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ZOOPLANKTON COMMUNITY OF THE VITÓRIA BAY ESTUARINE SYSTEM (SOUTHEASTERN BRAZIL). CHARACTERIZATION DURING A THREE-YEAR STUDY

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ABSTRACT

In order to characterize the zooplankton community at the Vitória Bay estuarine system (Southeastern Brazil), samples were collected in 10 sampling stations during a three-year study (1998-2000), every three months. A total of 64 taxa were identified. Copepoda contributed with the highest species number (49) in the community, especially with *Acartia lilljeborgi*, *Acartia tonsa*, *Paracalanus parvus*, *P. quasimodo*, *Parvocalanus crassirostris*, *Temora turbinata*, *Oithona hebes*, *Oithona oculata* and *Euterpina acutifrons*. Highest abundances occurred in the summer of 2000. Diversity indexes were higher at the estuary mouth. Zooplankton composition was characterized by coastal and estuarine species, their distribution being influenced mainly by the salinity variation in this estuarine system.

RESUMO

Com o objetivo de caracterizar a comunidade zooplanctônica no sistema estuarino Baía de Vitória/Canal da Passagem, Vitória, E.S., foram coletadas amostras em dez pontos amostrais, trimestralmente durante três anos (1998-2000). Um total de 64 táxons foram identificados. Copepoda contribuiu com o maior número de espécies (49) na comunidade, destacando-se *Acartia lilljeborgi*, *Acartia tonsa*, *Paracalanus parvus*, *Paracalanus quasimodo*, *Parvocalanus crassirostris*, *Temora turbinata*, *Oithona hebes*, *Oithona oculata* e *Euterpina acutifrons*. A maior abundância ocorreu no verão do ano 2000. Os índices de diversidade foram maiores na entrada do estuário. A composição do zooplâncton se caracterizou por apresentar espécies estuarinas e costeiras, sendo a distribuição destas espécies influenciada principalmente pela variação dos valores de salinidade no estuário.

Key words: Zooplankton; Estuary; Copepoda; Salinity; Vitoria Bay estuarine system.
Palavras chave: Zooplâncton; Estuário; Copepoda; Salinidade; Sistema estuarino da Baía de Vitória.

INTRODUCTION

Estuaries are characterized as one of the most dynamic ecosystems, presenting diel and seasonal variations of tides, salinities, temperatures, dissolved oxygen, currents and nutrients (Summerhayes & Thorpe, 1998) which influence species density and diversity (Kramer *et al.*, 1994). Estuarine plankton is required to respond to changes in the physical and chemical characteristics of the environment that impose diel and seasonal patterns, influencing population dynamics. High primary production levels make estuarine zooplankton very abundant, however some other biological factors, as well as environmental parameters, may restrict the variety of the zooplankton species when compared to that of the marine areas (Kennish, 1990).

Estuarine zooplankton is dominated by Copepoda and other less abundant groups such as Chaetognatha, Appendicularia and meroplanktonic larvae (Tundisi, 1970). Many zooplankton species may occur, but generally few dominate the population. These species may vary seasonally and spatially along the estuary, being influenced by freshwater and coastal inputs (Lansac-Tôha & Lima, 1993; Lopes, 1994).

In Brazil, several zooplankton studies describing species composition and abundance related to abiotic parameters such as temperature and salinity have been made (Montú, 1980, 1987; Nascimento-Vieira & Sant'-Anna, 1989; Lansac-Tôha & Lima, 1993; Lopes, 1994). Other studies associate composition, abundance and distribution of the zooplankton with nutrients, observing mesozooplankton biomass reduction, changes in species composition and trophic relations in response to nutrient variations and increase in eutrophication (Lopes, 1996; Park & Marshal, 2000; Breitburg *et al*., 1999).

Zooplankton communities have been studied in the Espírito Santo State coastal region and in the Espírito Santo Bay (Bonecker *et al*., 1987; Bonecker *et al*., 1991; Dias, 1994), focusing on composition, abundance and distribution, as well as their relation with environmental parameters such as temperature and salinity. The Vitória Bay estuarine system, an adjacent area to the Espírito Santo Bay, has undergone many changes due to anthropogenic actions along the years. It receives daily a great amount of domestic and industrial effluents from the neighboring cities that surround the estuary and also from a port system. Studies on zooplankton ecology in the Vitória Bay estuarine system are scarce, being the work by Loureiro Fernandes *et al*. (1998), who studied the morphological alterations in the copepod *Acartia lilljeborgi*, the only known paper. The main purpose of this study is to report zooplankton species composition and abundance in the Vitória Bay.

MATERIAL AND METHODS

Study Site

The Vitória Bay estuarine system (around 20º23'S and 40º22'W) is located in the Vitória metropolitan area, Espírito Santo State, Brazil. With a mangrove of 2051 hectares, extending along approximately 25 km, this horseshoe-shaped system has two coastal water entrances, one in the Vitória Bay and the other in the Passage Channel. Local depth varies from 1.5 to 10 m outside the main port channel. Tidal currents enter the estuary by the Vitória Bay as well as by the Passage Channel (Fig. 1).

