MEIOFAUNA DISTRIBUTION IN A TROPICAL ESTUARY OF THE SOUTH-WESTERN ATLANTIC (BRAZIL)

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VIE ET MILIEU, 2000, 50 (3) : 151-162

MEIOFAUNA DISTRIBUTION IN A TROPICAL ESTUARY OF THE SOUTH-WESTERN ATLANTIC (BRAZIL)

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MEIOFAUNA
SUBTIDAL
ESTUARY
DISTRIBUTION
DRY SEASON
RAINY SEASON
BRAZIL
SOUTH-WESTERN ATLANTIC

ABSTRACT. – The horizontal distribution and abundance of metazoan meiofauna in relation to environmental variables were examined at 10 stations in the Jacuacanga Bay (Rio de Janeiro, Southeastern Brazil), at two seasons of the year (rainy and dry). Samples were obtained from 9 and 17 m depth. Environmental and biological variables were sampled by SCUBA diving and with a van Veen grab. Principal Component Analysis, Canonical Correspondence Analysis, SIMPER and Hierarchical Clustering were used to describe and evaluate associations of variables and samples. Meiofauna was composed by 22 faunistic groups, with mean densities varying from 1425 to 5226 ind. 10 cm^{-2}. The highest values were observed during the rainy saison. The communities were dominated by nematodes, followed by copepods. Statistical analysis showed that the main environmental variables influencing the meiofauna distribution were: coarse silt, dissolved oxygen, organic carbon, C/N ratio and depth. The dissimilarity between the stations can be explained by nematodes, copepods, rotifers, ostracodes and kinorhynchs. The comparison between rainy and dry seasons revealed the existence of temporal variability related to seasonal inputs of organic matter into the benthos.

MÉIOFAUNE
SUBTIDAL
ESTUAIRE
DISTRIBUTION
SAISON SÈCHE
SAISON HUMIDE
BRÉSIL
ATLANTIQUE SUD-OUEST

RÉSUMÉ. – La répartition horizontale et l'abondance du méiobenthos en relation avec les variables de l'environnement ont été examinées à 10 stations échantillonnées dans la Baie de Jacuacanga (Rio de Janeiro, Brésil), à deux périodes de l'année (saisons humide et sèche). Les échantillons ont été prélevés à 9 et 17 m de profondeur. Les relevés environnementaux et biologiques ont été obtenus en plongée et avec une benne van Veen. Les analyses en Composantes Principales, de Correspondance Canonique, hiérarchique et SIMPER ont été utilisées pour décrire et évaluer des associations des variables avec les échantillons. La méiofaune est composée de 22 groupes faunistiques, et sa densité moyenne varie de 1 425 à 5 226 ind. 10 cm^{-2}. Les plus fortes abondances ont été observées pendant la saison humide. Les communautés sont dominées par les Nématodes et les Copépodes. L'analyse statistique a montré que les principales variables de l'environnement influençant la distribution de la méiofaune sont le limon grossier, l'oxygène dissous, le carbone organique, la proportion C/N et la profondeur. La dissimilarité entre les stations peut être expliquée par l'abondance des Nématodes, des Copépodes, des Rotifères, des Ostracodes et des Kinorhynques. La comparaison entre saisons humide et sèche a révélé l'existence d'une variabilité temporelle en rapport avec la quantité de matière organique dans le sédiment.

INTRODUCTION

Meiofauna is represented by almost all the invertebrate groups and occurs in great abundance in estuarine sediment shet worldwide where they facilitate biomineralization of organic material and enhance nutrient regeneration, and serve as food for a variety of higher trophic levels (Coull 1999). According to Bodiou (1999), the predation on meiobenthos by young benthic fishes is a well-known phenomenon in which the harpacticoid copepods take an important part.

The meiobenthos exhibits a high sensitivity to anthropogenic inputs, making them excellent model organisms for the study of estuarine pollution (Coull 1999). They have been used more recently in many benthic studies because they have a number of advantages over the macrofauna in field and laboratory studies. These characteristics include their small size and high densities which permit collecting small samples and shorter generation times combined with a lack of a planktonic phase in their life cycles suggesting a potentially shorter response time and therefore higher sensitivity to anthropogenic disturbance (Heip *et al.* 1988, Warwick 1993). Furthermore the meiofauna is abundant and diverse even in habitats where it is subject to considerable natural, physical and chemical stress, where very few if any macrofauna species remain (Lampadariou *et al.* 1994).

There are several factors that control the composition and meiobenthos distribution. These factors usually act together, thus making difficult the evaluation of the role of each one in the community. Abiotic factors such as grain size, temperature, salinity, redox potential and oxygen concentration, are directly responsible for this variation (Findlay 1981, Coull 1988,1999, Giere 1993). The influence of microphytobenthos has also been pointed out by Gray (1981), Giere (1993) and Schewe & Soltwedel (1999). There is little information available on the scale of spatial distribution and usually it is very difficult to separate temporal from spatial variability (Fleeger & Decho 1987).

Organic content of the sediments seems to play a key role in the meiofauna density and it is a nutrient source that induces settlement and determines benthic organism distributions (Parsons *et al.* 1984).

In the south-western Atlantic, there are distinct variations in precipitation throughout the year, with either a high amount of rainfall or dry seasons. This phenomenon directly influences the amount of continental freshwater runoff and thus the biogeochemical processes in coastal and marine ecosystems of the south-western Atlantic (Ciotti *et al.* 1995).

The purpose of this work is to study the horizontal distribution of the benthic sublitoral major meiofauna taxa in Jacuacanga Bay, Rio de Janeiro, by comparing two seasons of the year (rainy and dry) and by trying to identify the environmental variables that most heavily influenced this distribution.

STUDY AREA

The Jacuacanga Bay (Fig. 1) is located south of Rio de Janeiro, between 22°59' and 23°03'S, and 044°13' and 044°17'W. It has a surface area of 24 km^2 and 5.2 km of width at its entrance. It is characterized by a hot and humid climate, presenting a high rainfall rate (1500 to 2000 mm annual) and a 22 °C annual mean temperature (FEEMA 1980). The water circulation near Ilha Grande Bay, in which Jacuacanga Bay is inserted, is gravitational, and influenced by an almost fixed flow induced by density gradients and being little influenced by tide and winds (Signorini 1980). The Jacuacanga Bay presents a strong anthropogenic influence due not only to the presence of shipyards, a petrol terminal but also to the Jacuacanga river, the main pluvial and continental runoff drainage. The sediment is predominantly composed by silt, clay and sandy silt. This sediment spreads up to the west portion of Ilha Grande Bay varying gradually in terms of sand grain sizes (Mahiques & Furtado 1989).

MATERIAL AND METHODS

Samples were taken during rainy (November 1997) and dry seasons (July 1998) in nine stations located along three transects of the coastline (Fig. 1). The station 10 was located outside of the Jacuacanga Bay (23°07'S and 044°16'W), close to Ilha Grande Island, named here Ilha Grande station. This station had been chosen because it is under low anthropogenic influence.

Sediment samples were taken with a modified seringe corer (3.5 cm inner diameter) by SCUBA diving. At each station, four core samples were taken for the meiofauna study, two for microphytobenthos, one for redox potential and temperature data and one for heavy metal data. Preliminary studies were carried out to determine the number of meiofauna subsamples sufficient to detect spatial and temporal differences within meiofauna populations. Sediment samples for granulometric analysis, organic carbon and organic nitrogen were collected with a van Veen grab covering 0.1 m^2.

