Revista de Biología Marina y Oceanografía
Vol. 46, Nº1: 17-25, abril 2011
Article

Composition and spatial distribution of the benthic macrofauna in the Cachoeira River estuary, Ilhéus, Bahia, Brazil

Composición y distribución espacial de la macrofauna bentónica en el estuario del Río de Cachoeira, Ilhéus, Bahía, Brasil

Thailla M. Ourives[1], Alexandra E. Rizzo[2] and Guisla Boehs[1]

[1]Universidade Estadual de Santa Cruz (UESC), Departamento de Ciências Biológicas, Programa de Pós-Graduação em Sistemas Aquáticos Tropicais, Rodovia Ilhéus-Itabuna, km 16, 45650-900 Ilhéus, Bahia, Brasil. gboehs@uesc.br
[2]Universidade do Estado do Rio de Janeiro (UERJ), IBRAG, Departamento de Zoologia, Rua São Francisco Xavier, 524, Maracanã, 20.550-013, Rio de Janeiro, Brasil

Resumen.- En este estudio se analizó la composición y la distribución espacial del macrobentos en el estuario del río Cachoeira, Ilhéus, Bahía, Brasil. Las muestras fueron recolectadas cada dos meses desde julio de 2008 a mayo de 2009 en seis estaciones de muestreo. En total, se recogieron 613 individuos pertenecientes a 71 taxa. Los gasterópodos mostraron la mayor riqueza y abundancia, seguidos por los poliquetos. La distribución del macrobentos fue influenciada por la salinidad y los parámetros de sedimentos. En la parte externa del estuario fueron abundantes los microgastrópodos, el bivalvo *Donax gemmula* y el poliqueto *Drilonereis* sp. En la desembocadura predominaron gasterópodos carnívoros *Olivella minuta* y *Anachis obesa* y pastoreadores *Neritina virginea* y *Littorina ziczac*. Predominaron en la zona intermedia el poliqueto *Hemipodia californiensis* y en el sector interno bivalvos eurihalinos *Tellina* sp., *Anomalocardia brasiliana* y *Tagelus plebeius* y los poliquetos depositívoros *Heteromastus filiformes* y *Capitella* cf. *capitata*. Características de salinidad, sedimentos, y hábitos alimentarios son importantes en la composición y distribución de los organismos en este estuario.

Palabras clave: Bentos, ecología, noreste de Brasil

Abstract.- We analyzed the composition and spatial distribution of macrobenthos in the Cachoeira River estuary, Ilhéus, Bahia, Brazil. Samples were taken bimonthly from July 2008 to May 2009 at six stations along the estuary. In total, 613 individuals belonging to 71 taxa were collected. Molluscs showed the highest richness and abundance, followed by polychaetes. The spatial distribution of macrobenthos was influenced by salinity and by sediment characteristics. In the outer area microgastropods, the bivalve *Donax gemmula,* and the polychaete *Drilonereis* sp., were conspicuous. In the river mouth, the carnivorous gastropods *Olivella minuta* and *Anachis obesa* and the algal grazers *Neritina virginea* and *Littorina ziczac* predominated. In the middle estuary, there was a predominance of the polychaete *Hemipodia californiensis*. The euryhaline bivalves *Tellina* sp., *Anomalocardia brasiliana,* and *Tagelus plebeius* and the deposit-feeding polychaetes *Heteromastus filiformis* and *Capitella* cf. *capitata* were predominant in the inner estuary. Salinity, sediment characteristics, and dietary habits were important in the composition and distribution of organisms in this estuary.

Key words: Benthos, ecology, Brazilian northeast

Introduction

Because of their high productivity and allochthonous organic-matter input, estuarine systems are hospitable for feeding and reproduction of many species of fish and invertebrates, in at least one stage of life (Day *et al*. 1989). The benthos includes a set of animals belonging to a variety of invertebrate groups including polychaetes, molluscs, crustaceans, and nemertine worms, and which have direct relationships with consolidated or unconsolidated bottoms. These organisms act to aerate and remobilize sediment, promote decomposition and nutrient cycling, and transfer energy to other components of the food web (Tenore *et al.* 1984, Schaffner *et al.* 1987, Hutchings 1998). They regulate and alter the physical, chemical, and biological agents, and therefore have a strong structuring effect (Day *et al.* 1989).

Because of the wide range of physiological tolerance, feeding habits and trophic interactions of its component organisms, the benthos responds to various types of environmental stresses (Pearson & Rosenberg 1978) and natural (Canfield *et al.* 1994, Teske & Wooldridge 2003) and anthropogenic changes (Brown *et al.* 2000, Hatje *et al.* 2008), which makes this community a good indicator of biological characteristics and environmental conditions.

In estuaries, the spatial and temporal distribution of the macrobenthos is related to changes in freshwater flow and salinity (Salen-Picard & Arlhac 2002, Rozas *et al.* 2005), nutrient input and primary production (Heip *et al.* 1995), sediment particle size (Snelgrove & Butman 1994, Mannino & Montagna 1997, Kendall & Widdicombe 1999), periodic sediment anoxia (Diaz & Rosenberg 1995) and the presence of grasses and seaweed (Hyndes *et al*. 2005). The distribution of the macrobenthos may also be influenced by anthropogenic biotic processes such as organic enrichment (Surugiu 2005) and contamination by toxic compounds and heavy metals (Brown *et al*. 2000, Hatje *et al*. 2008).