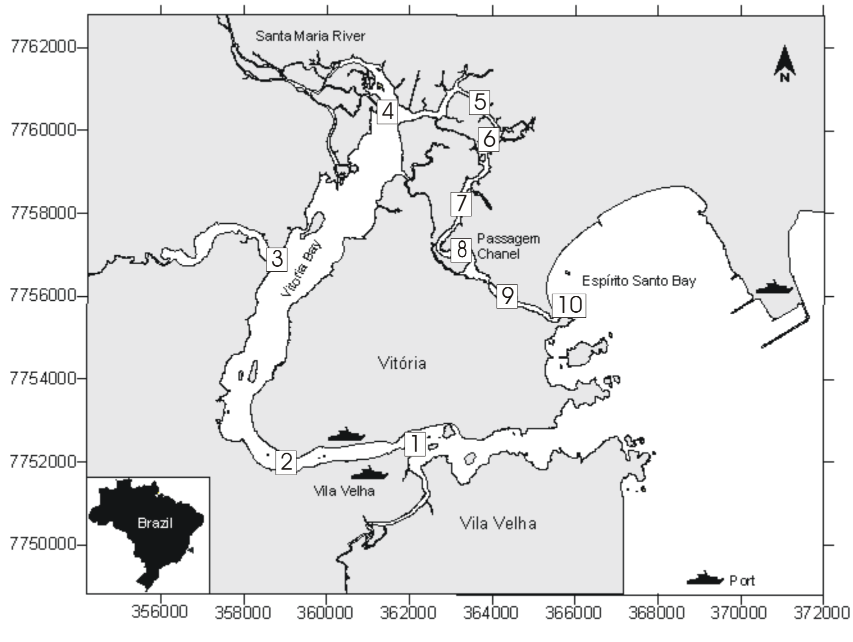


Fig. 1.Vitória Bay/Passage Channel estuarine system with the sampling stations.

Sampling

Four sampling stations were selected in the Vitória Bay, determined mainly by their proximity to freshwater inputs, and six stations were selected at the Passage Channel following a salinity gradient that occurs from the mouth of the channel towards the Santa Maria River (Fig. 1). Sampling of the biological material and physical-chemical parameters were made every three months in ten stations from February 1998 to November 2000.

Single zooplankton hauls were taken using a conical-cylindrical plankton net with a 30-cm mouth opening and a 200µm mesh size, fitted with a mechanical flow meter to estimate the amount of water filtered (Omori & Ikeda, 1992). Sub-surface tows were obtained with the boat at approximately 1 knot during a five-minute period. Samples were preserved in aqueous solution of formaldehyde 5%, buffered with sodium tetra-borate. Along with the biological parameters, environmental parameters such as salinity, temperature and dissolved oxygen were measured "in situ" in each sampling station throughout the water column using a portable multi-sound (YSI 85).

Aliquots were obtained using a Folsom plankton splitter according to their concentration degree. Dominant species were identified to the lowest taxonomic level possible (Boltovskoy, 1981, 1999; Montú & Gloeden, 1986; Sendacz & Kubo, 1982; Matsumura-Tundisi & Rocha, 1983; Edmondson, 1959; Elmoor-Loureiro, 1997).

For the zooplankton community diversity study, Shannon-Wiener diversity indexes were calculated (Henderson & Seaby, 1997) only for Copepoda because they represent the bulk of the population.

Analysis of variance (ANOVA) was applied to the chemical-physical parameters (temperature, salinity and dissolved oxygen) and to the abundance of the dominant species, in order to test differences among samples (temporal patterns) and sampling stations (spatial patterns). Towards equalizing the variance and normalizing distribution, all data used in the ANOVA were log transformed [$\log_{10}(x+1)$]. When significant differences were detected by the ANOVA, Tukey´s Honestly Significantly Different (DHS) test was applied to identify sources of variation.

To obtain possible distributional patterns and their relation with the physical-chemical parameters, a Principal Component Analysis (PCA) was performed with data of three year sampling after they were log transformed. Matrices were composed only by species and groups with relative abundance higher than 5%. Analyses were performed using the STATISTICA 6.0 software package.

RESULTS

Environmental Variables

Significant seasonal differences occurred for dissolved oxygen, where winter values were higher than in spring (ANOVA F= 3,65 and p= 0,01). Regarding sampling locations, differences were also observed (ANOVA F= 9,90 and p= 0,00). Highest dissolved oxygen values occurred at the stations near the entrance of the Vitória Bay and Passage Channel, whereas the lowest values occurred in the inner estuary region (Fig. 2).

Salinity values were significantly higher during fall and winter in relation to spring (ANOVA F= 7.68 and p= 0.00). A spatial distribution pattern for salinity was observed in all stations (Fig. 3). The highest values were registered at the stations located in the entrance of the Vitória Bay and Passage Channel, being these significantly higher than the ones located in the inner estuary (ANOVA F= 21.7 and p= 0.00).

