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SEASONAL COMPOSITION AND SPATIAL DISTRIBUTION OF MACROBENTHIC ASSOCIATIONS ALONG AN ESTUARINE GRADIENT IN ITANHAÉM, SÃO PAULO, BRAZIL

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ABSTRACT. Macrobenthos distribution along the salinity gradient and the pattern of species temporal changes were investigated in the Itanhaém River Estuary. Environmental variables such as grain size, sediment organic content, water salinity, water temperature and dissolved oxygen were examined as factors likely to influence the distribution of species. A total of 2130 individuals, distributed in 16 taxa (species/genera) were collected from the 12 samples obtained. The most abundant species were *Cyprideis salebrosa*, *Heteromastus similis*, *Scololepsis squamata*, *Nephtys squamosa*, *Diplodonta* sp. and *Tellina* sp. The canonical ordinations analysis indicated the presence of three benthic associations: a marine *Diplodonta* sp. - *Tellina* sp. community; a brackish water *C. salebrosa - N. squamosa* community and a wide spread *S. squamata - H. similis* community. The distribution of the estuarine macrozoobenthic species seems to be mainly controlled by salinity and the observed gradient in species compositon and dominance in the marine and brackish part of the Itanhaém River Estuary is similar to the one occurring in other mixohaline habitats of the Brazilian Southeastern Coast.

Keywords: Estuary, macrobenthos, seasonal variation, spatial distribution, Itanhaém River Estuary, Brazil.

Composición estacional y distribución espacial de asociaciones macrobentónicas en un gradiente estuarino de Itanhaém, São Paulo, Brasil

RESUMEN. La distribución de los macrobentos a lo largo del gradiente de la salinidad y el patrón de los cambios temporales de las especies fueron investigados en el estuario del Río Itanhaém. Las variables ambientales tales como tamaño de grano, contenido orgánico del sedimento, salinidad del agua, temperatura del agua y el oxígeno disuelto fueron examinados como factores que determinan la distribución de las especies. Se recolectaron un total de 2130 individuos, de 16 taxa (especies/géneros) de las 12 muestras obtenidas. Las especies más abundantes fueron *Cyprideis salebrosa*, *Heteromatus similis, Scololepsis squamata*, *Nephtys squamosa*, *Diplodonta* sp. y *Tellina* sp. El análisis canónico de correspondencia indicó la presencia de tres asociaciones bentónicas: una comunidad marina, *Diplodonta* sp. - *Tellina* sp.; una comunidad de agua salobre, *C. salebrosa - N. squamata* y una comunidad de extensión amplia, *S. squamata - H. similis*. La distribución de la especies macrozoobentónica de estuario parece ser controlada principalmente por la salinidad y el gradiente observados en composición. La dominancia de especies en las partes marina y salobre del estuario del Río de Itanhaém es similar a la de otros hábitats mixohalinos de la costa del sudeste brasileño.

Palabras claves: Estuario, macrobentos, variación estacional, distribución espacial, estuario del Río de Itanhaém, Brasil.

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INTRODUCTION

Estuarine systems constitute a proper environment for the reproduction, nursing and feeding of at least one stage of the life cycle of many species of fishes, birds and invertebrates (Muniz & Venturini, 2001). Due to the concentration of man's activities in the coastal zones, estuarine areas have been exposed to an increasing level of distress. Thus, the biological

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components of these areas should be known to assess more accurately the impact of a possible disturbance (Bachelet *et al.,* 1996; Ieno & Bastida, 1998).

Estuarine benthic communities have been characterized as having low diversity, high abundance and biomass, high resistence and resiliency due to a combination of low environmental constancy and predictability (Rainer, 1981). The distribution of benthic organisms depends on the spatial and temporal heterogeneity of physical factors, mainly salinity and bottom sediments. High abundance reflects the wide range of food resources avaiable, both from local source and imported from outside the system (Sumerhayes & Thorpe, 1996).

A coherent model of soft-substrate community organization can only be developed if questions about the relative importance of various physical and biological factors affecting the distribution of organisms along the estuarine salinity gradients were answered. For that, description of estuarine distribution pattern of soft-substrate organisms, scarce in the literature, must be attended to permit an understanding of the community dynamics (Attolini *et al*., 1997).