Water samples for hydrological analysis of temperature, salinity, pH and dissolved oxygen were collected at 1 m above the sediment surface with a van Dorn bottle.

Sea water temperature and pH were measured with a pH-meter of Hanna Instruments, HI 8424 microcomputer. Salinity was determined by chemical titulation and dissolved oxygen was obtained by the Winkler method (Strickland & Parsons 1972).

Granulometric analyses were done according to Suguio (1973) and the separation of the different grain size followed the Wentworth scale. The redox potential was obtained in the uppermost cm layer using a platinum electrode. Organic carbon was obtained by wet oxidation with dichromate and the concentration of organic nitrogen through the Kjeldahl-method (Strickland & Parsons 1972). Heavy metals were analysed using I.C.P. – AEES (Inductively Coupled Plasma Atomic Emission Espectrometer-Optima 3000 – Perkin Elmer) by means of the total element analysis by wet digestion in aqua regia. For this study only the cadmium, zinc, lead and copper concentrations were considered. This analysis has been achieved by the Laboratory of Centro Nacional de Pesquisas do Solo (CNPS) of EMBRAPA (Empresa Brasileira de Pesquisa de Agricultura).

Microphytobenthic biomass of the sediment first cm was obtained by the chlorophyll *a* concentration and the pigment extraction being processed with 90 % acetone. Pigment analysis was done by spectrophotometry

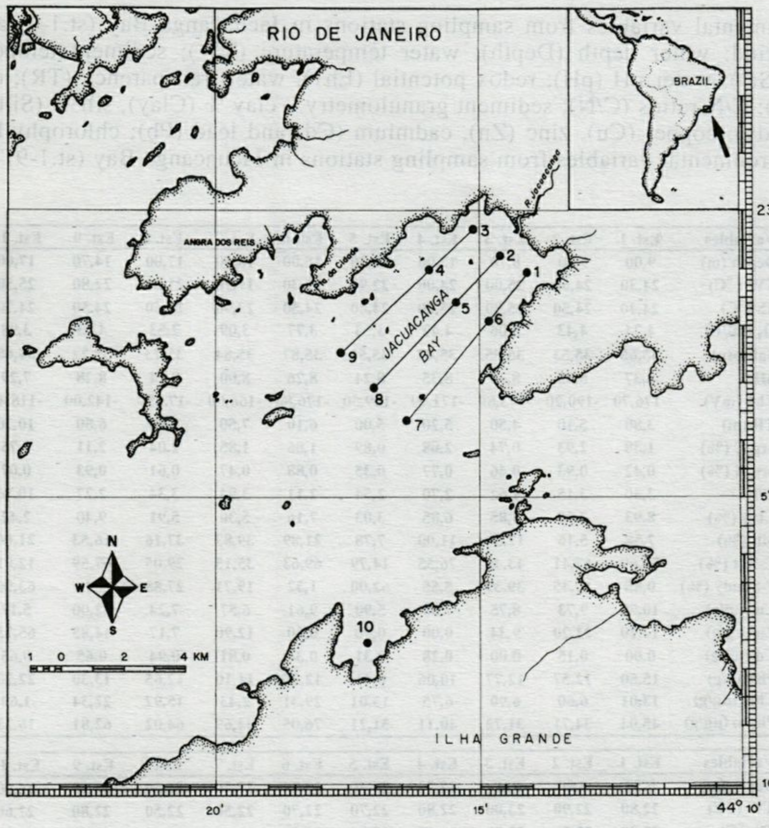


Fig. 1. – Map of the Jacuacanga Bay (Brazil, Rio de Janeiro State) showing the positions of sampling stations.

(Blanchard *et al.* 1988). Chlorophyll *a* concentrations as well as pheophytin *a* were calculated from modified Lorenzen's equations (1967) modified for Plante-Cuny (1978).

Meiofauna was studied in the first 5 cm of the sediment and the samples were preserved in 4 % formalin and stained with Rose Bengal. Meiofauna was extracted from the sediment by decantation and flotations in Ludox HS 40 % at a specific gravity of 1.15. To enable the meiofauna extraction, samples have been centrifuged and decanted into a 45 µm meshsieve. The preserved material was sorted under a binocular stereomicroscope and only major taxa of meiofauna were identified. The organism density of meiofauna taxa was calculated for $10\ cm^{-2}$.

Meiofaunal distribution patterns were determined by multivariate analyses, hierarchical classification and ordination, using logarithmic transformation log n (x + 1). The Bray-Curtis distance and Hierarchical Clustering were performed with the defined groups for UPGMA algorithm. The matrix used for statistical analyses contains 12 faunistic groups (nematodes, copepods, nauplii, polychaetes, oligochaetes, turbellarians, ostracodes, bivalves, kinorhynchs, cnidarians, gastropods and rotifers). A Principal Components Analysis (PCA) was used to determine if the stations were distributed in multidimensional space in function of environmental variables. 20 environmental variables and 20 samples were used for this purpose. The variables were centered and reduced (X mean/standart deviation). Canonical Correspondence Analysis (CCA) was used to correlate the environmental and biological variables. The variables utilized in multivariate analyses were selected by the BIOENV procedure. The SIMPER (Similarity Percentage Breakdown) was applied to determine the contribution of faunistic groups to dissimilarity between the stations (Clarke & Warwick 1994). Data manipulation, statistical and graphical summarization utilized STATISTIC, CANOCO (Ter Braak 1986) and FITOPAC (developed by Shepard, Universidade Estadual de Campinas– SP-Brazil) softwares.

RESULTS

Environmental variables

The predominant fraction of sediment in most of the sampling stations was coarse silt, especially in the stations near the coast and in station 9. Some stations however presented high fine sand percentages during the rainy season (station 5) and during the dry season (station 7). The Ilha Grande station also presented a high percentage of fine sand in both seasons (63.90 and 78.86 %). The redox potential values were already negative in the first cm of the sediment in both seasons (Table I).

Table I. – Top, environmental variables from sampling stations in Jacuacanga Bay (st.1-9) and Ilha Grande station (st.10) at the rainy period: water depth (Depth); water temperature (TW); sediment temperature (TS); dissolved oxygen (DO); salinity (Sal); water pH (pH); redox potential (Eh1); water transparency (TR); organic carbon (org C); organic nitrogen (org N); C/N ratios (C/N); sediment granulometry:– clay % (Clay), silt % (Silt), coarse silt % (C-Silt) and fine sand % (F-Sandy); copper (Cu), zinc (Zn), cadmium (Cd) and lead (Pb); chlorophyll *a* (Chl*a*), phaeophytin *a* (Phaeo*a*). Below, environmental variables from sampling stations in Jacuacanga Bay (st.1-9) and Ilha Grande station (st.10) at dry period.