Fall temperatures were significantly higher than the ones registered for summer and winter (ANOVA F=9.37 and p= 0.00). Temperature had an inverse pattern in relation to salinity, with values in the inner part of the estuary higher than in the outer region (ANOVA F=2.01 and p= 0.04), although these differences were not significant (Fig. 4).

Zooplankton

During the three-year study a total of 64 *taxa* was observed, with forty-nine species of Copepoda identified (Table 1).

Average total zooplankton abundances during summer and fall were significantly greater than during winter and spring (ANOVA F=4,83 and p= 0,00). Along the sampling stations, no significant differences were observed (ANOVA F=0,39 and p= 0,93). Figure 5 shows the average, standard deviation and standard error of species and group abundances.

Acartia lilljeborgi was the most abundant species. No significant differences were observed between sampling stations (Table 2). *Acartia tonsa* was significantly more abundant at station 4, the upper portion of the estuary (Table 2). The same was observed for copepodites of the *Pseudodiaptomus* genus, occurring mainly at stations in the inner part of the estuary (Table 2).

Appendicularia, *Temora turbinata*, *Euterpina acutifrons*, *Paracalanus parvus*, *Paracalanus quasimodo* and *Parvocalanus crassirostris* were significantly more abundant at the lower portion of the estuary. Decapod larvae were significantly more abundant at station 2 (outer region) and station 6 (inner region). The other species and groups did not show significant difference among stations (Table 2).

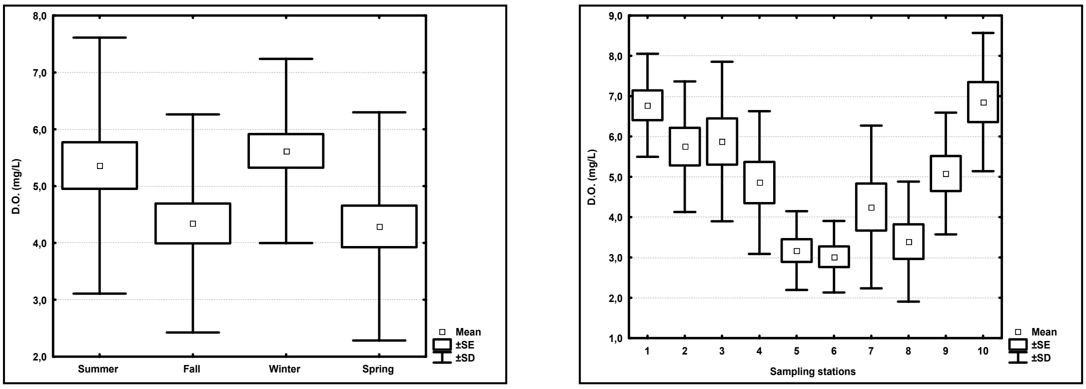


Fig. 2. Average, standard error and standard deviation (n=120) of the dissolved oxygen values for the different seasons and sampling stations.

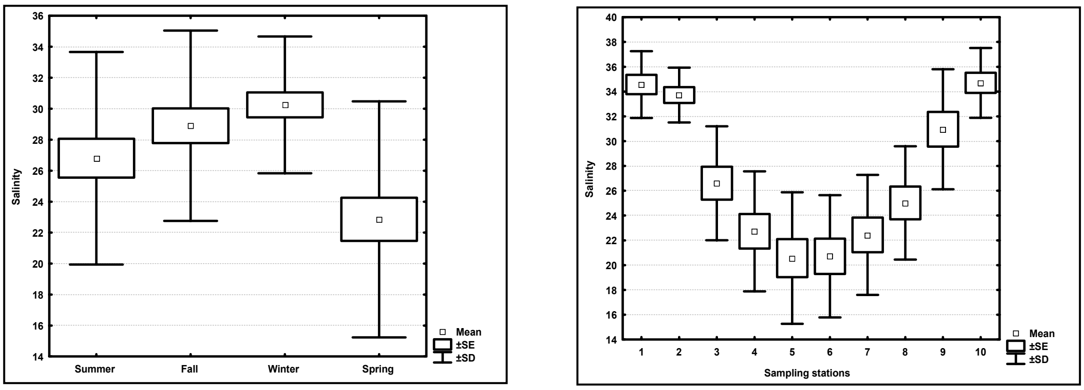


Fig. 3. Average, standard error and standard deviation (n=120) of the salinity values for the different seasons and sampling stations.

