BRAZILIAN JOURNAL OF OCEANOGRAPHY, 56(3):211-224, 2008

SPATIAL AND TEMPORAL VARIATION OF THE ZOOPLANKTON COMMUNITY IN THE AREA OF INFLUENCE OF THE ITAJAÍ-AÇU RIVER, SC (BRAZIL)

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ABSTRACT

On the north coast of the State of Santa Catarina (Brazil), the Itajaí-Açu River mouth shows a low-saline water plume on the internal shelf with strong density gradients. This oceanographic condition has a possible influence over the pelagic community, and it has been little investigated on the Brazilian coast. The present work seeks to evaluate the spatial and temporal variations of the zooplankton community in the area of influence of the Itajaí-açu River, and its relations with the abiotic forces of temperature (seasonal variation) and salinity of the river plume. For this purpose, 14 monthly oceanographic cruises were carried out during the years 2002 and 2003, to obtain physical and chemical parameters, and zooplankton hauls in 9 sampling points. The zooplankton analyses were carried out at the lowest taxon possible to characterize the resident community of the river mouth. It was observed that the zooplankton presented the highest densities in winter and spring. The species with higher densities and frequencies of occurrence were *Paracalanus quasimodo, Parvocalanus crassirostris*, *Acartia lilijeborgi*, *Temora stylifera*, *T. turbinata*, and *Penilia avirostris,* indicating a prevalence in this region, of Tropical Water from the Brazil Current and greater similarity with the coastal community of the Southeast region of Brazil. However, even for the species typical of Tropical Water, there were alterations in dominance of the species, due to the seasonality and level of flow rate of the river on the salinity of the internal shelf of the study area.

RESUMO

No norte do estado de Santa Catarina (Brasil) a desembocadura do Rio Itajaí-açu apresenta uma pluma de água de baixa salinidade e com forte gradiente de densidade sobre a plataforma interna. Essa condição oceanográfica pode influenciar a comunidade pelágica costeira local e este processo tem sido pobremente investigado na costa brasileira. O presente trabalho teve como objetivo estudar as variações espaço-temporais da comunidade zooplanctônica na região da pluma do Rio Itajaí-açu e determinar a existência de alguma influência sobre esta comunidade. Para isso, 14 campanhas oceanográficas foram realizadas mensalmente entre os anos de 2002 e 2003 com a obtenção de parâmetros físico-químicos e arrastos de zooplâncton em 9 pontos amostrais. Foi observado que o zooplâncton apresentou suas maiores densidades nos meses de inverno e primavera. As espécies com maiores densidades e freqüências de ocorrência foram *Paracalanus quasimodo, Parvocalanus crassirostris*, *Acartia lilijeborgi, Temora stylifera, T. turbinata*, e *Penilia avirostris,* indicando domínio da Água Tropical da Corrente do Brasil na região e maior similaridade com a comunidade da costa da região sudeste do Brasil. Entretanto, mesmo para as espécies típicas da Água Tropical, houve alterações na dominância de espécies em função da sazonalidade e do grau de influência da vazão do rio sobre a salinidade na plataforma interna da área de estudo.

Descriptors: Zooplankton, Itajaí-Açu River, River plume, Santa Catarina.
Descritores: Zooplâncton, Rio Itajaí-Açu, Pluma de rio, Santa Catarina.

INTRODUCTION

River plumes are formed by the advection of freshwater from the drainage over the adjacent shelf, when there is insufficient tidal energy to generate a mixture inside the estuarine basin. The strong density gradient between the freshwater and marine salt water produces a buoyancy flow, when liberated from the lateral confines of the estuary banks, producing a fine layer which spreads radially across the surface and tends to hug the coast, shifting to the left in the southern hemisphere (e.g. O'DONNELL, 1993;

WISEMAN JR.; GARVINE, 1995). River plumes are characterized by high concentrations of suspended particulate matter (SPM), and their waters present high concentrations of nutrient salts. The gradual dilution and decantation of the SPM present favorable conditions for the development of phytoplankton and other levels of the trophic chain (e.g., SCHETTINI et al., 1998).