Variables	Est. 1	Est. 2	Est. 3	Est. 4	Est. 5	Est. 6	Est. 7	Est. 8	Est. 9	Est. 10
Depth (m)	9,00	9,40	8,70	12,00	13,20	15,00	18,50	17,00	14,70	17,00
TW (°C)	24,30	24,60	25,00	24,00	22,90	22,30	19,90	21,30	22,80	25,50
TS (°C)	24,40	24,50	25,00	25,00	24,00	24,50	23,90	24,60	24,50	24,70
O_2 (ml/L)	4,74	4,43	5,06	4,42	3,53	3,77	3,09	2,53	4,53	3,98
Sal (psu)	35,65	35,53	35,55	35,47	35,51	35,87	35,84	35,73	35,22	34,68
pH	8,37	8,35	8,41	8,35	8,24	8,26	8,00	8,14	8,28	7,29
Eh1 (mV)	-176,70	-190,20	-173,80	-171,90	-169,50	-176,80	-166,00	-173,90	-142,00	-118,40
TR (m)	3,80	5,10	4,50	5,20	5,00	6,10	7,50	5,00	6,80	10,20
org C (%)	1,38	2,93	0,74	2,08	0,89	1,86	1,85	2,04	2,11	0,76
org N (%)	0,42	0,93	0,46	0,77	0,35	0,88	0,47	0,61	0,93	0,07
C/N	3,30	3,15	1,62	2,70	2,54	2,11	3,94	3,34	2,27	10,86
Clay (%)	8,93	7,99	4,85	6,85	3,03	7,16	5,30	5,91	9,40	2,42
Silt (%)	2,58	5,16	12,30	11,00	7,78	21,89	39,83	37,16	16,53	21,66
C-Silt (%)	87,69	67,41	43,46	76,55	14,79	69,63	35,15	29,05	67,59	12,01
F-Sandy (%)	0,85	19,45	39,39	5,55	62,00	1,32	19,71	27,88	6,48	63,90
Cu (µg/g)	10,78	9,73	8,75	7,60	5,90	9,61	6,57	7,24	12,00	5,17
Zn (µg/g)	14,20	21,20	9,34	0,00	0,00	0,00	12,90	7,17	14,85	65,73
Cd (µg/g)	0,00	0,15	0,00	0,28	0,31	0,34	0,81	0,94	0,65	0,63
Pb (µg/g)	15,50	12,57	12,77	10,06	6,41	12,25	11,10	12,65	13,30	22,20
Chl*a* (µg/g)	13,01	6,60	6,90	6,75	13,01	29,31	2,43	15,97	22,34	1,69
Pheo*a* (µg/g)	45,04	34,71	31,72	40,11	51,21	76,05	34,69	64,02	62,81	16,23

Variables	Est. 1	Est. 2	Est. 3	Est. 4	Est. 5	Est. 6	Est. 7	Est. 8	Est. 9	Est. 10
Depth (m)	9,50	8,90	9,00	12,70	14,40	15,20	17,70	16,50	14,20	16,90
TW (°C)	22,80	22,90	23,00	22,80	22,70	22,70	22,50	22,50	22,80	22,60
TS (°C)	22,70	22,70	22,80	22,10	22,80	22,30	22,10	22,40	23,10	22,00
O_2 (ml/L)	5,18	5,13	5,12	4,98	5,09	4,95	5,45	4,46	4,62	4,39
Sal (psu)	34,47	34,65	34,36	34,04	34,04	34,39	34,93	34,61	33,86	34,11
pH	8,16	8,10	8,15	8,20	8,19	8,18	8,20	8,18	8,20	8,18
Eh1 (mV)	-201,40	-97,80	-66,60	-99,90	-118,50	-207,20	-81,70	-76,50	-41,70	-31,10
TR (m)	7,60	8,30	8,10	10,70	10,90	11,50	10,90	8,00	10,40	9,70
org C (%)	1,07	1,66	1,07	0,92	0,94	0,89	0,48	0,65	0,98	0,85
org N (%)	1,70	1,80	1,10	1,90	2,60	1,60	0,60	1,80	1,90	0,40
C/N	0,63	0,92	0,97	0,48	0,36	0,55	0,80	0,36	0,52	2,13
Clay (%)	12,83	7,62	4,43	9,06	10,36	12,09	3,04	10,14	8,46	3,75
Silt (%)	17,27	7,60	10,06	24,34	15,41	15,40	4,28	32,20	15,64	7,81
C-Silt (%)	68,39	40,42	36,40	63,18	69,09	71,62	2,19	2,05	72,17	9,58
F-Sandy (%)	1,51	44,36	49,10	3,41	5,14	0,90	90,48	55,62	3,73	78,86
Cu (µg/g)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Zn (µg/g)	56,00	66,80	48,80	57,60	54,20	50,20	0,00	42,20	43,50	0,00
Cd (µg/g)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Pb (µg/g)	21,40	15,20	12,80	17,40	17,20	18,20	0,00	13,00	14,80	7,46
Chl*a* (µg/g)	34,86	114,25	3,43	17,69	21,43	60,11	0,89	2,29	5,36	0,46
Pheo*a* (µg/g)	38,63	129,67	14,60	96,86	40,86	113,82	37,67	35,41	107,22	17,01

Organic carbon and heavy metal concentrations were higher in the rainy season, especially in the stations near the coast and at the Ilha Grande station and only cadmium presented significant concentrations in the Jacuacanga Bay during the rainy season. On the other hand, the organic nitrogen concentrations were higher during the dry season mainly in stations 4, 5 and 9. The C/N ratio was very low in all stations, especially in the dry season, varying from 0.36 to 3.94 and the highest value was found in the Ilha Grande station (10.86). Station 2 presented the highest organic carbon concentrations. Dissolved oxygen concentrations were higher in the dry season when the temperatures were lower with higher values near the coast.

Chlorophyll *a* concentrations were clearly higher in stations 2 and 6 in the dry season (114.25 and 60.11 µg/g) while the station 7 and the Ilha Grande station presented low values in both seasons.

Meiofauna composition, abundance and distribution

A total of 22 faunistic groups was found including copepod nauplii. The mean density of the total meiofauna varied from 1425 to 5226.5 ind. 10 cm^{-2} (Fig. 2A) and reached its maximum at station 2 and at the Ilha Grande station in the rainy season. Nematodes, copepods and nauplii

Table II. – Mean density (n. ind. 10 cm^{-2}) of meiofauna groups at the sampling stations in Jacuacanga Bay (st.1-9) and Ilha Grande station (st.10) in the rainy period.