In Brazil, research on estuarine macrobenthos has been concentrated in the south and southeast, e.g. the studies of Rosa-Filho & Bemvenuti (1998), Yamamuro (2000), Arasaki *et al.* (2004), Angonese (2005), and Rosa & Bemvenuti (2006). Fewer investigators have worked in the estuaries of northeastern Brazil. For example, on the coast of Bahia, there are studies of Barroso *et al.* (2002), Venturini & Tommasi (2004), and Alves *et al.* (2006) in Todos os Santos Bay; Barros *et al.* (2008) in the estuary of the Paraguaçu River; and Hatje *et al.* (2008) in Camamu Bay. In the estuary of the Cachoeira River, located in southern Bahia, Almeida *et al.* (2006) conducted an inventory of decapod crustaceans, with a taxonomic approach. Studies on human impacts in this region were carried out by Severo (1999) and Fontes *et al.* (2009). This estuary receives domestic and industrial sewage from two cities in southern Bahia, Itabuna and Ilhéus, each with about 300,000 inhabitants. Ilhéus, in addition to many diffuse sources of pollution, has a sewage treatment plant located in the upper estuary, which according to Fontes *et al.* (2009), after primary treatment, still discharges an effluent rich in nutrients. Nevertheless, many species of fish and shellfish are harvested in the region, providing basic food and income for coastal communities. This study aimed to analyze the composition and spatial distribution of the macrobenthos in this estuarine system.

Materials and methods

The estuary of the Cachoeira River, located at 14°46'-14°50'S and 39°05'-39°01'W, with an area of about 16 km^2, is formed by the Cachoeira, Santana, and Fundão rivers and is bordered by the city of Ilhéus (Torres *et. al* 2001[1]) (Fig. 1). Mangroves are a dominant feature in the region, which has a humid tropical climate, with no defined dry season, rainfall over 60 mm in the driest month, and an annual rainfall of 1400 mm (Klumpp *et al.* 2002).

Samples were taken bimonthly from July 2008 through May 2009 at five sampling stations (St1-St5), established along the estuary of the Cachoeira River, and one (St6) in front of the river mouth (Fig. 1), with depths between 1.5 and 5 m. At each sampling station, we obtained five sediment samples for macrofauna and one for organic matter and particle size, using a van Veen grab with an area of 0.12 m^2, during flood and high tides. With the aid of a van Dorn bottle, water samples were collected near the bottom for the measurements of temperature and salinity, taken aboard a boat with a standard mercury thermometer and an Atago S/Mill manual refractometer, respectively. Rainfall data for this period were obtained from the Executive Commission Plan of Cocoa Farming - CEPLAC, in Ilhéus.

The sediment was washed over sieves with meshes of 0.5 and 1.0 mm, and the macrofauna retained were fixed in 4% formaldehyde, preserved in 70% ethanol, and then identified and counted. Part of the biological material is stored in the Laboratory of Marine Molluscs of the State University of Santa Cruz (UESC), and another part is deposited in the Museum of Zoology, University of São Paulo (MZUSP, São Paulo). The organic-matter content of sediment was estimated by the method described by Dean (1974). The particle-size analysis was done by the sieving method described by Suguio (1973) and classified according to Folk & Ward (1957), with the values expressed on the phi scale (Φ), the base 2 negative logarithm of the size in mm. The statistical parameters of particle size were calculated using the program SYSGRAN 2.0. The index of constancy was used to classify the frequency of occurrence of species in the samples (Dajoz 1971). One-factor analysis of variance (ANOVA) and an *a posteriori* LSD (Least Square Difference) test were used to compare the variation of abiotic factors (temperature, salinity, grain size, organic matter, and percentage of fine granules) and biotic (species richness and abundance) among sampling stations. For

[1]Torres MLG, NC Rego, F Geuz, MC Levy & M Moreau. 2001. Programa de Recuperação das Bacias dos Rios Cachoeira e Almada Diagnóstico Regional. Núcleo de Bacias Hidrográficas da UESC, Superintendência de Recursos Hídricos do Estado da Bahia. Technical Report BAHIA/SRH/UESC 1(4) Ilhéus.

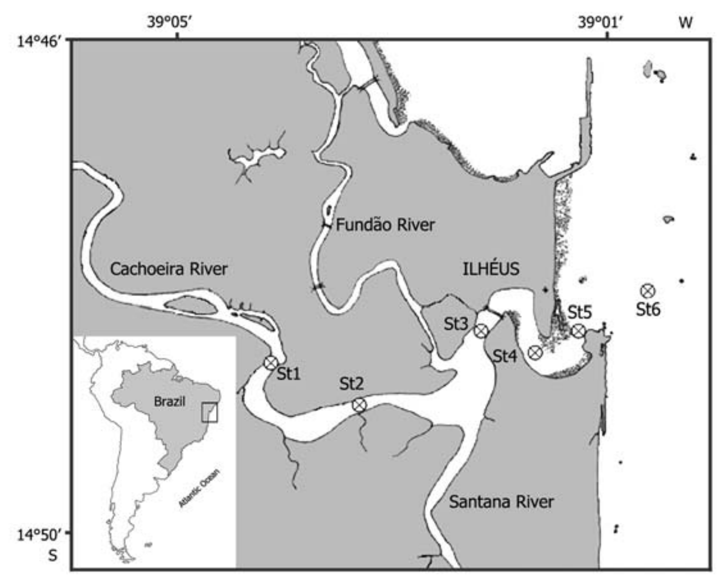

Figure 1. Map of study area indicating the sampling stations (St1-St6) along the Cachoeira River estuary, Brazil / Mapa del área de estudio con las estaciones de muestreo (St1-St6) a lo largo del estuario del río Cachoeira, Brasil

analysis we used the STATISTICA 6.0. The spatial distribution of the most abundant species (abundance greater than 2%) in relation to abiotic factors with spatial variation ($P < 0.05$) was assessed by Pearson correlation analysis and visualized by a principal components analysis (PCA), using the PRIMER v5. Data on the number of individuals were previously transformed by log (x+1). For all analyses, we used the 95% significance level.