According to Mann and Lazier (2005), there are differences in biological production between river and estuarine plumes. In river plumes, the increase of nutrients tends to occur in regions of the shelf which vary according to distance, position and flow rate of the river. In estuarine plumes, the nutrient load is used within the estuary. If the nutrient load is not assimilated by the plankton communities, it will be exported to the coastal zone.

Few studies have been carried out on the influence of river plume fronts over the shelf, on the zooplankton community (MANN; LAZIER, 2005). Meanwhile, Le Fèvre, (1986) observes that fronts associated with river plumes present a build-up of plankton or associations of distinct species, from adjacent waters. Other types of biotic response to the processes of convergence of waters from different origins include metabolic and behavioral alterations in the organisms, and alterations in the structure of the pelagic community (HAURY ; PIEPER, 1988).

Despite the lack of information on plankton communities on the coast of Santa Catarina (BRANDINI et al. 1997; VALENTIN et al., 1994), several studies have already been carried out on the zooplankton of the area of influence of the Itajaí-açu River (SCHETTINI et al., 1998; RÖRIG et al., 2003). These studies are based on a transect through the river plume during a period of high discharge of the Itajaí-açu River in the summer. Although the data are from just one cruise, the sample detailing in the water column reveals the presence in the shelf of a layer of South Atlantic Central Water (SACW) occupying the water column medium as far as the sea bed. This water mass was associated with the high biological activity of the zooplankton in the sub-surface layer close to the river mouth. Subsequently, the work by Schettini et al. (2005) highlighted the influence of the fluvial contribution of the Itajaí-açu River to the physical and ecological characteristics of the region. The effects of the fluvial contribution were also observed in the plankton communities of beaches adjacent to the river mouth. This influence is such that the species found by Rörig et al. (2003) in the river are also carried by the plume located to the north of the river mouth (RÖRIG et al., 1997).

The present work seeks to evaluate the spatial and temporal variations of the zooplankton community in the area of influence of the Itajaí-açu River, and its relations with the abiotic forces of temperature (seasonal variation) and salinity of the river plume. It presents the distribution of the main species occurring in this environment, in comparison with the communities studied to the north (States of Paraná and São Paulo), and south (Rio Grande do Sul) of the study area.

Study Area

The Itajaí-açu River empties on the north coast of the State of Santa Catarina, between the cities of Itajaí and Navegantes, and has the largest river drainage basin in the State, covering an area of 15,500 km². The largest industrial park in the State is located within the river basin, in the cities of Rio do Sul, Blumenau, Brusque and Itajaí. In the river mouth and estuarine region is located the Itajaí Harbor, which is the main foreign trade route in the State, and one of the most important in Brazil.

The Itajaí-açu River has an average flow rate of 228 ± 282 $m^3.s^{-1}$, measured at the Indaial fluviometric station. This station represents around 70% of the drainage and has historical data going back to 1934. The regional climate is mesothermal, humid and sub-tropical, with rainfall distributed throughout the year (GAPLAN, 1986). This results in a river flow rate pattern with a weak seasonal signal. Most of the time, the flow rate is below 150 $m^3.s^{-1}$, with sporadic peaks resulting from hydrological events generated by convective storms or cold fronts. These peaks are usually over 1,000 $m^3.s^{-1}$, and can reach extremes of 5,000 $m^3.s^{-1}$ (SCHETTINI, 2002).