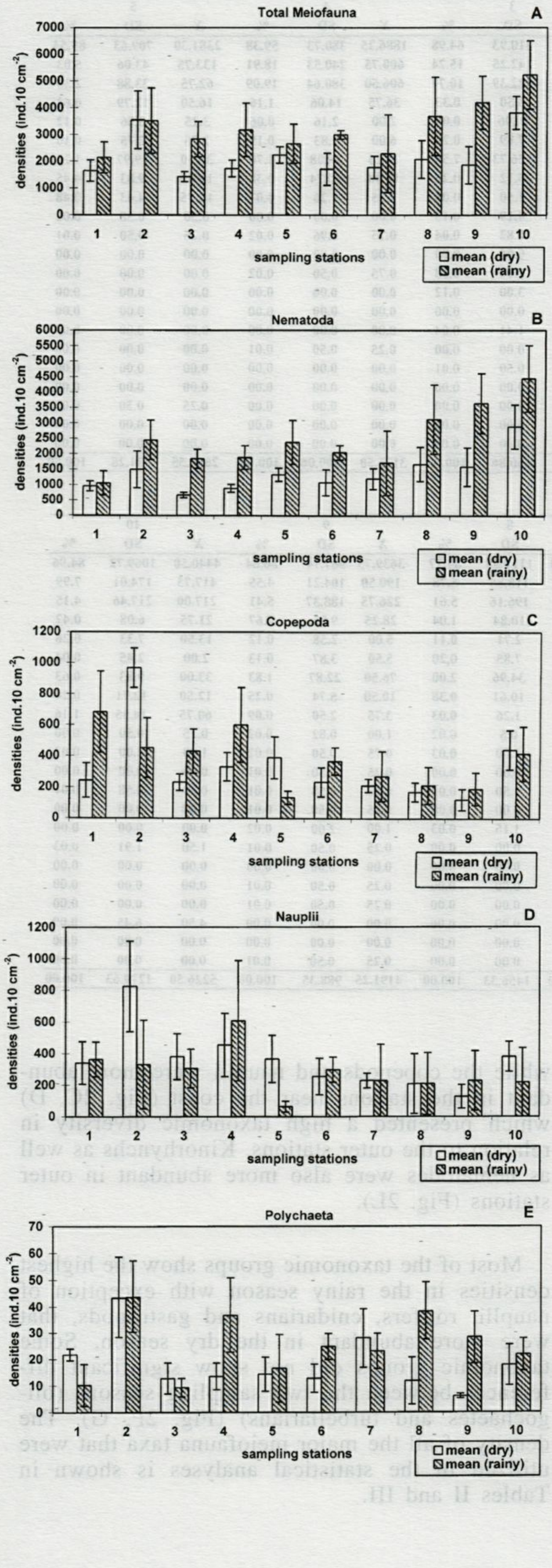
Stations	1			2			3			4			5		
Taxa	X	SD	%	X	SD	%	X	SD	%	X	SD	%	X	SD	%
Nematoda	1046	394.26	48.87	2448.00	639.36	69.56	1840.00	310.93	64.98	1886.25	380.73	59.38	2381.30	709.63	89.54
Copepoda	683.25	262.09	31.92	453.00	191.39	12.87	431.50	142.25	15.24	600.75	240.53	18.91	133.75	43.06	5.03
Nauplii	363	109.32	16.96	330.00	279.85	9.38	305.00	122.39	10.77	606.50	380.64	19.09	62.75	33.88	2.36
Polychaeta	10.25	7.89	0.48	43.75	13.45	1.24	9.25	3.50	0.33	36.75	14.06	1.16	16.50	12.79	0.62
Oligochaeta	2.5	1.73	0.12	6.75	3.50	0.19	1.25	0.,96	0.04	2.00	2.16	0.06	3.25	3.86	0.12
Turbellaria	7.25	4.99	0.34	8.25	7.09	0.23	6.75	7.89	0.24	6.00	2.83	0.19	2.75	2.75	0.10
Ostracoda	19.75	15.48	0.92	134.00	91.09	3.81	214.00	136.73	7.56	22.25	14.08	0.70	33.50	19.97	1.26
Bivalvia	4.5	1.00	0.21	6.75	6.29	0.19	7.25	5.12	0.26	12.00	10.74	0.38	12.00	9.83	0.45
Kinorhyncha	0.5	0.58	0.02	0.00	0.00	0.00	1.75	1.50	0.06	2.25	1.26	0.07	12.75	4.43	0.48
Cnidaria	0.5	0.58	0.02	9.25	6.65	0.26	4.25	4.19	0.15	0.00	0.00	0.00	0.50	0.58	0.02
Acarina	0.5	0.58	0.02	0.75	0.96	0.02	1.00	0.82	0.04	0.75	0.96	0.02	0.25	0.50	0.01
Cladocera	0.25	0.50	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda	0.25	0.50	0.01	2.75	2.36	0.08	5.00	2.00	0.18	0.75	0.50	0.02	0.00	0.00	0.00
Rotifera	1.25	0.50	0.06	71.00	54.49	2.02	3.50	3.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Tardigrada	0.25	0.50	0.01	0.75	1.50	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gnathostomulida	0.5	1.00	0.02	3.25	3.77	0.09	1.00	1.41	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Archiannelida	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00
Gastrotricha	0.00	0.00	0.00	0.50	0.58	0.01	0.25	0.50	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Isopoda	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tanaidacea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.50	0.01
Priapulida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Echinodermata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Meiofauna	2140.5	581.06	100.00	3519.25	1213.90	100.00	2831.75	660.86	100.00	3176.50	1000.06	100.00	2659.55	731.28	100.00

Stations	6			7			8			9			10		
Taxa	X	SD	%	X	SD	%	X	SD	%	X	SD	%	X	SD	%
Nematoda	2050.00	234.32	68.36	1711.25	1043.38	74.67	3122.50	1117.58	84.77	3639.75	967.74	86.84	4440.50	1069.72	84.96
Copepoda	368.50	86.93	12.29	270.75	159.39	11.81	213.00	118.85	5.78	190.50	104.21	4.55	417.75	174.01	7.99
Nauplii	295.50	79.72	9.85	225.50	230.86	9.84	206.50	196.16	5.61	226.75	188.37	5.41	217.00	217.46	4.15
Polychaeta	24.75	4.92	0.83	23.00	6.68	1.00	38.25	10.84	1.04	28.25	9.95	0.67	21.75	6.08	0.42
Oligochaeta	1.75	0.50	0.06	3.75	3.59	0.16	4.00	2.71	0.11	5.00	2.58	0.12	13.50	7.33	0.26
Turbellaria	4.75	2.50	0.16	3.00	0.82	0.13	7.25	7.85	0,20	5.50	3.87	0.13	2.00	2.45	0.04
Ostracoda	222.75	83.53	7.43	24.75	11.70	1.08	73.75	34.96	2.00	76.50	22.87	1.83	33.00	9.83	0.63
Bivalvia	17.00	7,30	0.57	9.00	8.25	0.39	14.00	10.61	0.38	10.50	5.74	0.25	12.50	12.71	0.24
Kinorhyncha	2.75	2.22	0.09	16.25	9.22	0.71	1.25	1.26	0.03	3.75	2.50	0.09	60.75	14.55	1.16
Cnidaria	8.25	4.92	0.28	0.50	0.58	0.02	0.75	0.5	0.02	1.00	0.82	0.02	0.25	0.50	0.00
Acarina	0.50	0.58	0.02	0.50	1.00	0.02	1.00	2.00	0.03	0.75	0.50	0.02	1.00	2.00	0.02
Cladocera	0.25	0.50	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00
Gastropoda	0.75	0.96	0.03	0.25	0.50	0.01	0.25	0.50	0.01	0.50	0.58	0.01	0.50	0.58	0.01
Rotifera	0.50	1.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00
Tardigrada	0.25	0.50	0.01	2.00	2.45	0.09	1.00	1.15	0.03	1.00	2.00	0.02	0.00	0.00	0.00
Gnathostomulida	0.25	0.50	0.01	0.75	1.50	0.03	0.00	0.00	0.00	0.25	0.50	0.01	1.50	1.91	0.03
Archiannelida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastrotricha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00
Isopoda	0.25	0.50	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00
Tanaidacea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.50	6.45	0.09
Priapulida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Echinodermata	0.00	0.00	0.00	0.50	0.58	0.02	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00
Total Meiofauna	2998.75	163.52	100.00	2291.75	1451.51	100.00	3683.50	1456.33	100.00	4191.25	988.35	100.00	5226.50	1279.63	100.00

were the most abundant groups, representing more than 89 % of total meiofauna. However, some other taxonomic groups occurred in most of the stations showing significant densities, having therefore been included in the statistical analyses (ostracodes, polychaetes, oligochaetes, turbelarians, bivalves, kinorhyncs, cnidarians, gastropods and rotifers) (Tables II, III). Other groups with very low densities occurred only in some stations or in just one sampling season (acarins, cladocerans, tardigrades, gnathostomulids, archiannelids, gastrotrichs, isopods, tanaidaceans, priapulids and juveniles of echinoderms) and then they were excluded from the statistical analyses.