RESULTS

The water temperature varied between 20°C (St3) and 29°C (St1), and was significantly different ($F_{(5, 27)} = 4.55$, $P = 0.003$) between the inner (St1-St3) and outer stations (St4-St6) (Fig. 2A). This difference was related to the shallower depths of the inner area, and the greater tidal influence on the outer estuary. The salinity, which ranged between 3 (St1) and 37 (St5), decreased toward upstream, and varied significantly ($F_{(5, 27)} = 11.25$, $P < 0.001$) (Fig. 2B). The organic-matter content, ranging between 0.04% and 7.1%, was higher at St1 compared to the other sampling sites, except St6; the other stations had similar levels of organic matter ($F_{(5, 27)} = 1.66$, $P = 0.177$) (Fig. 2C). The highest organic-matter content (7.1%) was measured in November 2008, at a time of low rainfall. The sediment was sandy-silty, with a percentage of sand between 67.8% and 99.8%. The entire sector was characterized by the predominance of very fine sand (Φ between 3 and 4) and medium sand (Φ between 1 and 2). Coarse sand (Φ between 0 and 1) predominated, in some periods, only at St6. The textural changes were not significant ($F_{(5, 27)} = 0.33$, $P = 0.886$) along the estuary profile (Fig. 2D). Similarly to the organic-matter content, the highest proportion of fine sediments (silts and clays) was observed at St1, similarly ($P > 0.05$) for St6, and different from the other stations ($F_{(5, 27)} = 2.55$, $P = 0.051$) (Fig. 2E). The highest content of fine sediments (32%) was measured in St1 in January 2009, after a period of heavy rainfall (over 200 mm).

In total, 613 individuals were collected, belonging to 71 taxa. The molluscs showed the highest richness (46 taxa: 26 gastropods and 20 bivalves) and abundance (63.6%), followed by polychaetes, with 23 species and 32.1% of the total abundance of macrofauna. We also observed one species each of nemertean worm, echinoderm, and crustacean, totaling 4.3% of the macrobenthos. The most abundant organisms were: *Tellina* sp., *Olivella minuta*, *Heteromastus filiformis*, *Hemipodia californiensis*, *Capitella* cf. *capitata*, *Anomalocardia brasiliana*, *Tagelus plebeius*, *Littorina ziczac*, *Anachis obesa*, Nemertea, *Drilonereis* sp., *Onuphis* sp., *Neritina virginea*, *Mactra constricta*, and *Tricolia affinis*. These taxa accounted for 70% of the total individuals. Regarding the frequency of occurrence in the samples, only the polychaetes *H. californiensis* and *C.* cf. *capitata* and

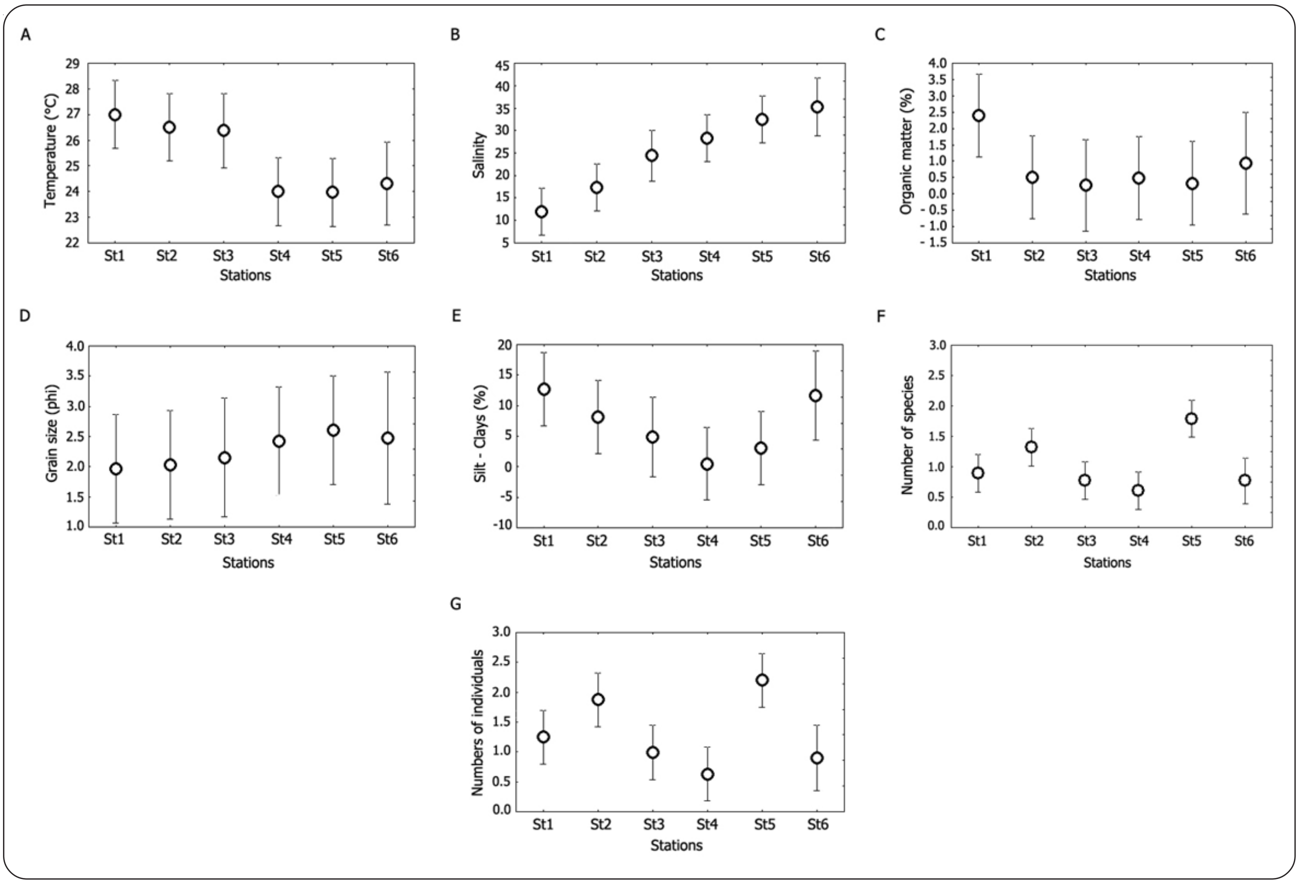

Figure 2. Means of abiotic factors, number of species and individuals along the estuary of the Cachoeira River and the adjacent area (Ilhéus, Bahia, Brazil), from July 2008 through May 2009. (A) temperature, (B) salinity, (C) organic matter, (D) grain size, (E) silt-clays, (F) number of species, (G) number of individuals. Richness and abundance data were square-root-transformed. Vertical bars: 0.95 confidence intervals / Promedios de los factores abióticos, número de especies e individuos a lo largo del estuario del río Cachoeira y el área adyacente (Ilhéus, Bahía, Brasil), desde julio de 2008 a mayo 2009. (A) temperatura, (B) salinidad, (C) materia orgánica, (D) tamaño de grano, (E) limo-arcillas, (F) número de especies, (G) número de individuos. Los valores de la riqueza y abundancia fueron transformados por la raíz cuadrada. Barras verticales: 0,95 intervalos de confianza