The circulation in the Itajaí-açu River estuary is predominantly of the highly stratified type (SCHETTINI, 2002), which favors the liberation of water with low salinity to the adjacent shelf. When the flow rate conditions are above 500 $m^3.s^{-1}$ a river plume is formed. This develops rapidly from the river mouth, and fans out in a northeasternly direction, being more notable several kilometers away from the river mouth (SCHETTINI et al., 1998; TROCHIMCZUK FILHO; SCHETTINI, 2003). The dissipation of the flow of the plume gradually forms the local coastal water, with salinity between 30 and 33 throughout the year, and a temperature variation of 18 to 28°C in winter and summer, respectively. During the months of June and July, the presence of low-salinity waters was also observed coming from the Prata/Patos Lagoon front (SCHETTINI et al., 2005) and from the south of Brazil, Uruguay and the north of Argentina (Fig. 1). The coastal waters, which suffer dilution by the river load from the Itajaí-açu River, were observed by Carvalho et al. (1998) as having a larger area of scope, shifting northwards due to the prevailing winds.

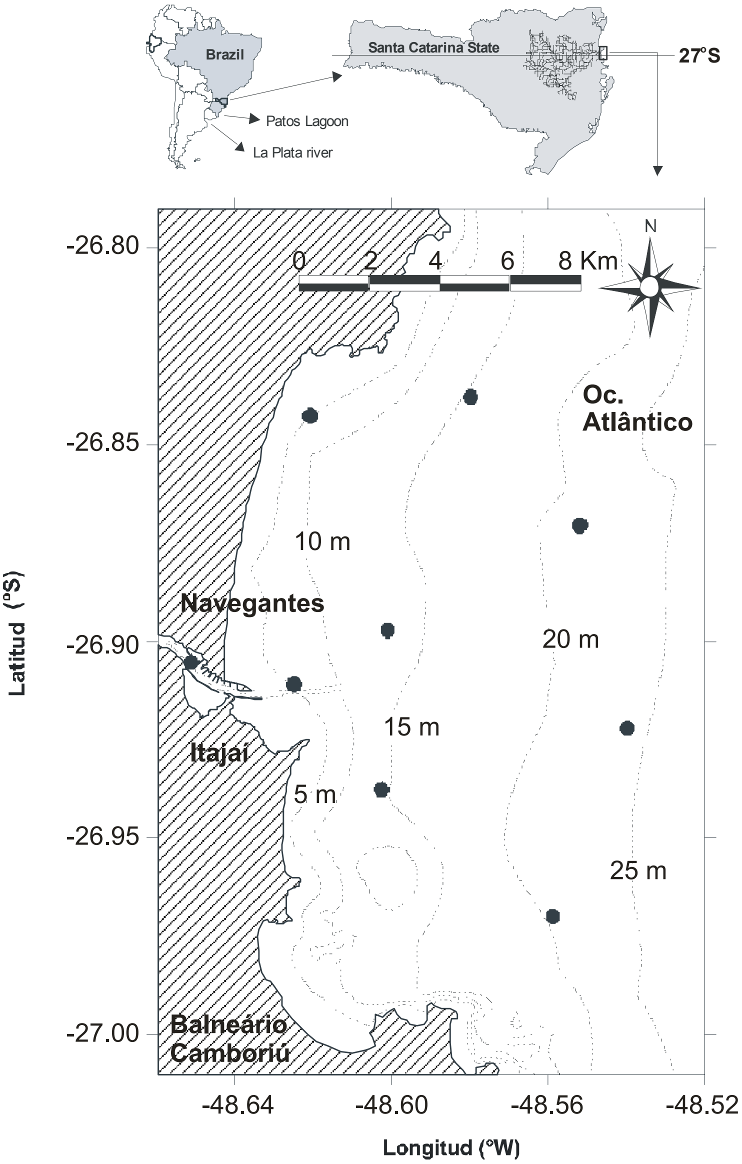


Fig. 1. Location of the zooplankton collection points in the Itajaí-Açu River mouth during 14 monthly cruises carried out between 2002 and 2003. On the map, the state of Santa Catarina is highlighted, with the location of the Patos Lagoon Estuary and the mouth of the La Plata River.

Material and Methods

The data used in this work were obtained during the 14 oceanographic cruises performed in the period November 2002 to December 2003. During the cruises, sampling was carried out to determine the physical, chemical and biological parameters (SCHETTINI et al., 2005). Data on temperature, salinity and suspended particulate matter at a depth of 0.5 m were used to characterize the water masses, and to determine the tolerance of the organisms observed in the samples obtained by surface hauls. These abiotic parameters were obtained using a Sensordata® CTD.