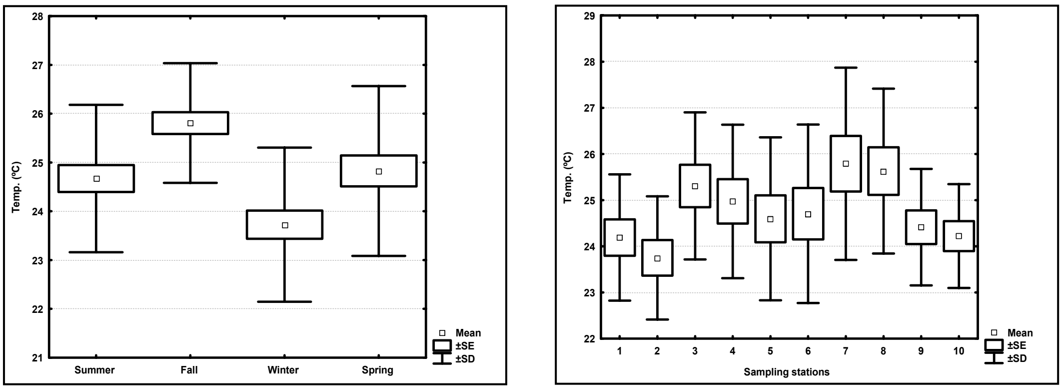


Fig. 4. Average, standard error and standard deviation (n=120) of the temperature values for the different seasons and sampling stations.

Table 1. Inventory of the zooplankton in the Vitória Bay/Passage Channel estuarine system (Southeastern Brazil).

FORAMINIFERA
ROTIFERA
NEMATODA
CNIDARIA
CTENOPHORA
SIPHONOPHORA
POLYCHAETA
BIVALVIA
THECOSOMATA
COPEPODA
Acartia lilljeborgi
Acartia tonsa
Paracalanus parvus
Paracalanus quasimodo
Parvocalanus crassirostris
Calocalanus pavoninus
Pseudodiaptomus acutus
Pseudodiaptomus richardi
Pseudodiaptomus marshi
Temora turbinata
Temora stylifera
Bestiolina sp
Subeucalanus subtenuis
Subeucalanus pileatus
Clausocalanus furcatus
Calanopia americana
Centropages velificatus
Lucicutia flavicornis
Oithona oculata
Oithona hebes
Oithona nana
Oithona setigera
Oithona similis
Oithona plumifera
Oncaea venusta
Oncaea media
Oncaea curta
Sapphirina sp
Thermocyclops minutus
Paracyclops fimbriatus
Halocyclops sp
Microcyclops anceps
Cletocamptus deitersi
Hemicyclops thalassius
Farranula gracilis
Corycaeus speciosus
Corycaeus giesbrechti
Corycaeus amazonicus
Caligus sp
Euterpina acutifrons
Microsetella norvergica
Microsetella rosea
Myracea efemerata
Mesochra lilljeborgi
Tigriopus sp
Clytemnestra rostrata
Clytemnestra scutellata
Cymbasoma gracilis
Cymbasoma rigidum
CIRRIPEDIA
OSTRACODA
DECAPODA
Lucifer faxoni
BRACHYURA
ANOMURA
EUPHAUSIACEA
AMPHIPODA
ISOPODA
MYSIDACEA
Promysis atlantica
CUMACEA
STOMATOPODA
CLADOCERA
Penilia avirostris
Pleopsis polyphemoides
Moina micrura
ACARI
BRYOZOA
ECHINODERMATA
CHAETOGNATHA
Sagitta enflata
Sagitta friderici
Sagitta decipiens
Sagitta hispida
Sagitta minima
PHORONIDA
APPENDICULARIA
Oikopleura dioica
Oikopleura rufescens
Oikopleura longicauda
Oikopleura fusiformis
ASCIDIACEA
THALIACEA
PISCES (eggs and larvae)

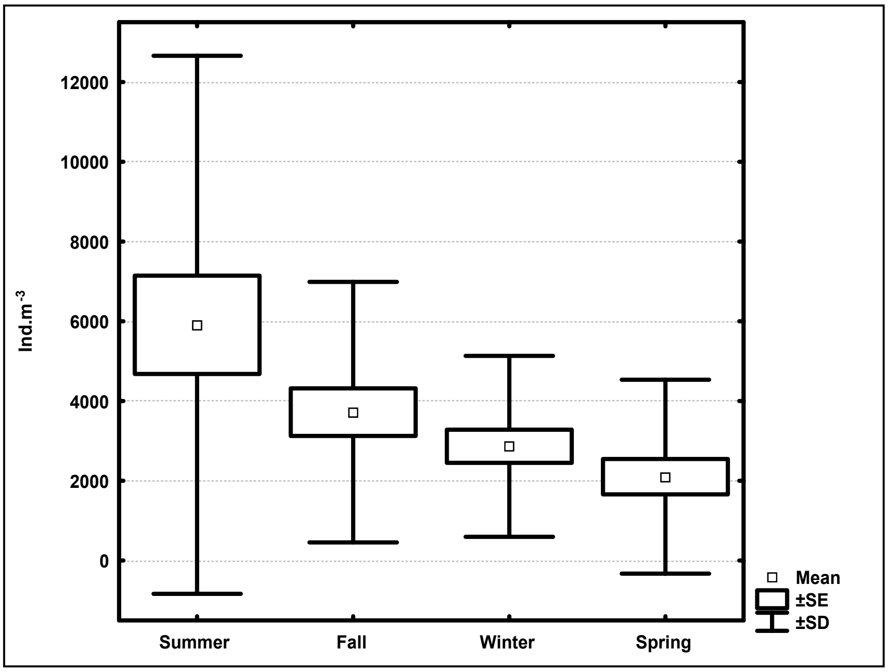


Fig. 5. Average, standard error and standard deviation (n=120) of the total zooplankton abundance values for the different seasons and sampling stations.