the nemertean were classified as constant, *i.e.*, occurring in more than 76% of the samples. The bivalves *Tellina* sp., *Ventricolaria* sp., *A. brasiliana,* and *Protothaca pectorina* were very common (constancy between 51 and 75%). Thirty-seven percent of the species were classified as common (frequency between 26 and 50%) and 53.4% as uncommon (13-25%). There were no rare species (less than 12% frequency) (Table 1).

The sampling stations differed significantly ($F_{(5, 164)}$ = 8.02, $P < 0.05$) in both the richness and abundance of macrofauna. St5 had the highest richness and abundance, followed by St2, and both differed significantly ($F_{(5, 164)}$ = 8.02, $P < 0.001$; $F_{(5, 164)}$ = 6.86, $P < 0.001$), respectively) from the other points (Table 1, Figs. 2F, G). The capitellid polychaetes *C.* cf. *capitata* and *H. filiformis*, and the bivalves *Tagelus plebeius*, *Tellina* sp., and *A. brasiliana* were dominant in the inner area of the estuary (St1 and St2) and were negatively correlated with salinity (Table 2). Also, both *H. filiformis* and *C.* cf. *capitata* were more abundant in collections from January and March 2009, made after periods of heavy rainfall in summer. Prominent species in the area of the mouth (St5) included the gastropods *T. affinis*, *N. virginea*, *L. ziczac*, and *A. obesa*, all positively correlated with salinity (Table 2). In the adjacent area (St6), the polychaetes *Onuphis* sp. and *Drilonereis* sp. were prominent. *Olivella minuta* was abundant at both St5 and St6. Nemertea gen. sp. occurred throughout the estuary, but was not found at St6. The polychaete *H. californiensis* and the bivalve *M. constricta* were important at the middle stations (St3 and St4), and were negatively correlated with organic matter and fine granules (Table 2). The projection plot of PCA, based on the most abundant species and main

Table 1. Composition, spatial distribution, constancy (C) and abundance (A) of macrobenthos in the estuary of the Cachoeira River, Ilhéus, Bahia, Brazil, between July 2008 through May 2009. CS = constant, VC = very common, CM = common, UN = uncommon / Composición, distribución espacial, constancia (C) y abundancia (A) del macrobentos en el estuario del río Cachoeira, Ilhéus, Bahía, Brasil, entre julio de 2008 hasta mayo de 2009. CS = constante, VC = muy común, CM = común, UN = poco común