The chlorophyll *a* “in vivo” surface was estimated using a Turner Designs® fluorimeter, model TD-700. The flow rate data of the Itajaí-açu River, for the same sampling period, were obtained from the Agência Nacional de Águas (National Waters Agency) (ANA).

The samples for the zooplankton analysis were collected at 9 points distributed radially around the mouth of the estuary (Fig. 1). These points were selected in such a way that they covered the area from the Itajaí-açu River mouth, as far as the furthest point influenced by the river plume, on the internal shelf. The hauls for the zooplankton collection were carried out using a cylindrical-conical WP-2- like net with a mesh size of 200 µm, 30 cm in diameter at the opening, equipped with a flowmeter. Surface hauls (0,5 m of depth) were carried out, each one lasting 2 min. After the collection, the material retained in the net was stored in 1-liter plastic bottles, and fixed in 4% formalin.

In the laboratory, the qualitative and quantitative analyses of the zooplankton samples were carried out, at the lowest possible taxon, using a binocular stereoscopic microscope, biological microscope, and Bogorov counting chambers. The procedure recommended by Boltovskoy (1981) consisted of the fractioning of samples, using subsamplers of the “piston” type, covering a minimum of 10% of the samples. For the organism classifications, the works of Boltovskoy (1981, 1999), Montú and Gloeden (1986), Reid (1995) and El Moor Loureiro (1997) were used.

The data obtained in the qualitative and quantitative analyses were expressed by the number of organisms per cubic meter ($N.Org.m^{-3}$) of water filtered through the net. Different indices were calculated relating to the structure of the community, according to Omori and Ikeda (1984). The Margalef richness index, *D,* was obtained by:

$$D = \frac{S-1}{LnN}$$

where S is the number of species and N is the total number of organisms; the Shannon-Weaver diversity index, H', obtained by:

$$H' = -\sum_{i=1}^{s} P_i Log_2 P_i$$

where P is the proportion of the number of individuals of the n^{th} species in relation to the total number, n_i/N; and the Pielou equitability index, J', obtained by

$$J' = \frac{H'}{Log_2 S}$$

with the same captions as before.

The relationship between the more frequent species in the samples and the water masses present in the study area was shown by diagram T-S Plankton and by ordenation analysis. The density data of the species used in the ordenation analysis were standardized by logarithmic transformation (PIELOU, 1984).

RESULTS

Abiotic Factors (River Discharge, Temperature, Salinity and suspended matter)

Figure 2 presents the average flow rate for an interval of 30 days prior to each cruise. The flow rate of the Itajaí-açu River during the period usually presented time values of below 200 $m^3.s^{-1}$ between November 2002 and August 2003, and over 300 $m^3.s^{-1}$ from September 2003 on. However, about two weeks before the first cruise, in November 2002, there was an exceptional peak of 3,500 $m^3.s^{-1}$. Apparently, this peak induced a lower salinity value during the sampling, which was 22.03 in the first cruise.

The average monthly temperature values presented a seasonal standard in the waters of the Itajaí-açu River mouth, with maximum levels in the autumn (31.1ºC in 2003) and minimum levels in winter (18.1ºC in August 2003) (Fig. 3A). For salinity, no standard variation was observed, with the lowest averages during the spring 2002 and 2003 (minimum of 22.0 in November 2002) and in the winter of 2003 (Fig. 3B). The lower values observed during the winter are not related to the local freshwater load, given the low flow rate for the period, but are influenced by the Plata coastal front. The Plata coastal front is formed by the dilution of sub-Antarctic water coming from the Malvinas Current, by the river discharge from the Plata estuary, and largely, from the contribution of the Patos Lagoon. During the winter, the front shifts northwards, over the continental shelf of the South and Southeast of Brazil (PIOLA et al., 2000). The physical characterization and water masses occurring during this period and in all the extracts of the water column were presented by Schettini et al. (2005).