This paper focuses on the identification of the macrobenthos community of the Itanhaém River estuary. The description of their distribution along the salinity gradient and the pattern of species temporal changes were investigated. Environmental variables such grain size, sediment organic content, water salinity, water temperature and dissolved oxygen were examined as factors likely to influence the distribution of species.

MATERIAL AND METHODS

Study Area

The Itanhaém River basin is located in the southern region of São Paulo State (24° 11' S - 46° 48' W). It is formed at the confluence of Branco and Preto rivers, draining a considerable area of the adjacent coastal plain (Batres, 1978) and presenting low turbulence as a result of the relief declivity (Camargo & Florentino, 2000). According to Cassoli-Goya & Tessler (2000), the river plays an important role in the sedimentation dynamics of the region near its mouth. The climate of the region is classified as tropical with distinct variations in precipitation throughout the year, with an annual rainfall between 1000 mm and 2000 mm (Setzer, 1966). The river hidrological regime varies according to the seasonal pluvial variation, with higher flux in summer and lower in winter. It shows the influence of the tide regime by presenting oligohaline waters during dry periods (Camargo *et al.,* 1994).

The estuarine south margin is entirely covered by mangroves, with the presence of *Rhizophora* sp*., Laguncularia* sp*.* and *Avicennia* sp. The north margin is totally occupied by small piers of local fishermen. The first sampling station (# 1 - 24º 11´ S - 46º 47´ W), was located at the mouth of Itanhaém river, the second sampling station (# 2 - 24º 10´ S - 46º 47´ W), was located close to mangrove swamps, on the northern margin of the river, and the third sampling point (# 3 - 24º 10´ S - 46º 48´ W) was far from the sea, being surrounded by mangrove swamps. The sampling sites were spaced 1000 meters (Figure 1).

Sampling

Macrobenthos sampling was conducted seasonally, during neap tide, from May to December 2001 (autumn, winter, spring and summer), at the three sampling stations, at which two replicates were taken. The sampling gear was a van Veen´s grab, with a 625 cm^2 capacity. Each set of samples was collected in an area of about 10 m^2. Surface sediment sample was taken for evaluation of grain size and organic matter. Sediment was dried and 100 g of each sample was processed through graded sieves. Particles smaller than 63 mm were considered as the mud fraction (silt-clay). Fractions were weighted and expressed as percentage of dried weight. The percentage of organic matter was de-