Taxa	Stations						C	A	(%)
	St1	St2	St3	St4	St5	St6			
Phylum Nemertea									
Nemertea (undetermined species)	3	9	2	1	4		CS	**19**	3,1
Phylum Annelida									
Class Polychaeta									
Orbiniidae gen. sp. Hartman, 1942	3						IN	3	0,5
Malacoceros sp. Quatrefages, 1843			1				IN	1	0,2
Scolelepis sp. Blainville, 1828					3		IN	3	0,5
Magelona sp. (Müller, 1858)		1				7	CM	8	1,3
Cirratulidae gen. sp. Carus, 1863		1				4	CM	5	0,8
Capitella cf. *capitata* (Blainville, 1828)	13	13	1		1	1	CS	**29**	4,7
Heteromastus filiformis (Claparède, 1864)	9	39			2		CM	**50**	8,1
Phyllodocidae gen. sp. Williams, 1851				1			IN	1	0,2
Polynoidae gen. sp. Malmgren, 1867		1				1	CM	2	0,3
Sigalionidae gen. sp. Malmgren, 1867						1	IN	1	0,2
Sigambra sp. (Müller, 1858)			2				IN	2	0,3
Laeonereis acuata Treadwell, 1923					1		IN	1	0,2
Neanthes succinea (Frey and Leuckart, 1847)	1	1					CM	2	0,3
Nereididae gen. sp. Johnston, 1845	3						IN	3	0,5
Hemipodia californiensis (Hartman, 1938)	3	1	10	10	7	2	CS	**33**	5,4
Glycinde multidens F. Müller, 1858	6	5	1				CM	12	2,0
Nephtys sp. (Cuvier, 1817)						1	IN	1	0,2
Onuphis sp. Audouin and Milne-Edwards, 1833	2					15	CM	**17**	2,8
Lumbrineris sp. Blainville, 1828					1		IN	1	0,2
Drilonereis sp. Claparède, 1870		5				15	IN	**20**	3,3
Owenia sp. Delle Chiaje, 1841						1	IN	1	0,2
Melinna sp. Malmgren, 1866	1						IN	1	0,2
Phylum Mollusca									
Class Gastropoda									
Tegula viridula (Gmelin, 1791)					1		IN	1	0,2
Tricolia affinis (C. B. Adams, 1850)				1	11		CM	12	2,0
Nerita sp. (Linnaeus, 1758)					1		IN	1	0,2
Neritina virginea (Linnaeus, 1758)	1				16		CM	**17**	2,8
Littorina ziczac (Gmelin, 1791)					18	3	CM	**21**	3,4
Rissoina bryerea (Montagu, 1803)					3		IN	3	0,5
Cerithium atratum (Born, 1778)					2		IN	2	0,3
Bittium varium (Pfeiffer, 1840)					7		IN	7	1,1
Cerithiopsis emersoni (C. B. Adams, 1838)					2		IN	2	0,3
Seila adamsi (H. Lea, 1845)					1	1	CM	2	0,3
Triphora sp. Blainville, 1828					2		IN	2	0,3
Epitonium sp. Roding, 1798						1	IN	1	0,2
Anachis catenata Sowerby, 1844					3		IN	3	0,5
Anachis sertulariarum (Orbigny, 1841)					4		IN	4	0,7
Anachis obesa (C. B. Adams, 1845)				2	15	3	CM	**20**	3,3
Mitrella argus Orbigny, 1842					1		IN	1	0,2
Mitrella lunata (Say, 1826)					1		IN	1	0,2
Olivella minuta (Link, 1807)				1	28		CN	1	8,8
Nannodiella vespuciana (Orbigny, 1842)						1	IN	1	0,2
Brachycytara sp. Woodring, 1928			1		2	2	CM	5	0,8
Cryoturris sp. Woodring, 1928					1		IN	1	0,2
Terebra sp. Bruguiere, 1789					4	1	CM	5	0,8
Pyramidella sp. Lamarck, 1799						1	IN	1	0,2
Odostomia sp. Fleming, 1813					1		IN	1	0,2
Turbonilla krebsii (Mörch, 1875)					1		IN	1	0,2
Turbonilla sp. Risso, 1826					5		IN	5	0,8
Class Bivalvia									
Nucula cf. *semiornata* Orbigny, 1846						1	IN	1	0,2
Brachidontes sp. Swainson, 1840			1		2		CM	3	0,5
Lucina pectinata (Gmelin, 1791)	1	4	1				CM	6	1,0
Crassinela sp. Guppy, 1874						1	IN	1	0,2
Laevicardium sp. Swainson, 1840		1					IN	1	0,2
Mactra constricta (Woods, 1850)			13	1	1		CM	**15**	2,4
Tellina sp. Linnaeus, 1758	35	33	19			4	MC	**91**	14,8
Tellina versicolor De Kay, 1843			1				IN	1	0,2
Strigilla carnaria (Linnaeus, 1758)				2		4	CM	6	1,0
Semele purpurasceus (Gmelin, 1791)			1	1			CM	2	0,3
Ervilia sp. (Turton, 1822)				1			IN	1	0,2
Heterodonax bimaculata (Linnaeus, 1758)			1		4	1	CM	6	1,0
Tagelus plebeius (Lightfoot, 1786)	4	16			1		CM	**21**	3,4
Donax cf. *gemmula* Morrison, 1971				2		5	CM	7	1,1
Iphigenia brasiliana (Lamarck, 1818)		1	4		2		CM	7	1,1
Ventricolaria sp. Keen, 1854	1	4	4		2		MC	11	1,8
Anomalocardia brasiliana (Gmelin, 1791)	2	16	4		1		MC	**23**	3,7
Protothaca pectorina (Lamarck, 1818)	1	5			1	1	MC	8	1,3
Corbula sp. Bruguière, 1797	2	2					CM	4	0,7
Martesia cuneifomis (Say, 1922)					1		IN	1	0,2
Phylum Crustacea									
Isopoda (undetermined species)			2		1		CM	3	0,5
Phylum Echinodermata									
Ophiuridae (undetermined species)						4	IN	4	0,7
Species richness	18	19	18	11	40	28		71	
Abundance	91	158	69	23	165	107		613	

Table 2. Coefficients (r) obtained by Pearson correlation analysis between abiotic factors (salinity, organic matter and fine sediments) and the most abundant species in the estuary of the Cachoeira River, Ilhéus, Bahia, Brazil / Coeficientes (r), obtenidos por análisis de correlación de Pearson entre factores abióticos (salinidad, materia orgánica y sedimentos finos) y las especies más abundantes en el estuario del río Cachoeira Brasil, Ilhéus, Bahía, Brasil

	Factors and species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Salinity																	
2	Organic matter	**-0,62**																
3	Silt-clays	-0,43	**0,76**															
4	NE	**-0,59**	-0,09	0,06														
5	Cc	**-0,90**	**0,62**	**0,60**	**0,69**													
6	Hf	**-0,59**	0,04	0,26	**0,92**	**0,78**												
7	HC	0,35	**-0,50**	**-0,83**	-0,44	**-0,69**	**-0,62**											
8	On	0,43	0,21	**0,57**	-0,49	-0,21	-0,26	-0,44										
9	Dr	0,37	0,02	**0,54**	-0,16	-0,07	0,08	**-0,65**	**0,91**									
10	Nv	0,38	-0,23	-0,34	0,12	-0,26	-0,20	0,16	-0,23	-0,29								
11	Lz	**0,51**	-0,28	-0,28	0,04	-0,35	-0,25	0,11	-0,06	-0,12	**0,98**							
12	Ao	**0,57**	-0,31	-0,37	-0,01	-0,42	-0,30	0,17	-0,06	-0,12	**0,96**	**0,99**						
13	Mc	0,07	-0,40	-0,30	-0,20	-0,35	-0,30	**0,61**	-0,27	-0,32	-0,15	-0,18	-0,21					
14	Te	**-0,93**	**0,54**	**0,58**	**0,58**	**0,91**	**0,67**	**-0,50**	-0,26	-0,14	-0,42	**-0,56**	**-0,61**	0,04				
15	Tp	**-0,60**	0,05	0,23	**0,92**	**0,79**	1,00	**-0,63**	-0,27	0,07	-0,19	-0,24	-0,29	-0,31	**0,68**			
16	1b	**-0,51**	-0,16	0,14	**0,91**	**0,65**	**0,95**	-0,46	-0,33	0,04	-0,23	-0,28	-0,34	-0,02	**0,65**	**0,95**		
17	Om	**0,75**	-0,18	0,03	-0,26	-0,43	-0,37	-0,14	**0,54**	0,46	**0,67**	**0,79**	**0,79**	-0,30	**-0,65**	-0,37	-0,42	
18	Ta	0,44	-0,31	-0,43	0,09	-0,33	-0,22	0,23	-0,25	-0,30	**0,99**	**0,97**	**0,98**	-0,15	**-0,50**	-0,22	-0,25	**0,66**