The particulate matter in suspension load was, in general, low for all the periods sampled (< 5 $mg.L^{-1}$), but with peaks in November 2002 (maximum 15.2 $mg.L^{-1}$) and October and late December 2003 (Fig. 3C), associated with high flow rates in the river.

Chlorophyll *a*

The data for chlorophyll-*a* do not present any continuity over the sampling period, and there is a lack of information for the spring (Fig. 4). However, the average values show a low phytoplankton concentration for the study area (< 0.4 $\mu g.L^{-1}$) with a small peak in February 2003, of 0.68 $\mu g.L^{-1}$.

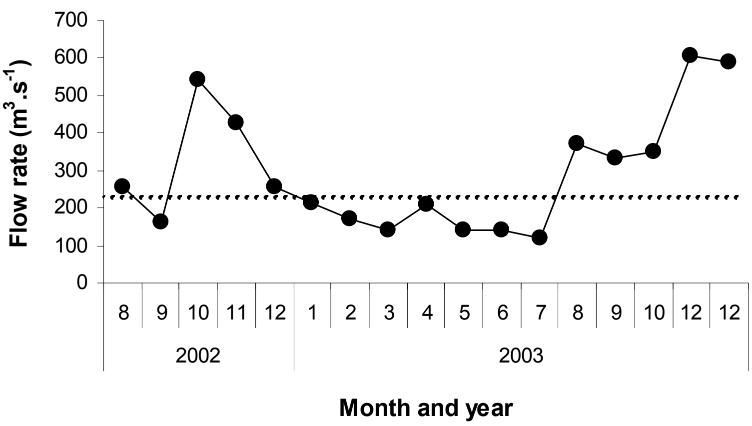


Fig. 2. Average flow rate values for the Itajaí-açu River, estimated 30 days prior to each cruise. The dotted line indicates the average flow rate for the last 34 years.

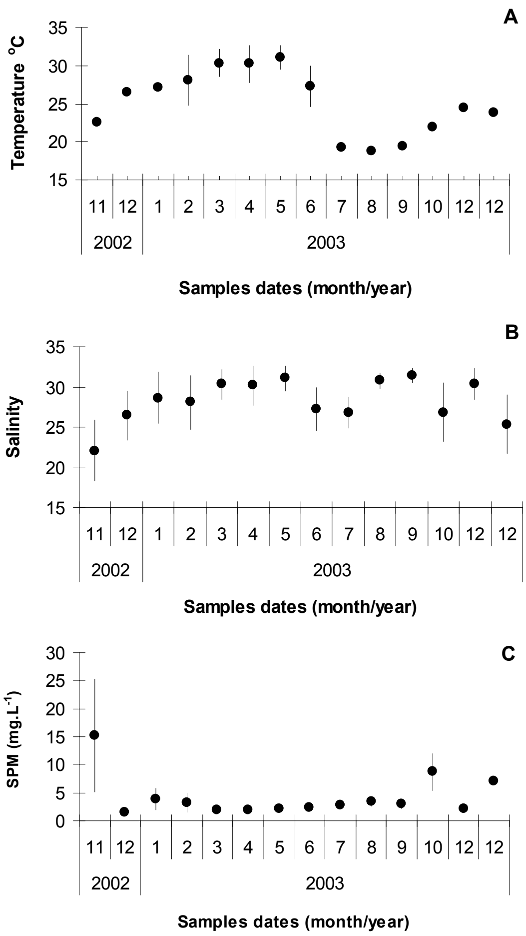


Fig. 3. Average values and standard error for: A - temperature (°C); B – salinity and C – Suspended particulate matter (SPM, $mg.L^{-1}$) for the 14 cruises carried out between 2002 and 2003.

Zooplankton

Temporal Variation

The average density values for the total zooplankton presented more or less constant behavior throughout the sampling period, with an overall average of 736 Org.m^{-3}. However, density peaks were observed in the winter and the early spring 2003, with a maximum value of 1,560 Org.m^{-3} in October 2003 (Fig. 5).