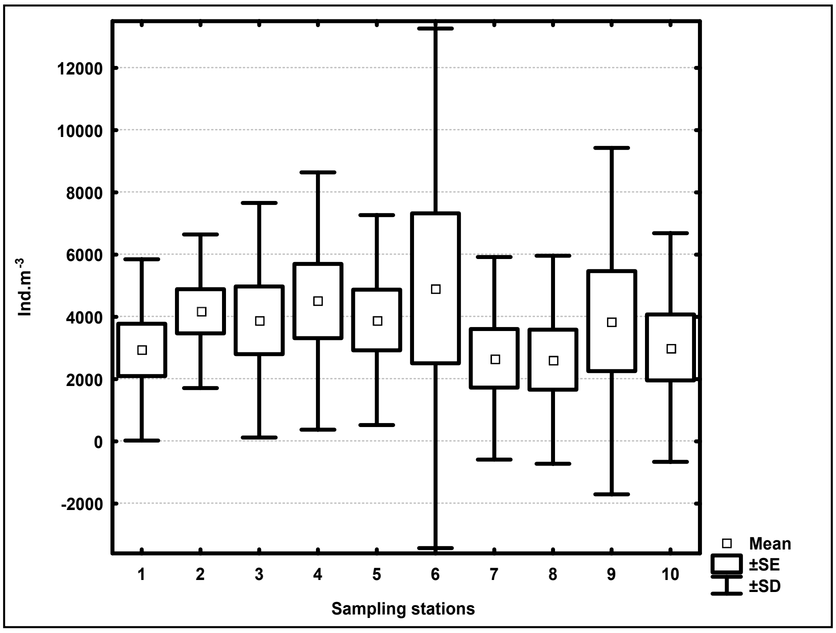


Fig. 5 Cont.

Table 2. Analysis of Variance (ANOVA) of the most abundant species and groups along the sampling stations (n=120).

		STATIONS												
		1	2	3	4	5	6	7	8	9	10	All Groups	F	P<0,05
Acartia lilljeborgi	Means	778	1663	1609	1289	872	614	789	824	1824	1215	1148	1,54603	0,140796
	Std. Dev.	1508	1392	2025	1155	1153	624	1127	1076	2813	1522	1546		
Acartia tonsa	Means	151	350	566	740	345	337	306	296	474	342	391	2,04778	0,040500
	Std. Dev.	395	434	946	824	361	469	626	583	862	617	637		
Temora turbinata	Means	157	402	78	3	3	1	0	0	27	47	72	19,43271	0,000000
	Std. Dev.	259	472	152	6	10	2	1	1	24	83	211		
Bestiolina sp	Means	90	62	66	128	172	420	318	442	275	124	210	0,39097	0,937228
	Std. Dev.	141	59	108	333	401	975	733	1288	696	259	624		
Oithona hebes	Means	163	158	296	267	265	343	488	220	143	209	255	0,64089	0,759902
	Std. Dev.	173	118	265	369	366	606	570	245	167	229	350		
Oithona oculata	Means	53	78	358	328	262	270	194	101	47	58	175	0,74580	0,666244
	Std. Dev.	71	88	715	733	381	691	281	141	87	130	425		
Paracalanus parvus	Means	158	148	15	0	1	2	1	3	10	32	37	13,79905	0,000000
	Std. Dev.	228	206	31	1	2	5	2	5	19	59	113		
Paracalanus quasimodo	Means	182	126	44	21	29	48	67	51	207	81	86	4,30317	0,000082
	Std. Dev.	231	140	77	61	71	156	202	140	634	134	242		
Euterpina acutifrons	Means	65	81	28	2	8	7	4	4	17	30	24	9,60844	0,000000
	Std. Dev.	74	65	56	2	18	8	6	6	23	42	46		
Parvocalanus crassirostris	Means	76	118	56	37	26	210	59	80	132	89	88	2,37802	0,016926
	Std. Dev.	93	95	83	44	35	644	138	173	222	165	235		
Cirripedia	Means	520	389	204	362	269	246	153	285	256	378	306	0,51260	0,862770
	Std. Dev.	657	470	352	517	444	291	172	395	338	757	462		
Acartia copepodite	Means	74	104	245	260	297	113	63	98	131	151	154	0,56613	0,822179
	Std. Dev.	51	114	244	272	489	97	60	78	108	148	217		
Pseudodiaptomus copepodite	Means	6	13	13	647	1006	1728	97	82	60	25	368	7,08781	0,000000
	Std. Dev.	8	18	19	1831	1440	4254	190	120	69	31	1578		
Appendicularia	Means	159	102	21	28	25	8	7	5	60	93	51	2,48696	0,012620
	Std. Dev.	368	225	23	79	76	17	12	8	172	179	163		
Decapod larvae	Means	75	100	58	51	62	267	20	39	62	37	77	2,73787	0,006369
	Std. Dev.	84	91	77	74	91	638	19	32	83	69	216		
Pteropoda	Means	20	55	124	39	34	37	12	7	19	12	36	0,84451	0,576949
	Std. Dev.	29	88	231	80	38	67	22	9	24	21	90		
Copepoda nauplii	Means	108	112	69	118	36	21	15	28	38	25	57	1,44811	0,176559
	Std. Dev.	135	157	92	196	40	27	17	45	54	52	104		

