1987; Ansari & Parulekar 1993, Ingole & Parulekar 1998, Dittman 2000). In this work increased abundance of total meiofauna in the wet period occurred but was not statistically significant.

Results allowed the conclusion that the hydrodynamics of Coroa do Avião sandbank changes the physico-chemical sedimentary environment as well as food availability, represented here by chlorophyll-*a* concentrations. This variability is directly related to higher taxa meiofauna spatial distribution patterns.

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