Abbreviations of species /abreviaciones de las especies: Ab = *Anomalocardia brasiliana*, Ao = *Anachis obesa*, Cc = *Capitella* cf. *capitata*, Dr = *Drilonereis* sp., Hc = *Hemipodia californiensis*, Hf = *Heteromastus filiformis*, Lz = *Littorina ziczac*, Mc = *Mactra constricta*, Ne = Nemertea n. id., Nv = *Neritina virginea*, Om = *Olivella minuta*, On = *Onuphis* sp., Ta = *Tricolia affinis*, Te = *Tellina* sp., Tp = *Tagelus plebeius*

abiotic factors (Fig. 3) showed that the variables projected on the right of the graph were influenced by the ocean (St5, St6), whereas the left reflected the continental effects (St1, St2) on the spatial distribution of benthic macrofauna.

Discussion

The results revealed marked differences in richness, abundance, and distribution of macrofauna along the sampling stations. These differences appeared to be related primarily to the salinity gradient of the system and secondarily to the sediment parameters, such as the contents of organic matter and fine sediments, as well as the feeding habits of the benthos. There were no characteristic freshwater species, and the marine-stenohaline species contingent was prominent, showing the influence of the entry of seawater into the system and the importance of salinity for the distribution of organisms. The bivalves *Tagelus plebeius*, *Anomalocardia brasiliana*, and *Lucina pectinata*, typically euryhaline (Boehs *et al*. 2004) although widely distributed, were more numerous at the inner, less saline stations.

Sediment characteristics and dietary habits are also reported as important in the distribution of benthos (Whitlatch 1981). The trophic distribution observed in this study was similar to those observed by Muniz & Venturini (2001) and Barroso (2002), in particular the relationship of carnivorous species with organic poor, filtering sand bottoms, and of detritivores with greater sedimentation and accumulation of debris. In the present study, the carnivorous gastropods *Anachis obesa* and *Olivella minuta* and the algae grazers *Neritina virginea*, *Littorina ziczac*, and *Tricolia* sp. were most conspicuous near the mouth (St5), which was probably related to greater food availability at that location. In this respect, bivalves were more widely distributed in the estuary than gastropods, as also found in a study in Paranaguá Bay in southern Brazil (Boehs *et al*. 2004). Fauchald & Jumars (1979) considered that carnivorous polychaetes generally occur more commonly in substrates with a predominance of sand, enabling greater penetration of oxygen into the sediment as well as greater ease of movement of these animals. In this study, the sediment composition (high percentage of sand, low percentage of

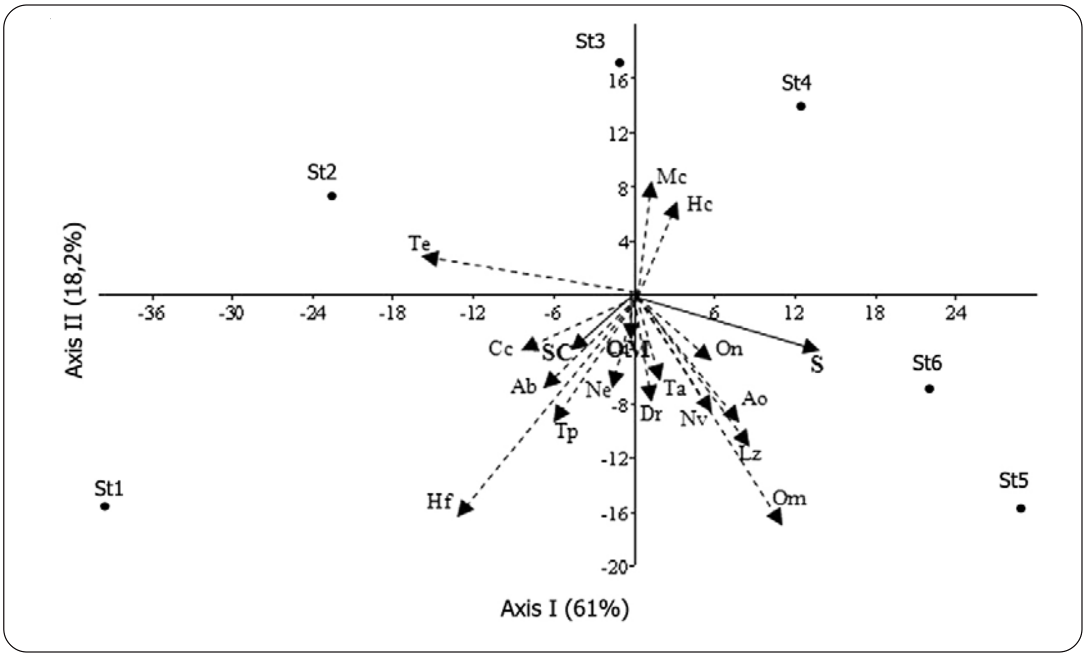

Figure 3. Graphical result of principal components analysis (PCA) with the projection of the vector-variables (abiotic factors and species) and observations (sampling stations: St1-St6) on factorial plans. Abbreviations as in Table 1 / Gráfico del análisis de componentes principales (ACP) con la proyección del vector de las variables (factores abióticos y especies) y las observaciones (estaciones de muestreo: St1-St6) sobre los planos factoriales. Abreviaciones como en la Tabla 1