Principal Component Analysis (PCA) allowed the corroboration of the above observed patterns, where copepodites of the *Pseudodiaptomus* genus were related with temperature, which, despite not being significant, had its greatest values in the inner estuary region. Appendicularia, *Temora turbinata*, *Euterpina acutifrons* and *Paracalanus parvus* were associated with salinity and dissolved oxygen, which had high values in the outer portion of the estuary. *A. lilljeborgi* revealed no significant correlation with the environmental variables, showing only a positive tendency with the dissolved oxygen and salinity values (Fig. 6).

Zooplankton diversity showed different seasonal and spatial patterns (Fig. 7). The highest values were observed for summer and spring (ANOVA F=3,55 and p= 0,01) at stations located at the Vitória Bay mouth (ANOVA F=4,26 and p= 0,00).

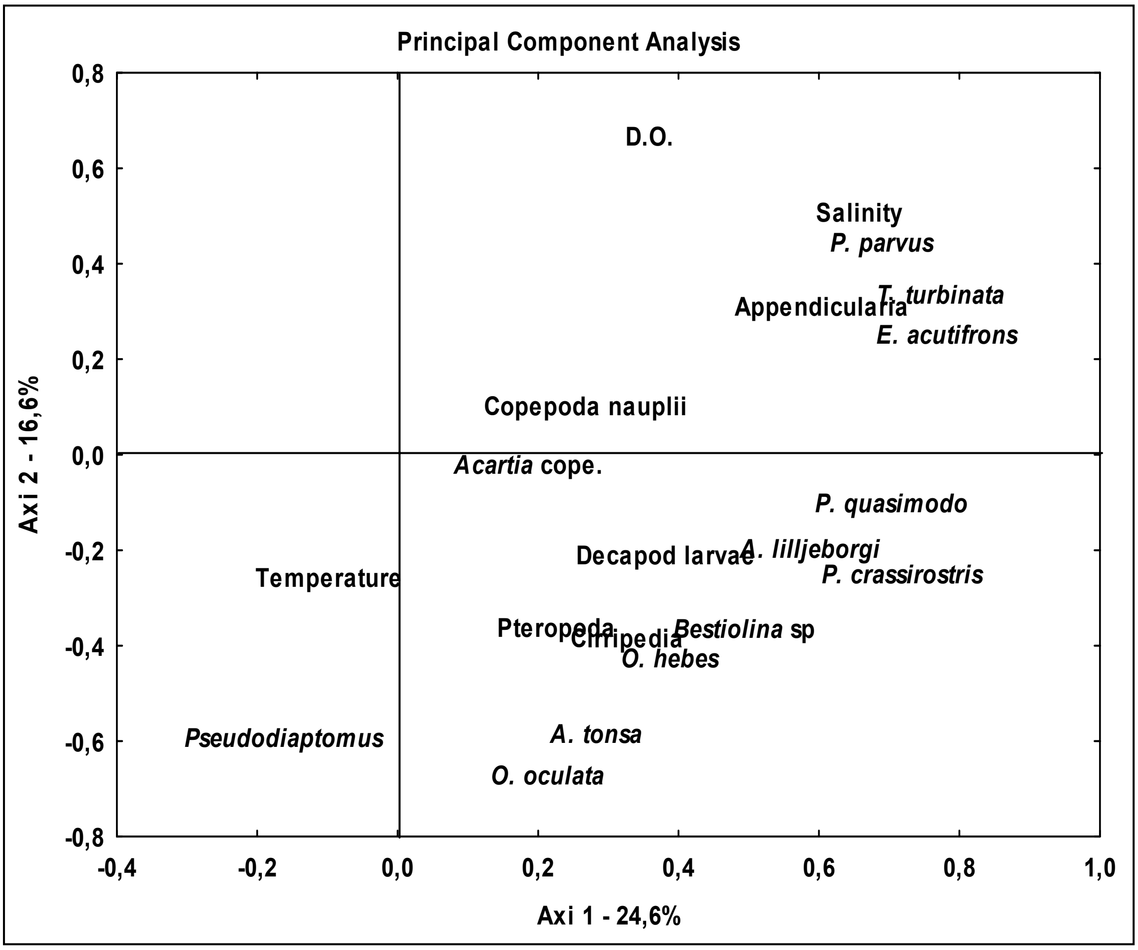
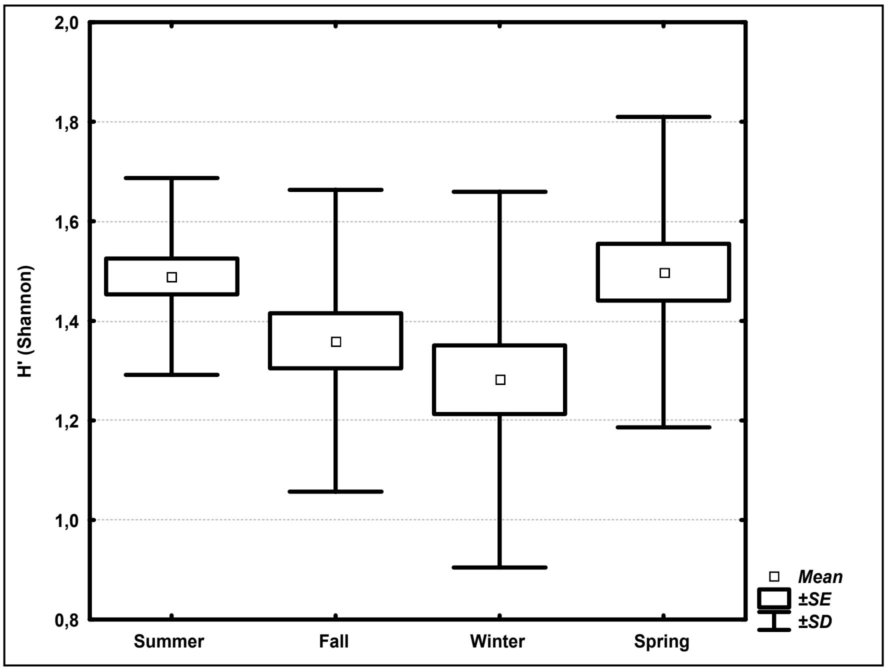