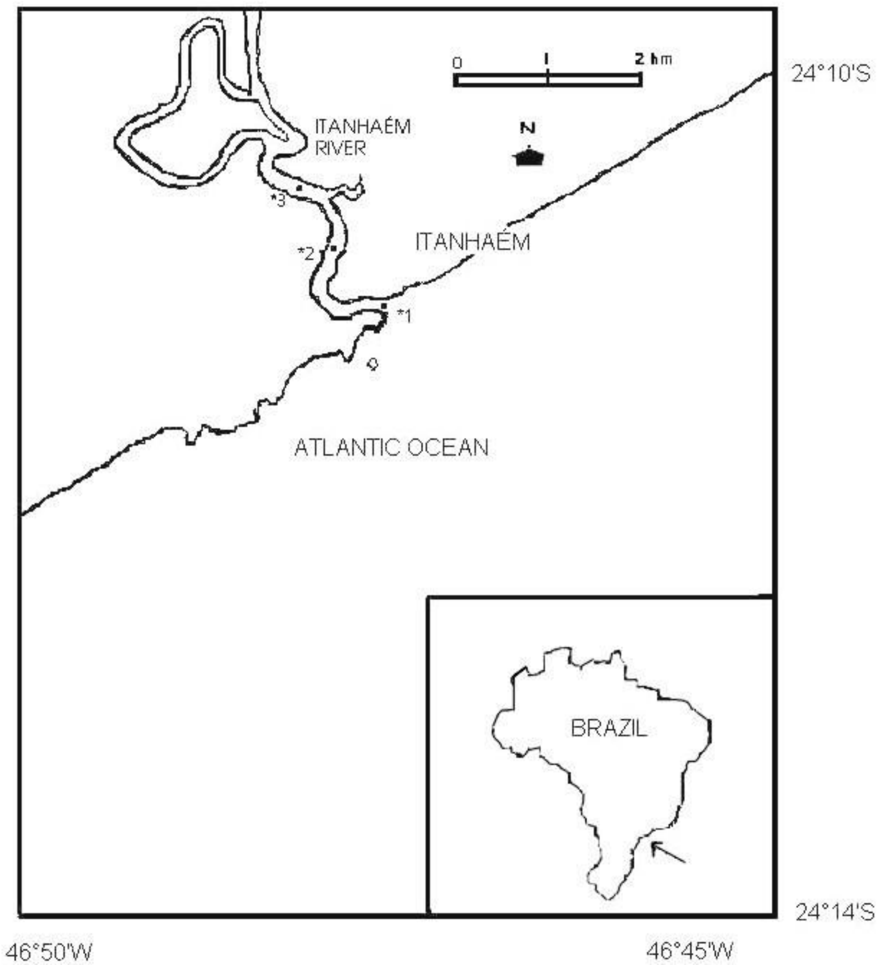

Figure 1. Study area in the Itanhaém River Estuary showing sampling stations (1 to 3).

Figura 1. Area de estudio en el estuario del Río de Itanhaém y localización de las estaciones de recolecta (1 a 3).

termined by the method described by Suguio (1973). Environmental data were obtained using Nansen bottles. Salinity, temperature and dissolved oxygen were measured at each station at 0.5 m above the bottom surface. Water and air temperatures were determined with a thermometer, salinity with a hand refractometer and dissolved oxygen was determined following Strickland & Parsons (1968). Macrobenthic samples were sieved in the laboratory through a 0.5 mm mesh, fixed in 4% buffered formalin and stained with Bengal Rose. The individuals were sorted, identified to the lowest taxon and counted.

Data analysis

The structure of the community was evaluated by the total mean number of individuals (n), species richness (s), diversity (Shannon's index, H'), eveness (Pielou index , J') and dominance (Berger-Parker index, D). Diversity, eveness and dominance were calculated using $\log_2$. Replicates were grouped, mean va- lues of species densities calculated and consi- dered as one sample. The species number was reduced following Jackson (1972), *i.e.*, counts of species with at least two individuals per sample were considered. Canonical Correspondence Analysis (CCA) (Ter Braak, 1988), was employed in order to reduce the multivariate nature of the data to a few intepretable dimensions. Log (x + 1) transformation was applied the set a standard of the raw data. Abiotic parameters such as temperature, salinity, dissolved oxygen, organic matter and sediment were used in CCA. The selection of the variables was done by Monte Carlo testing, where the variables that are most related to the species data are selected (Oug, 1998).

RESULTS

Air temperature varied from 25º C to 34º C, and was higher in autumn. Water temperature varied from 21º C to 28º C being also higher in autumn. Salinity varied from 5 PSU to 34 PSU and was higher in autumn and winter; and the data also showed the existence of an increasing gradient towards the mouth of the river. Dissolved oxygen showed higher values in spring, and pH values were stable and around 7. Bottom sediment was predominantly sand. Organic matter values were higher in autumn and winter (Table 1).

A total of 2130 individuals were collected from the 24 samples obtained, distributed in 16 taxa (species or genera) (Table 2). The ostracoda *Cyprideis salebrosa* was the most abundant species with 57% of the total, followed by the polychaeta *Heteromastus similis* (21%), *Scololepsis squamata* (9.7%) and *Nephtys squamosa* (1.7%) and the bivalves *Diplodonta* sp. and *Tellina* sp..

Diversity and eveness indices were calculated for each station (Table 3). H' ranged from 0.94 (Station 3 in summer) to 2.57 (Station 1 in autumn). Values were always higher at station 1. Eveness values varied from 0.37 (Station 3 in summer) to 0.86 (Station 1 in autumn).

Species coordinates of the CCA analysis were plotted on the basis of density data of the selected taxa. Sample and environmental parameter points were projected simultaneously in the factorial space (Figs. 2a and 2b). In the plane formed by the first and second axes (total eigen-value of 0.59) (Fig. 2) the sample scores clearly indicate a spatial separation with station 1 samples associated with higher salinity values in the right quadrant which contains *Diplodonta* sp. and *Tellina* sp. The species *H. similis* and *S. squamata* were located near the intersection of the axis, while most of the samples taken from stations 2 and 3 are located at the left quadrant and contained *C. salebrosa* and *N. squamosa*. This result suggests that salinity is the key factor determining the structure of the benthic community in the estuary, separating the marine section community from the freshwater areas.