Spatial variation

In the majority of the cruises, the zooplankton density values did not present any clearly-defined standard in their distribution, and did not show any relation with the distribution of salinity and with the river plume, despite observing strong saline gradients (Fig. 6). An exception was the December 2002 cruise, when high zooplankton density values were established in the source plume over the adjacent shelf and its river mouth.

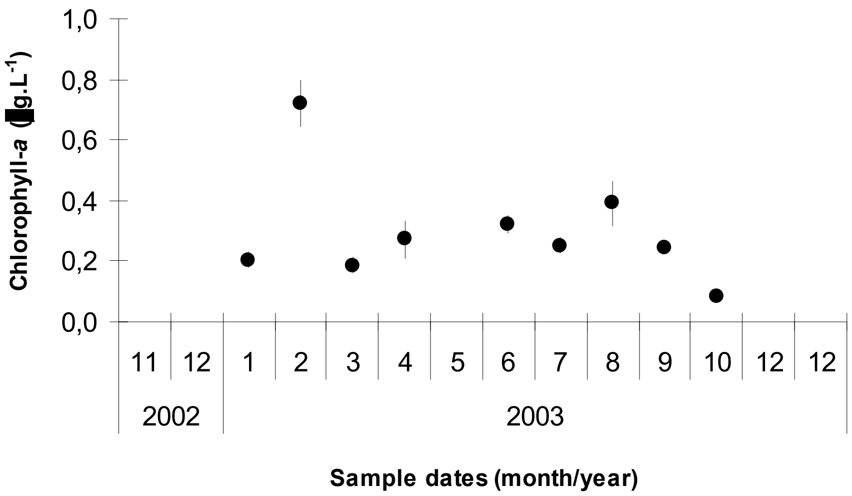


Fig. 4. Average values and standard error for Chlorophyll *a* obtained for the 9 cruises carried out in 2003.

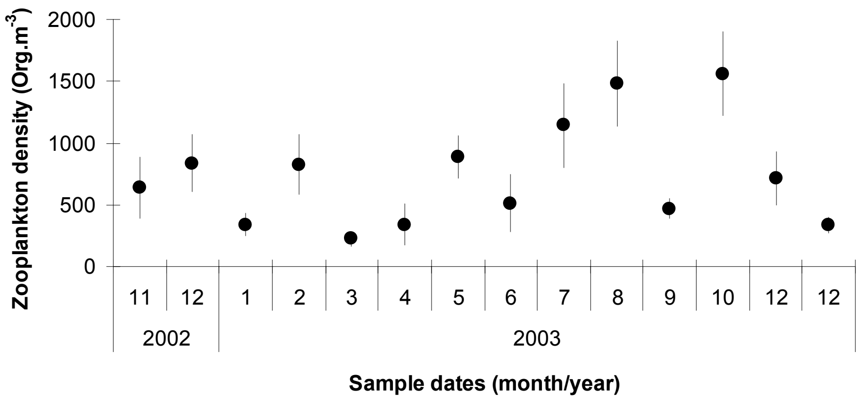


Fig. 5. Average values and standard error for total zooplankton density for each cruise between 2002 and 2003.