Fig. 6. Principal component analysis (PCA) for the environmental data and zooplankton (log transformed).



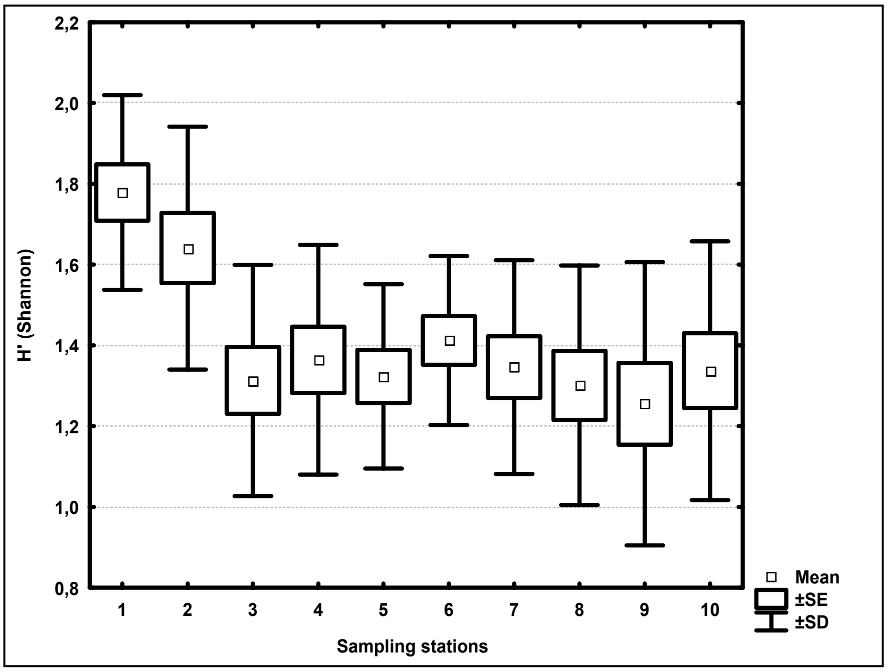


Fig. 7. Average, standard error and standard deviation (n=120) of the Shannon-Wiener diversity index for the different seasons and sampling stations.

DISCUSSION

Environmental Variables

The Vitória Bay Estuarine System can be divided into two portions: a lower part characterized by a water mass with high salinity and dissolved oxygen values, influenced mainly by coastal waters; and an upper portion characterized by a water mass with high temperatures, low salinity and dissolved oxygen, influenced by the input of continental waters.

According to Chapman (1992), low dissolved oxygen values in the upper estuary might be related to organic matter decomposition processes, due to the great input of rivers and sewages in the area, as observed by Barroso *et al.* (1997). Highest salinity values registered in the lower estuarine region evidence a strong influence of the coastal water input at both Vitória Bay and Passage Channel. The upper estuarine region, where freshwater runoff from sewage systems (Barroso *et al*., 1997) and rivers is evidenced, showed the lowest values as a consequence of the seawater dilution, characterizing a spatial variation. Winter presented the highest concentrations, typical for the dry period in the region (Bonecker *et al*., 1991). Although not significant, highest temperature values in the upper estuarine regions occurred because these areas are shallower and more confined, being subjected to greater influence of the air-water interactions in the heating processes and also due to warmer continental water contribution. Lopes *et al.* (1998) observed a similar pattern at the Paranaguá estuarine complex (Paraná State), presenting higher temperature values and salinity decrease in the upper region of the estuary.