Nematodes were dominant in all stations. They were more abundant in the outer stations of the Bay as well as in the Ilha Grande station (Fig. 2B) while the copepods and nauplii were more abundant in the stations near the coast (Fig. 2C, D) which presented a high taxonomic diversity in relation to the outer stations. Kinorhynchs as well as nematodes were also more abundant in outer stations (Fig. 2L).

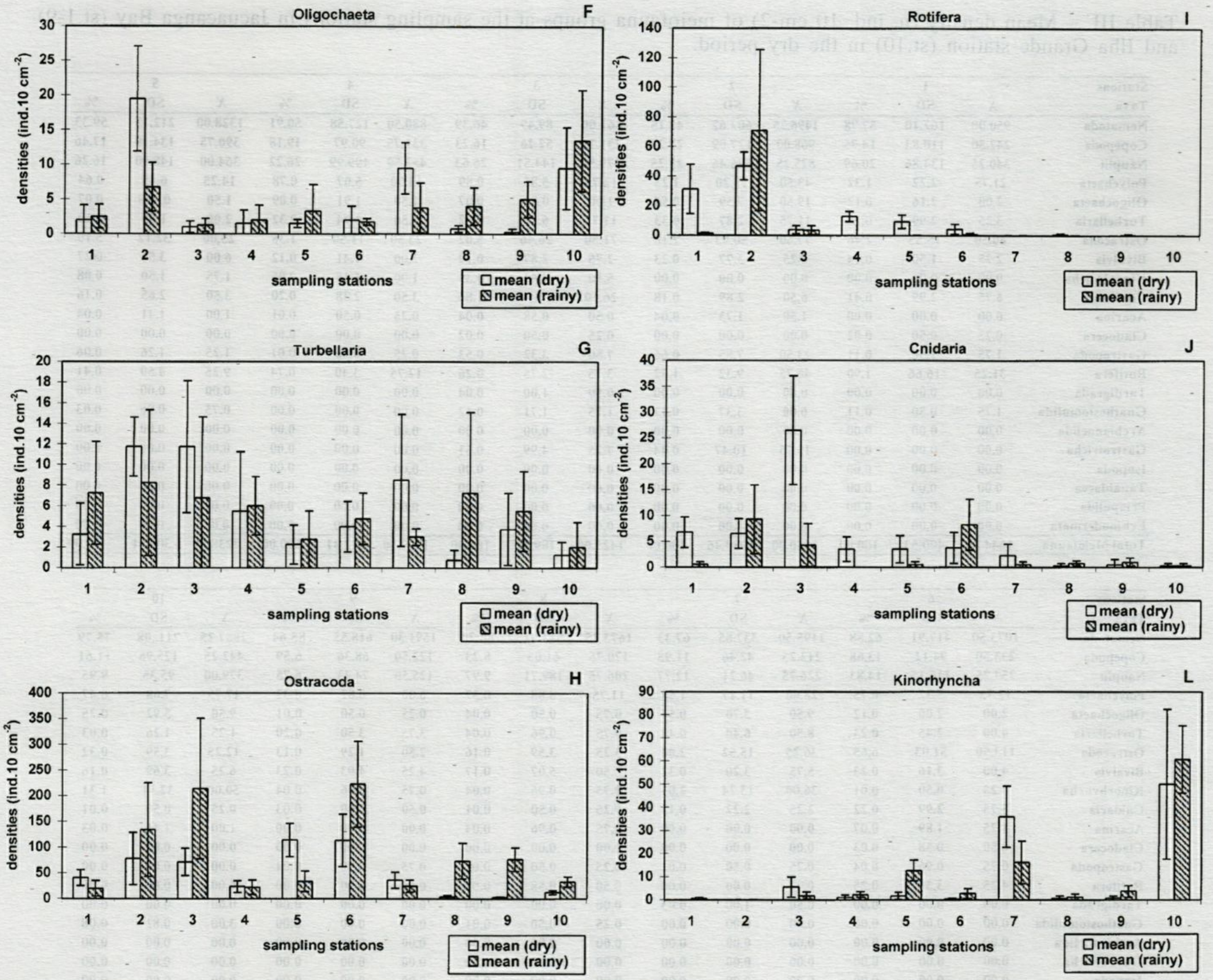
Most of the taxonomic groups show the highest densities in the rainy season with exception of nauplii, rotifers, cnidarians and gastropods, that were more abundant in the dry season. Some taxonomic groups did not show significant differences between the two sampling seasons (oligochaetes and turbellarians) (Fig. 2F, G). The density of all the major meiofauna taxa that were utilized in the statistical analyses is shown in Tables II and III.



SIMPER procedures (Tables IV and V) shows 16.62 % of dissimilarity between the stations of the dry season and 13.33 % in the rainy season. Nematodes, copepods, rotifers, ostracodes and kinorhynchs contributed with 50 % for this variability. The dendrogram of the rainy season (Fig. 3) indicates 3 station groups: group I formed by stations 1 and 4, group II formed by the outer stations (7, 8, 9 and 10) and st. 5, and group III formed by stations 2, 3 and 6. In the dendrogram of the dry season (Fig. 3) only two station groups are observed: group I formed by stations far from the coast (7, 8 and 9) and the Ilha Grande station and group II including stations near the coast (1, 2, 3, 4, 5 and 6). Canonical Correspondence Analysis represents the station distribution in relation to some environmental variables during the two seasons. During the rainy season (Fig. 4) 53.9 % of the variance was explained by the axis I, influenced by coarse silt and organic carbon. For this reason, it can be noticed that the st 2 location is due to its higher organic carbon concentration. St 5, 7, 8 and 10 are grouped together given their small percentage of coarse silt. The relationship between kinorhynchs and the stations 7 and 10 can be observed and it is probably due to the high fine sand percentage of these stations. In the dry season (Fig. 4), the variable that best explained the station distribution on the axis I (56.4 %) was the dissolved oxygen, while the axis II was represented by C/N ratio and organic carbon. They explained 9.5 % of the variability. The Ilha Grande station is isolated due to its C/N ratio high index as well as to its little amount of organic matter. On the other hand, the station 2 is isolated because of its high amount of organic carbon. The association of kinorhynchs with stations 7 and 10 can be observed once again.

Principal Components Analysis (Fig. 5) separates the two seasons, axis I being formed by granulometric variables and the axis II by physical-chemical variables. 5 station groups can be observed: group I was formed by the Ilha Grande station and st 7 (dry season); group II formed by st 1, 2, 3, 4, 6 and 9 (rainy season); group III formed by st 5, 7 and 8 (rainy season); group IV by st 1, 2, 4, 5, 6 and 9 (dry season) and group V formed by st 3 and 8 (dry season).