fine granules) in the area of the mouth (St5) probably acted as an adjuvant factor in the occurrence of several carnivorous species at this site, both polychaetes and molluscs. The high organic-matter content and the finer sediment in the inner estuary (St1) probably account for the occurrence of deposit-feeding species at this location, such as the capitellids *Capitella* cf. *capitata* and *Heteromastus filiformis*. These species were more abundant during periods of high rainfall (January to March 2009). This may be related to the input of debris from the surrounding mangroves, carried in by the rains, to the riverbed. It is likely that this site was stressed by the heavy rains in these summer months, becoming unstable and conducive to the establishment of r-strategist species such as those mentioned above. These polychaetes are known as opportunistic and indicators of organically enriched environments (Pearson & Rosenberg 1978, Surugiu 2005). *Hemipodia californiensis* constructs semi-permanent galleries in unconsolidated sediments, and its prevalence in the middle part of the estuary (St3 and St4) is probably due to greater sediment stability as indicated by the predominance of very fine sand in this location, but also because the salinity is closer to that of sea water than at the upstream stations. According to Böggemann (2002), *H. californiensis* is probably carnivorous, feeding on small crustaceans and other polychaetes, as do other glycerids. It is very common on fine and very fine sand beaches; is found from California to Peru, and from Rio de Janeiro (Brazil) to Argentina, from the intertidal to 100 m depth (Rizzo *et al.* 2002). The present record is the first of this species from northeastern Brazil.

The richness of macrobenthic organisms in the estuary of the Rio Cachoeira as estimated in this study (n = 71) is higher than that found in the estuary of the Paraguaçu River (n = 62) by Barros *et al.* (2008) and lower than that in Camamu Bay (n = 115) recorded by Hatje *et al.* (2008), both studies conducted in the state of Bahia, Brazil. For marine benthic macrofauna, polychaetes are usually the group with the highest relative abundance, followed by molluscs and crustaceans (Oliver & Mackie 1996). This pattern was not observed in this study, since there was a predominance of richness and abundance of molluscs over the other groups. The large number of microgastropods collected in the outer estuary (St6) explains, in part, the dominance of molluscs.

In conclusion, salinity, sediment characteristics, and dietary habits were important in the composition and distribution of organisms in this estuary. This is the first study of benthic ecology held in the Cachoeira River estuary and one of the few conducted in the estuaries of the State of Bahia. It is desirable to carry out studies on longer temporal scales, as well as to gather more information on the population ecology of commercially valuable species exploited in the region.

Acknowledgments

The authors are grateful to CAPES (Brazil) for providing financial support, to CEPLAC (Ilhéus) for providing the rainfall data, to Prof. Luiz R. Simone for confirming the identification of some of the mollusks, and to Rui R. Cavalcante and Liliane O. Ceuta for their assistance in sampling.

Literature cited

Almeida AO, PA Coelho, JTA Santos & NR Ferraz. 2006. Crustáceos decápodos estuarinos de Ilhéus, Bahia, Brasil. Biota Neotropica 6(2). [on-line] <http://www.scielo.br/pdf/bn/v6n2/v6n2a23.pdf>

Alves OFS, CLC Manso, RS Absalão & PC Paiva. 2006. Geoecology of sublittoral benthic communities in Todos os Santos Bay (Bahia, Brazil): Biotic e sedimentological diversity. Journal of Coastal Research 39 (Special Issue): 1152-1155.

Angonese LG. 2005. Dinâmica de curto prazo da macrofauna bentônica em uma enseada estuarina da Lagoa dos Patos: efeitos antrópicos e mecanismos de persistência e resiliência. Ph.D. Thesis, Universidade Federal do Rio Grande, Rio Grande do Sul [on-line] <http://bdtd.furg.br/tde_busca/arquivo.php?codArquivo=13>

Arasaki E, P Muniz & AMS Pires-Vanin. 2004. A functional analysis of the benthic macrofauna of the São Sebastião Channel (Southeastern Brazil). Marine Ecology 25(4): 249-263.

Barros F, V Hatje, MB Figueiredo, WF Magalhães, HS Dórea & ES Emídio. 2008. The structure of the benthic macrofauna assemblages and sediments characteristics of the Paraguaçu estuarine system, NE, Brazil. Estuarine, Coastal and Shelf Science 78(1): 753-762.

Barroso R, PC Paiva & OFS Alves. 2002. Polychaetes trophic structure in Todos os Santos Bay (BA-Brazil). Boletim do Museu Nacional, Nova Série, Zoologia, Rio de Janeiro 494(1): 1-11.

Boehs G, TA Absher & A Cruz-Kaled. 2004. Composition and distribution of benthic molluscs on intertidal flats of Paranaguá Bay (Paraná, Brazil). Scientia Marina 68(4): 537-543.

Böggemann M. 2002. Revision of Glyceridae Grube, 1850 (Annelida: Polychaeta). Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft Frankfurt am Main 555(1): 1-249.

Brown SS, GR Gaston, CF Rakocinski & RW Heard. 2000. Effects of sediment contaminants and environmental gradients on macrobenthic community trophic structure in Gulf of Mexico Estuaries. Estuaries 23(3): 411-424.

Canfield TJ, NE Kemble, WG Brumnaugh, FJ Dwyer, CG Ingersoll & FJ Fairchild. 1994. Use of benthic invertebrates community structure and sediment quality triad to evaluate metal-contaminated sediment in the upper Clark Fork River, Montana. Environmental Toxicology and Chemistry 13(12): 1999-2012.

Dajoz R. 1971. Précis d'Ecologie, 434 pp. Dunod, París.

Day JW Jr, CAS Hall, WM Kemp & A Yañez-Arancibia. 1989. Estuarine ecology, 576 pp. John Wiley & Sons, New York.

Dean WE Jr. 1974. Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: comparison with other methods. Journal of Sedimentary Petrology 44(1): 242-248.

Diaz RJ & RJ Rosenberg. 1995. Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanography and Marine Biology: an Annual Review 33(1): 245-303.

Fauchald K & PA Jumars. 1979. The diet of worms: a study of polychaete feeding guilds. Oceanography and Marine Biology: an Annual Review 17(1): 193-284.

Folk RL & WC Ward. 1975. Brazos river bar: a study of significance of grain size parameters. Journal of Sedimentary Petrology 27(1): 3-26.