Zooplankton Composition

Zooplankton community was characterized by the presence of freshwater, estuarine, coastal and oceanic species. *Acartia lilljeborgi*, *Acartia tonsa*, *Oithona hebes*, *Oithona oculata* and *Temora turbinata* are species commonly found in estuarine and coastal waters (Lopes *et al*., 1998). The coastal region is highly influenced by the continent, being inhabited by species that are well adapted to great salinity variations, freshwater and runoff (Bradford-Grieve *et al*., 1999). The presence of oceanic species was well characterized by the occurrence of *Calocalanus pavoninus*, *Clausocalanus furcatus*, *Subeucalanus subtenuis* and *Corycaeus giesbrechti* as well as by chaetognaths such as *Sagitta enflata*. Typical freshwater species such as *Thermocyclops minutus*, *Paracyclops fimbriatus*, *Halocyclops* sp, *Microcyclops anceps* and *Cletocamptus deitersi* were also observed in the inner portion of the estuary.

The genus *Bestiolina* has been recorded in the Pacific by Lenz *et al*. (2000) at the Kaneohe Bay, Oahu, Hawaii; by McKinnon & Duggan (2001) at the Exmouth Gulf, Australia; and by Lo *et al*. (2004) at Tapong Bay, Taiwan. The presence of *Bestiolina* sp in the Vitória Bay estuary is the first record for Brazilian waters.

Zooplankton composition in the Vitória Bay/Passage Channel estuarine system is similar to that of other Brazilian estuaries, where holoplanktonic organisms dominate. However, copepods showed higher species richness, with the occurrence of 49 species along the three-year study, higher than the numbers found in other estuaries (Paranaguá & Nascimento-Vieira, 1984; Lira *et al.,* 1996; Bonecker *et al.,* 1991). The only work that found numbers similar to those of this study was performed in the Una do Prelado river estuary in the São Paulo State (Lansac Tôha & Lima, 1993) with a total of 48 species of Copepoda. Nevertheless, a large part of these species was of benthic freshwater copepods associated with the marginal vegetation of the rivers that carried water to the estuary during the rainy period. Also, the authors used a net of smaller mesh size for their sampling. In estuaries of other countries, such as in the Caribbean region, Youngbluth (1976) found 31 species.

Space-time Distribution

Acartia lilljeborgi can be considered as a marine-estuarine species since it was found along the entire estuary, not presenting a significant correlation with salinity. *Acartia lilljeborgi* is usually the dominant species in most Brazilian estuaries (Lopes *et al.,* 1986; Lopes, 1994; Lira *et al.,* 1996; Bonecker *et al.,* 1991), mainly in intermediate and lower regions. *Acartia tonsa* is also another species developing well in intermediate (Lopes *et al*., 1998) and high salinities (Montú, 1980), being also dominant in estuaries, particularly in the Chesapeake Bay (Kennish, 1994). The concurrently occurrence of both *Acartia* species is an interesting fact. Although they compete for the same food resource (Kennish, 1986), they seem to co-exist in the environment, with *Acartia tonsa* being more abundant in the upper portion of the estuary. The relative confinement of *Acartia tonsa* in the upper region may not only reflect preference for some hydrographical conditions, but also interspecific competition among the two species (Kennish, 1986).

Temora turbinata, *Paracalanus parvus, P. quasimodo*, *Parvocalanus crassirostris*, as well as Appendicularia, have a marine-euryhaline behavior because they occur preferably in areas with elevated salinities (Lopes *et al*., 1998). The positive correlation with salinity indicates that these organisms are dependent on the recruitment from the adjacent coastal region.

Many studies report the occurrence of *Pseudodiaptomus richardi* in the inner estuarine region, being this species an excellent indicator of oligohaline areas (Lansac Tôha & Lima, 1993; Lopes *et al.*, 1986; Lopes, 1994, 1996; Lopes *et al.*, 1998; Mckinnon & Klumpp, 1998). In this study, *Pseudodiaptomus richardi*, *Oithona hebes* and *Oithona oculata* had also a similar pattern, presenting a typical estuarine behavior, occurring preferably in the upper part of the estuary.

Zooplankton of the Vitória Bay system was composed mainly by holoplanktonic organisms, with Copepoda as the most abundant group, and a high number of species. Among them, the most abundant were: *A. lilljeborgi*, *A. tonsa*, *P. parvus*, *P quasimodo*, *P. crassirostris*, *T. turbinata*, *O. hebes*, *O. oculata* and *E. acutifrons*. Zooplankton community showed seasonal variations, in general with greater abundances occurring during summer, the greatest diversity values being observed at stations with higher salinity. Since the majority of the species are from coastal areas, spatial distribution of the abundance is controlled by the salinity gradient as observed by Lopes (1996) and Villate *et al.* (1993). However, other factors must be considered to a better evaluation of the distribution and abundance of zooplankton. To obtain a better answer, future studies should take into consideration nutrient concentrations and chlorophyll-*a*, since the environment receives influence from anthropogenic sources along its extension.

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