Fig. 2 (A-E). – Mean density (n. ind.10 cm^{-2}) and standart deviation of the main meiofauna groups in Jacuacanga Bay and Ilha Grande station (st.10).



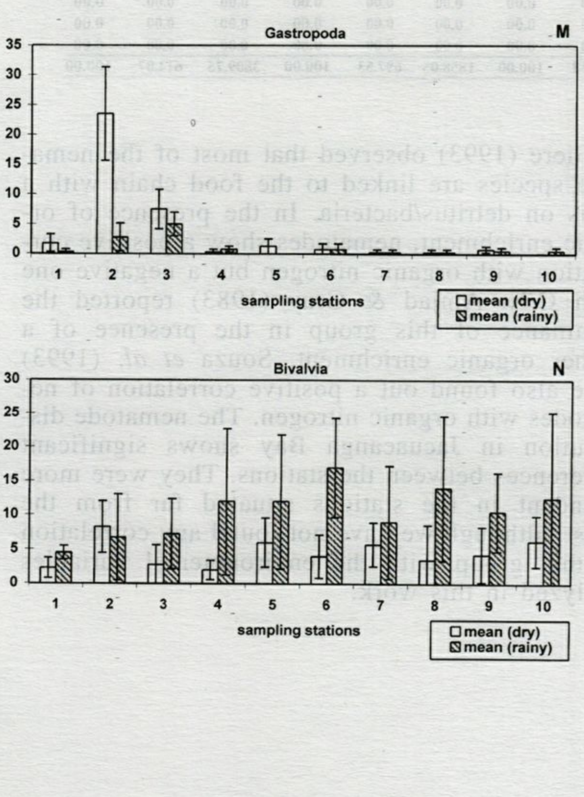


Fig. 2 (F-N). – Mean density (n. ind.10 cm^{-2}) and standart deviation of the main meiofauna groups in Jacuacanga Bay and Ilha Grande station (st.10).

Table III. – Mean density (n. ind. 10 cm-2) of meiofauna groups at the sampling stations in Jacuacanga Bay (st.1-9) and Ilha Grande station (st.10) in the dry period.

Stations	1			2			3			4			5		
Taxa	*X*	SD	%	*X*	SD	%	*X*	SD	%	*X*	SD	%	*X*	SD	%
Nematoda	950.00	162.10	57.78	1496.25	602.62	42.15	661.00	89.49	46.39	880.50	127.58	50.91	1328.00	212.13	59.33
Copepoda	242.50	110.83	14,75	968.00	127.09	27.27	231.25	52.26	16.23	331.75	90.97	19.18	390.75	134.19	17.46
Nauplii	340.25	134.86	20.69	825.25	286.46	23.25	379.50	144.51	26.63	453.50	199.99	26.22	364.00	148.90	16.26
Polychaeta	21.75	2.22	1.32	43.50	15.20	1.23	12.75	5.85	0.89	13.50	5.07	0.78	14.25	6.45	0.64
Oligochaeta	2.00	2.16	0.12	19.50	7.59	0.55	1.00	0.82	0.07	1.50	1.91	0.09	1.50	0.058	0.07
Turbellaria	3.25	2.99	0.20	11.75	2.87	0.33	11.75	6.40	0.82	5.50	5.74	0.32	2.00	1.89	0.10
Ostracoda	40.50	15.55	2.46	77.50	50.93	2.18	71.50	26.46	5.02	23.50	11.50	1.36	25,00	32.12	5.10
Bivalvia	2.25	1.50	0.14	8.25	3.77	0.23	2.75	2.87	0.19	2.00	1.41	0.12	6.00	3.56	0.27
Kinorhyncha	0.00	0.00	0.00	0.00	0.00	0.00	5.50	4.43	0.39	1.00	1.15	0.06	1.75	1.50	0.08
Cnidaria	6.75	2.99	0.41	6.50	2.89	0.18	26.50	10.54	1.86	3.50	2.38	0.20	3.50	2.65	0.16
Acarina	0.00	0.00	0.00	1.50	1.73	0.04	0.50	0.58	0.04	0.25	0.50	0.01	1.00	1.41	0.04
Cladocera	0.25	0.50	0.02	0.00	0.00	0.00	0.25	0.50	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda	1.75	1.50	0.11	23.50	7.85	0.66	7.50	3.32	0.53	0.25	0.50	0.01	1.25	1.26	0.06
Rotifera	31.25	16.66	1.90	46.75	9.32	1.32	3.75	2.75	0.26	12.75	3.40	0.74	9.25	4.50	0.41
Tardigrada	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Gnathostomulida	1.75	0.50	0.11	6.00	3.37	0.17	1.75	1.71	0.12	0.00	0.00	0.00	0.75	0.96	0.03
Archiannelida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastrotricha	0.00	0.00	0.00	15.75	10.47	0.44	7.25	4.99	0.51	0.00	0.00	0.00	0.00	0.00	0.00
Isopoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tanaidacea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Priapulida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Echinodermata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Meiofauna	1644.25	400.53	100.00	3550.00	1080.46	100.00	1425.00	189.89	100.00	1729.50	312.31	100.00	2238.50	309.51	100.00

Stations	6			7			8			9			10		
Taxa	*X*	SD	%	*X*	SD	%	*X*	SD	%	*X*	SD	%	*X*	SD	%
Nematoda	1073.50	417.91	62.88	1195.50	337.85	67.33	1673.25	553.91	80.70	1591.30	618.55	85.64	2887.25	711.,08	75.79
Copepoda	233.50	94.12	13.68	212.25	42.46	11.95	170.75	61.05	8.23	122.50	68.36	6.59	442.25	125.96	11.61
Nauplii	253.25	116.15	14.83	226.75	46.21	12.77	206.75	189.71	9.97	125.50	74.43	6.75	379.00	95.35	9.95
Polychaeta	12.75	5.32	0.75	28.00	11.17	1.58	11.75	8.88	0.57	6.00	0.82	0.32	17.75	7.68	0.47
Oligochaeta	2.00	2.00	0.12	9.50	3.70	0.54	0.75	0.50	0.04	0.25	0.50	0.01	9.50	5.92	0.25
Turbellaria	4.00	2.45	0.23	8.50	6.40	0.48	0.75	0.96	0.04	3.75	3.50	0.20	1.25	1.26	0.03
Ostracoda	113.50	51.03	6.65	36.25	15.52	2.04	3.25	3.59	0.16	2.50	1.29	0.13	12.25	3.59	0.32
Bivalvia	4.00	3.16	0.23	5.75	3.20	0.32	3.50	5.07	0.17	4.25	4.03	0.23	6.25	3.69	0.16
Kinorhyncha	0.25	0.50	0.01	36.00	13.24	2.03	0.75	0.96	0.04	0.75	0.96	0.04	50.00	32.34	1.31
Cnidaria	3.75	2.99	0.22	2.25	2.22	0.13	0.25	0.50	0.01	0.50	1.00	0.03	0.25	0.50	0.01
Acarina	1.25	1.89	0.07	0.00	0.00	0.00	0.75	0.96	0.04	0.00	0.00	0.00	1.00	1.41	0.03
Cladocera	0.50	0.58	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastropoda	0.75	0.96	0.04	0.25	0.50	0.01	0.25	0.50	0.01	0.75	0.50	0.04	0.00	0.00	0.00
Rotifera	4.25	3.30	0.25	0.00	0.00	0.00	0.50	0.58	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Tardigrada	0.00	0.00	0.00	0.50	1.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gnathostomulida	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00	3.00	0.82	0.08
Archiannelida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gastrotricha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isopoda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tanaidacea	0.00	0.00	0.00	13.75	6.85	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Priapulida	0.00	0.00	0.00	0.25	0.50	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Echinodermata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Meiofauna	1707.25	601.00	100.00	1775.50	415.93	100.00	2073.50	707.38	100.00	1858.05	697.53	100.00	3809.75	614.07	100.00