DISCUSSION

This is the first study carried out in the estuarine region of the Itanhaém River, that investigates the macrozoobenthos along its estuarine gradient in relation to water salt content, including the freshwater tidal part. A distinct species composition has been detected along a salinity gradient in many estuaries (Mees *et al.*, 1995).

Results suggest that spatial variation caused by the salinity gradient is the most important factor responsible for the structure of the benthic assemblages in the estuarine area of the Itanhaém River (Fig. 2). The study area also showed a distinct pattern of dry and wet seasons, which influences the temporal variations of the salinity in the estuary. In summer and spring, rain lowers salinity to 5 PSU to 15 PSU, while in autumn and winter it ranges from 15 PSU to 34 PSU. The seasonality in rainfall (more from December to March, less from May to August) determine a seasonal variation in the water salinity (Camargo & Florentino, 2000). There is also a clear spatial gradient of this factor from the freshwater tidal station to that of the marine part of the estuary. The higher values of salinity registered in winter in stations 2 and 3 when compared to station 1 can be explained by tide period and sampling hour.

The canonical analysis indicated the presence of three benthic associations largely determined by the salinity gradient: a marine *Diplodonta* sp. – *Tellina* sp. assemblage, a brackish *C. salebrosa* – *N. squamosa* assemblage and a widespread (salinity tolerant) *S. squamata* - *H. similis* assemblage. *H. similis* in

Table 1. Environmental variables at each sampling point during the study period. (T – water temperature, DO – dissolved oxygen, OM – organic matter content, A – Autumn, W- Winter, S- Spring, Su – Summer).

Tabla 1. Valores medidos de variables ambientales en cada estación de muestreo durante el período de estudio. (T - temperatura del agua, OD - oxígeno disuelto, OM - contenido de materia orgánica, A - Otoño; W- Invierno, S- Primavera, Su - Verano).

Stations	Depth (m)	T (oC)	Salinity	DO (ml/l)	pH	OM (%)	Sand (%)	Silt (%)
A1	3.5	27.00	30.00	4.06	7.80	1.20	99.86	0.14
A2	2.3	27.00	26.00	5.20	8.00	1.71	95.66	4.34
A3	2.5	28.00	15.00	5.07	7.80	2.15	97.33	2.67
W1	3.0	21.00	32.00	3.06	7.00	1.36	99.00	1.00
W2	2.5	23.00	34.00	2.90	7.00	2.62	98.50	1.50
W3	3.0	21.00	34.00	3.12	7.00	1.03	98.60	1.40
S1	3.5	23.00	15.00	6.56	6.00	0.87	99.00	1.00
S2	3.0	24.00	10.00	4.45	7.00	1.25	98.00	2.00
S3	3.5	23.00	9.00	5.07	7.00	0.70	99.00	1.00
Su1	3.0	24.00	12.00	3.69	7.00	0.30	98.60	1.40
Su2	3.0	24.00	7.00	3.91	6.00	0.50	98.50	1.50
Su3	3.0	24.00	5.00	3.65	7.00	0.30	95.20	4.80

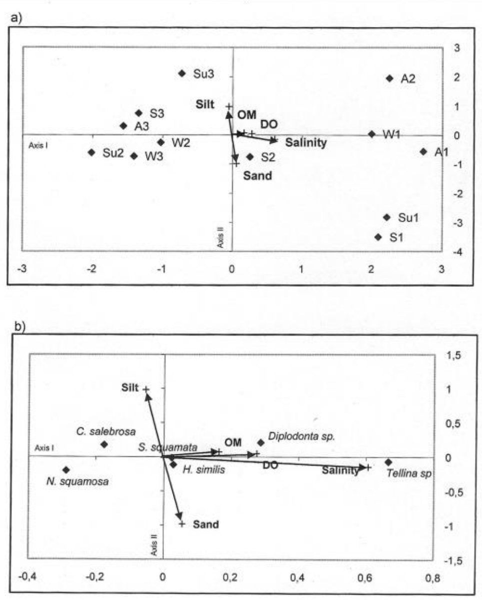

Figure 2. Canonical Correspondence Analysis. a) sample scores and environmental variables, b) species scores and environmental variables. (1-3 numbers of stations, A - autumn, W - winter, Su- summer, S- spring, OM = organic matter, DO = dissolved oxygen).