Fontes IBM, QR Araújo, MIG Severo & AH Oliveira. 2009. Avaliação dos micropoluentes inorgânicos da Estação de Tratamento de Esgoto de Ilhéus (Bahia). Geografia 18(1): 33-44.

Hatje V, F Barros, W Magalhães, VB Riatto, F Amorim, MB Figueiredo, S Spanó & M Cirano. 2008. Trace metals and benthic macrofauna distribution in Camamu Bay, Brazil: Sediment quality prior oil and gas exploration. Marine Pollution Bulletin 56(1): 348-379.

Heip C, NK Goosen, PMJ Herman, J Kromkamp, JJ Middelburg & K Soetaert. 1995. Production and consumption of biological particles in temperate tidal estuaries. Oceanography and Marine Biology: an Annual Review 33(1): 1-149.

Hutchings P. 1998. Biodiversity and functioning of polychaetes in benthic sediments. Biodiversity Conservation 7(1): 1133-1145.

Hyndes GA, PS Lavery & DI Walker. 2005. Does transported seagrass provide an important trophic link in unvegetated, nearshore areas? Estuarine, Coastal and Shelf Science 63(1): 633-643.

Kendall MA & S Widdicombe. 1999. Small scale patterns in the structure of macrofaunal assemblages of shallow soft sediments. Journal of Experimental Marine Biology and Ecology 237(1): 127-140.

Klumpp A, K Bauer, C Franz-Gerstein & M Menezes. 2002. Variation of nutrient and metal concentrations in aquatic macrophytes along the Rio Cachoeira in Bahia (Brazil). Environmental International 28(3): 165-171.

Mannino A & PA Montagna. 1997. Small-scale spatial variation of macrobenthic community structure. Estuaries 20(1): 159-173.

Muniz P & N Venturini. 2001. Spatial distribution of the macrozoobenthos in the Solís Grande Stream Estuary (Canelones-Maldonado, Uruguay). Brazilian Journal of Biology 61(3): 409-420.

Oliver PG & ASY Mackie. 1996. Marine macrofauna: Polychaetes, molluscs and crustaceans. In: Hall GS (ed). Methods for the examination of organismal diversity in soils and sediments, pp. 263-284. CAB International, London.

Pearson TH & R Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanography and Marine Biology: an Annual Review 16(1): 229-311.

Rizzo AE, FS MacCord & ACZ Amaral. 2002. Reproductive and parasitism in *Hemipodia californiensis* (Hartman, 1938) (Polychaeta: Glyceridae) from Brazilian Southeast. In: International Workshop, Restoration of Benthic Invertebrate Populations, pp. 57-58. Universidad Católica del Norte, Coquimbo.

Rosa LC & CE Bemvenuti. 2006. Temporal variability of the estuarine macrofauna of the Patos Lagoon, Brazil. Revista de Biología Marina y Oceanografía 41(1): 1-9.

Rosa-Filho JS & CE Bemvenuti. 1998. Caracterización de las comunidades macrobentónicas de fondos blandos em regiones estuarinas de Rio Grande do Sul (Brasil). Thalassas 14(1): 43-56.

Rozas LP, TJ Minello, I Munuera-Fernández, B Fry & B Wissel. 2005. Macrofauna distributions and habitat change following winter-spring release of freshwater into the Breton Sound estuary, Lousiana (USA). Estuarine, Coastal and Shelf Science 65(1): 319-336.

Salen-Picard C & D Arlhac. 2002. Long-term changes in Mediterranean benthic community: relationships between the polychaete assemblages and hydrological variations of the Rhône River. Estuaries 25(6): 1121-1130.

Schaffner LC, RJ Diaz, CR Olsen & IL Larsen. 1987. Faunal characteristics and sediment accumulation processes in the James River estuary, Virginia. Estuarine, Coastal and Shelf Science 25: 211-226.

Severo MIG. 1999. Etude de l´impact toxicologique des polluants (Cu, Cr) engendré par des rejets agrícoles sur les crustacés de l´état de Bahia - Brésil. Ph.D. Thesis, Université de Reims, 51687, Reims Cedex, 152 pp.

Snelgrove PVR & CA Butman. 1994. Animal-sediment relationships revisited: cause versus effect. Oceanography Marine Biology: an Annual Review 32(1):111-177.

Suguio K. 1973. Introdução à sedimentologia, 317 pp. Edgard Blücher/EDUSP, São Paulo.

Surugiu V. 2005. The use of polychaetes as indicators of eutrophication and organic enrichment of coastal waters: a study case - Romanian Black Sea Coast. Analele ªtiinþifice ale Universitãþii “Al.I. Cuza” Iaºi, Biologie animalã 51: 55-62. [on-line] < http://www.bio.uaic.ro/publicatii/anale_zoologie/issue/2005/10-V_Surugiu.pdf>

Tenore KR, RB Hanson, J McClain, AE Maccubbin & RE Hodson. 1984. Changes in composition and nutritive value to a benthic deposit feeder of decomposing detritus pools. Bulletin of Marine Science 35(1): 299-311.

Teske PR & TH Wooldridge. 2003. What limits the distribution of subtidal macrobenthos in permanently open and temporarily open/ closed South African estuaries? Salinity *vs.* sediment particle size. Estuarine, Coastal and Shelf Science 57(1): 225–238.

Venturini N & LR Tommasi. 2004. Polycyclic aromatic hydrocarbons and changes in the trophic structure of polychaete assemblages in sediments of Todos os Santos Bay, Northeastern, Brazil. Marine Pollution Bulletin 48(1): 97-107.

Whitlatch RB. 1981. Animal-sediment relationships in intertidal marine benthic habitats: some determinants of deposit-feeding species diversity. Journal of Experimental Marine Biology and Ecology 53(1): 31-45.

Yamamuro M. 2000. Abundance and size distribution of sublittoral meiobenthos along estuarine salinity gradients. Journal of Marine Systems 26(1): 135-143.

Received 7 October 2010 and accepted 18 January 2011