DISCUSSION

The abundance and taxonomic diversity found at the Jacuacanga Bay were expected for this kind of estuarine ecosystem. In this case, the numbers found were higher than the ones found by Coull (1970) in a subtropical area (Bermuda) and by Corbisier (1993) in the São Paulo coast (Brazil). We also were able to confirm high density of nematodes, followed by copepods. This is common in sublittoral sediments (Renaud-Mornant *et al.* 1984, Coull 1988). In some stations of Jacuacanga Bay, nematode abundance reached 82.64 % of the whole meiofauna. Beyrem & Aissa (1998) also observed in the littoral of Bizerta (Tunisia) that the nematode dominance was always > 80 %, even in the most polluted stations.

Giere (1993) observed that most of the nematode species are linked to the food chain with a basis on detritus/bacteria. In the presence of organic enrichment, nematodes show a positive correlation with organic nitrogen but a negative one with C/N. Amjad & Gray (1983) reported the dominance of this group in the presence of a higher organic enrichment. Souza *et al.* (1993) have also found out a positive correlation of nematodes with organic nitrogen. The nematode distribution in Jacuacanga Bay shows significant differences between the stations. They were more abundant in the stations situated far from the coast, although we have not found any correlation of this group with the environmental variables analyzed in this work.

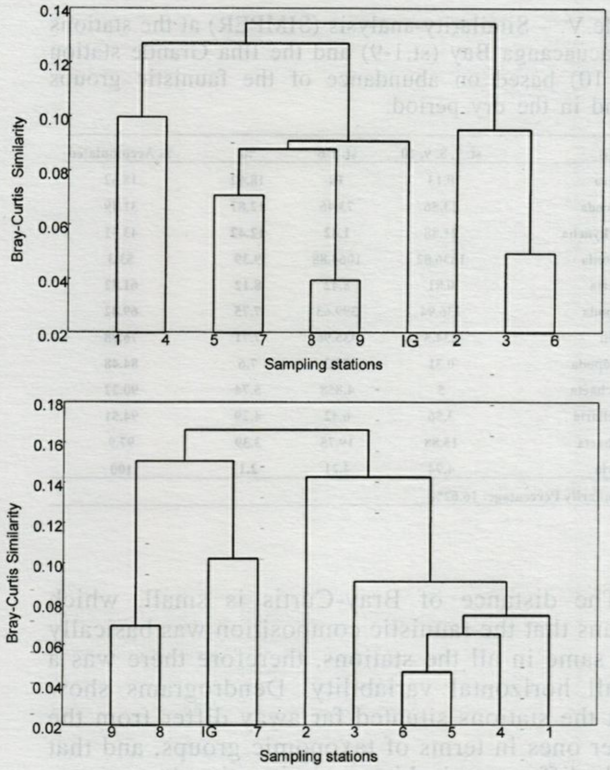


Fig. 3. – Dendrogram for hierarchical clustering of the Jacuacanga Bay stations and Ilha Grande station (IG) in the rainy period (top), and in the dry period (below).

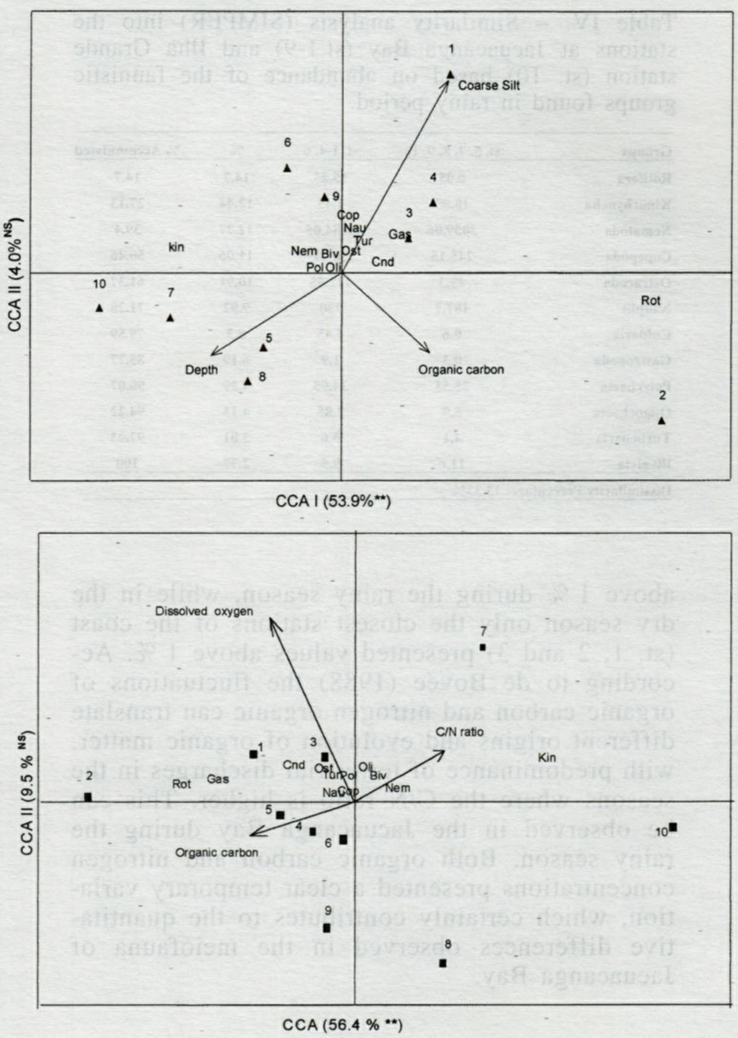


Fig. 4.– Canonical Correspondence Analysis (CCA) of the meiofauna group distribution and the sampling stations in the rainy period (top). Nem (Nematoda), Cop (Copepoda), Nau (Nauplii), Pol (Polychaeta), Oli (Oligochaeta), Tur (Turbellaria), Ost (Ostracoda), Biv (Bivalvia), Kin (Kinorhyncha), Cnd (Cnidaria), Gas (Gastropoda) and Rot (Rotifera). Canonical Correspondence Analysis (CCA) of the meiofauna group distribution and the sampling stations in the dry period (below).

Usually copepod distribution is influenced by the grain size, copepods being more abundant in coarser sediments (Tietjen 1969, Hicks & Coull 1983). However, this distribution patterns can also be explained by different types of feeding, some species being correlated with microphytobenthos (Dinet 1972, Giere 1993). The oxygen is another factor that has an influence on copepod distribution. Most of the species are sensitive to less oxygenated biotopes (Giere 1993). Copepods distribution in the Jacuacanga Bay was inverse to that of the nematodes. The highest densities were recorded in stations near the coast, where higher chlorophyll *a* values as well as higher dissolved oxygen concentrations are observed. In the Fal estuary system (Cornwall, UK), the heavy metal concentration was also an important factor that influenced the copepod community structures (Somerfield *et al.* 1994). However, the procedure of BIOENV indicated that other factors, for instance the percentage of silt and clay and the concentration of organic carbon, were also significant in the distribution of this group. This could also explain such a distribution of the copepods in the Jacuacanga Bay.