Figura 2. Análisis de correspondencia canónica. a) puntuaciones de muestras y variables ambientales, b) puntuaciones de especies y variables ambientales. (1-3 números de estaciones, A - otoño, W - invierno, Su - verano, S – primavera, ;

Table 2. Numerical abundance (inds./625cm^2) of the species sampled at Itanhaém estuary.

Tabla 2. Abundancia numérica (inds. /625cm^2) de las especies recolectadas en el estuario de Itanhaém.

Stations	A1	A2	A3	W1	W2	W3	S1	S2	S3	Su1	Su2	Su3
Capitella sp.			2	6			3				5	
Glycera sp.										1		
Heteromastus similis	9	11	26	41	28	118	10	51	39	11	67	35
Magelona sp.											4	
Nephtys cf. *squamosa*	1		5	1	5	24		10	11		34	3
Ophelina sp.	1			6								
Parandalia americana								1				
Scololepis squamata	11	24	1	20	42	1	5	4	5	35	23	37
Diplodonta sp.	4	6	1	4	1	3		2	3			7
Tellina sp.	5	13		10			1	4		2		
Assiminea sp.	5	2		1	2			3	5			
Cyprideis salebrosa	1	48	49	13	30	62		37	172		417	395
Eurydice littoralis							1			16	1	1
Cheiriphotis sp.					1							
Phoxocephalopsis zimmeri							1					
Caprella penantis							2					

particular, was a very abundant species in both the marine and the brackish part of the estuary (Table 2). It should be noted that *H. similis* has been reported as characteristic of unpredictable environments and tending to display a wide fluctuation in abundance throughout the year in South American estuaries. The sharp dominance exhibited by *H. similis*, with seasonal peaks followed by sharp declines in densities denotes an opportunist strategy (Ieno & Bastida, 1998; Bemvenuti, 1987). The observed disposition in species composition and dominance in the marine and brackish part of the Itanhaém estuary is similar to those occurring in other mixohaline habitats of nearby regions (Bemvenuti, 1987; Capitoli *et al*., 1978; Lana *et al*., 1989; Muniz & Venturini, 2001)

Itanhaém river estuary classifies as category I in the sense of Whitfield (1992). These estuaries receive relatively high inputs of freshwater, and fluctuations in salinity are more extreme because of variations in freshwater inflow. Diversity is low because the conditions are challenging for most species. Fluctuations in freshwater inflow associated to anthropogenic factors are likely to play a role in the maintenance of low values of diversity (Teske & Wooldridge, 2001). The low species richness and diversity values recorded here for the Itanhaém river estuary have also been recorded previously for

Table 3. Diversity (H'), evenness (J') and dominance (D) at each station and season (A – Autumn, W – Winter, S – Spring, Su - Summer).

Tabla 3. Diversidad (H'), uniformidad (J') y dominancia (D) en cada estación de muestreo y estación del año. (A – Otoño, W – Invierno, S – Primavera, Su - Verano).

Stations	H'	J'	D
A1	2.57	0.86	0.30
A2	2.07	0.80	0.46
A3	1.50	0.58	0.58
W1	2.49	0.79	0.40
W2	1.98	0.71	0.39
W3	1.47	0.63	0.57
S1	2.28	0.81	0.44
S2	2.00	0.67	0.46
S3	1.28	0.50	0.73
Su1	1.66	0.72	0.54
Su2	1.24	0.44	0.76
Su3	0.94	0.37	0.83

many estuarine regions along the Brazilian coast (Wakabara *et al.,* 1993; Tararam *et al*., 1996; Wakabara *et al.,* 1996; Ribeiro *et al.,* 1997; Pascual *et al*., 2002). The low values of diversity are associated to a high numerical abundance of a few species, *H. similis* and *C. salebrosa*, as well as to low species richness. The observed pattern in species dominance in the marine and brackish part of the Itanhaém estuary is comparable to other estuaries throughout the world (Ysebaert *et al.,* 1993).

In conclusion, distribution of the estuarine macrobenthos species seems to be mainly controlled by salinity, and the observed gradient in species composition and dominance in the marine and brackish part of the Itanhaém estuary is similar to those occurring in other mixohaline habitats of nearby regions.

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