Organic carbon concentrations between 1 and 10 % indicate a level of sediment contamination that can be tolerated by the majority of benthic organisms (Mudroch & Azcuel 1995). In Jacuacanga Bay most of the stations presented values

Table IV. – Similarity analysis (SIMPER) into the stations at Jacuacanga Bay (st.1-9) and Ilha Grande station (st. 10) based on abundance of the faunistic groups found in rainy period.

Groups	st. 5. 7. 8. 9. 10	st. 1-4. 6	%	% Accumulated
Rotifera	0.05	15.25	14.7	14.7
Kinorhyncha	18.95	1.45	12.44	27.13
Nematoda	3059.06	1854.05	12.27	39.4
Copepoda	245.15	507.4	11.06	50.46
Ostracoda	48.3	122.55	10.91	61.37
Nauplii	187.7	380	9.92	71.28
Cnidaria	0.6	4.45	8.3	79.59
Gastropoda	0.3	1.9	6.19	85.77
Polychaeta	25.55	24.95	4.29	90.07
Oligochaeta	5.9	2.85	4.15	94.22
Turbellaria	4.1	6.6	3.01	97.23
Bivalvia	11.6	9.5	2.77	100

Dissimilarity Percentage: 13.33%

Table V. – Similarity analysis (SIMPER) at the stations in Jacuacanga Bay (st.1-9) and the Ilha Grande station (st. 10) based on abundance of the faunistic groups found in the dry period.

Groups	st. 7. 8. 9. 10	st. 1-6	%	% Accumulated
Rotifera	0.13	18	18.62	18.62
Ostracoda	13.56	73.46	12.87	31.49
Kinorhyncha	21.88	1.42	12.42	43.91
Nematoda	1836.82	1064.88	9.39	53.3
Cnidaria	0.81	8.42	8.12	61.42
Copepoda	236.94	399.63	7.75	69.42
Nauplii	234.5	435.96	7.71	76.88
Gastropoda	0.31	5.83	7.6	84.48
Oligochaeta	5	4.858	5.74	90.22
Turbellaria	3.56	6.42	4.29	94.51
Polychaeta	15.88	19.75	3.39	97.9
Bivalvia	4.94	4.21	2.1	100

Dissimilarity Percentage: 16.62%

above 1 % during the rainy season, while in the dry season only the closest stations of the coast (st. 1, 2 and 3) presented values above 1 %. According to de Bovée (1988) the fluctuations of organic carbon and nitrogen organic can translate different origins and evolution of organic matter, with predominance of terrestrial discharges in the seasons where the C/N ratio is higher. This can be observed in the Jacuacanga Bay during the rainy season. Both organic carbon and nitrogen concentrations presented a clear temporary variation, which certainly contributes to the quantitative differences observed in the meiofauna of Jacuacanga Bay.

The distance of Bray-Curtis is small, which means that the faunistic composition was basically the same in all the stations, therefore there was a small horizontal variability. Dendrograms show that the stations situated far away differ from the inner ones in terms of taxonomic groups, and that such difference is bigger during the dry season. In this season two other groups were formed including the outer stations, probably due to the presence of kinorhynchs in st 7 as well as in the Ilha Grande station. The st 2 is distinguished from the ones located near the coast by the abundance of almost all the faunistic groups except kinorhynchs and cnidarians. We should point out

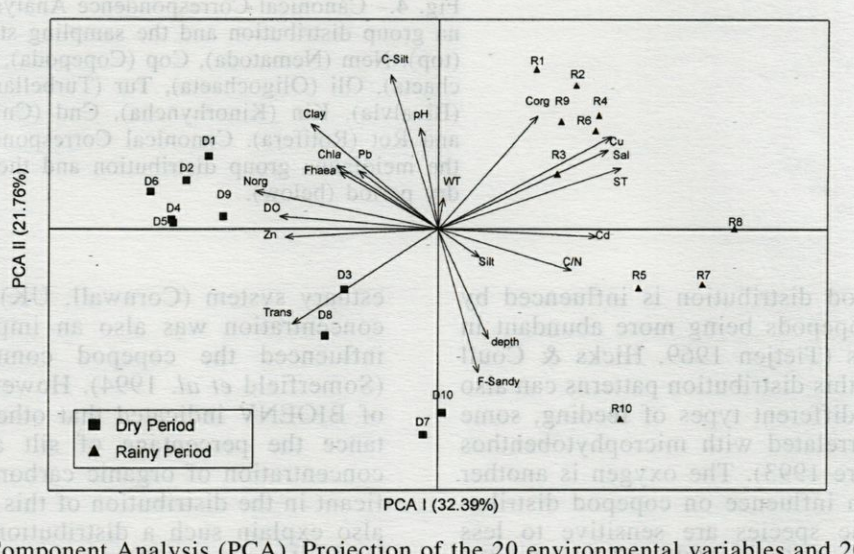


Fig. 5. – Principal Component Analysis (PCA). Projection of the 20 environmental variables and 20 sampling stations (R1-10: rainy period stations; D1-10: dry period stations) in the planes defined by the first two factorial axes (I and II). Environmental variables (vectors): water depth (depth); water temperature (WT); sediment temperature (ST); dissolved oxygen (DO); salinity (Sal); water pH (pH); water transparency (Trans); organic carbon (Corg); organic nitrogen (Norg); C/N ratios (C/N); sediment gramulometry: clay % (Clay), silt % (Silt), coarse silt % (C-Silt) and fine sand % (F-Sandy), copper (Cu), zinc (Zn), cadmium (Cd) and lead (Pb); chlorophyll *a* (Chl*a*), phaeophytin *a* (Phae*a*).

here that st 2 lies near the Jacuacanga river, receiving therefore a great amount of organic material.

During the rainy season, st 5 is near to the group of the most external stations, probably because of the low copepod number. The high values of ostracodes of st 2, 3 and 6 made these stations different from st 1 and 4.

Canonical Correspondence Analysis results show that grain size, organic carbon, depth, C/N ratio, and dissolved oxygen have a strong influence on the meiofauna distribution.

The SIMPER procedure provides evidence that the groups which contributed most to variability between the stations are nematodes, copepods, kinorhynchs, rotifers and ostracodes.

The organism abundance in the Jacuacanga Bay is higher in the rainy season, although presenting basically the same meiofauna composition observed in both seasons. In spite of this, the Principal Component Analysis (PCA) shows the evident influence of seasonal variation on the meiobenthic community mainly indicated by fluctuation of the studied physical-chemical variables, namely granulometry, dissolved oxygen, organic carbon, C/N ratio and cadmium that clearly distinguish the dry season from the rainy season.

ACKNOWLEDGEMENTS. – This research was supported by the Santa Ursula University, Rio de Janeiro, and also had a financial contribution of FAPERJ (Fundação de Amparo a Pesquisa do Estado do Rio de Janeiro). We are grateful to A Dinet for stimulating discussions and valuable advice and N Coineau, as well as to our colleagues, for critically reading the manuscript.

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Reçu le 2 janvier 2000; received January 2, 2000
Accepté le 30 mai 2000; accepted May 30, 2000