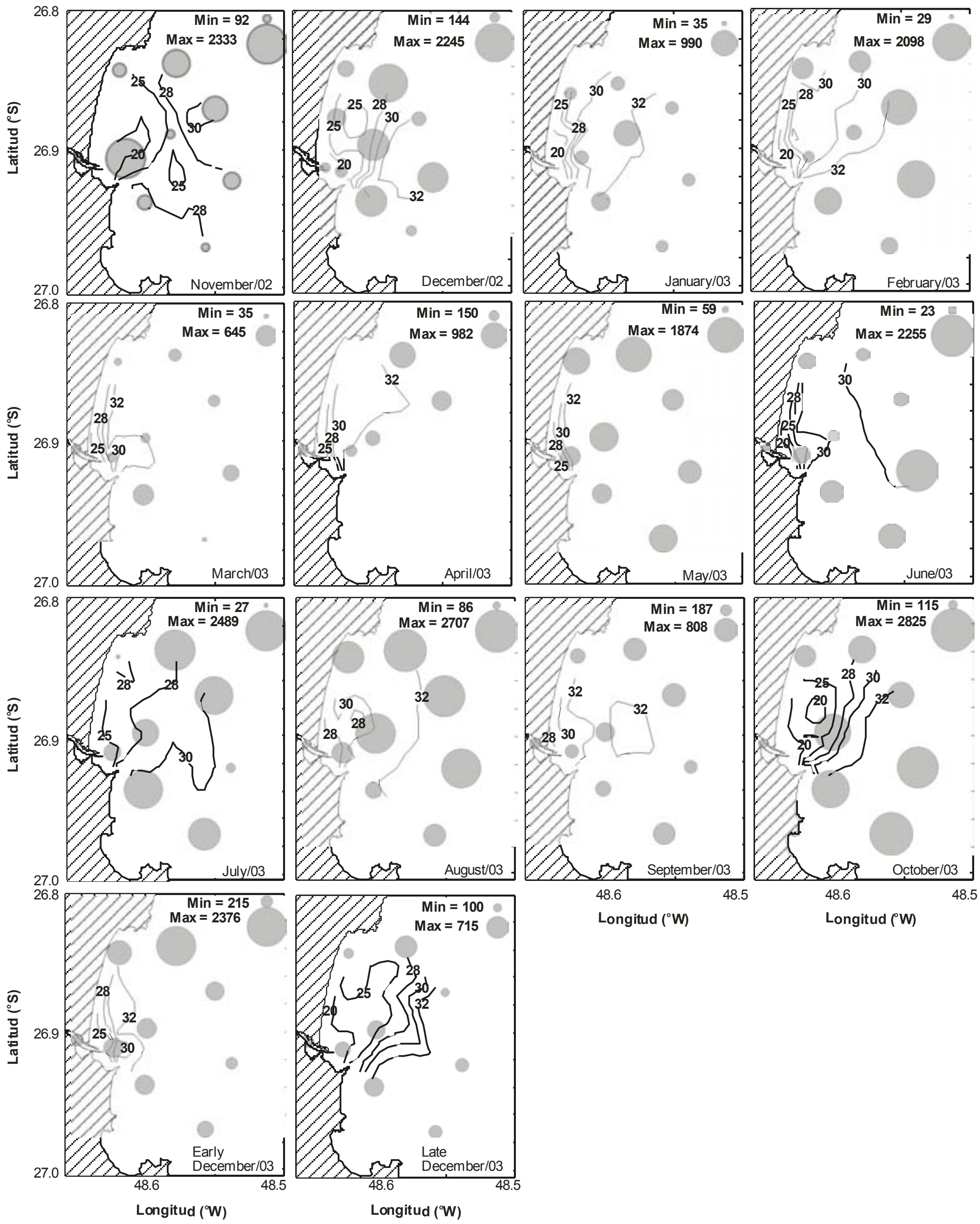


Fig. 6. Zooplankton density variation (Org.m^{-3}) (circles) in the Itajaí-açu River mouth, and the salinity (lines) distribution at the 0.5 m for the 14 cruises carried out between 2002 and 2003.

Zooplankton Composition

For the 14 cruises carried out, a total of 56 taxa were identified, the majority of them being copepods (Table 1). The highest diversity of species was observed at the end of spring 2002 and beginning of summer 2003 (Fig. 7) due to the greater species richness and higher equitability. In winter and spring 2003, the diversity was low, due mainly to the lower equitability between the species.

Table 1. Average density (A.D., Nº Org.m^{-3}) and frequency of occurrence (F.O., %) of the zooplankton species occurring in the samples from the Itajaí-açu River mouth obtained in 14 cruises carried out between 2002 and 2003.

Organism	A.D. (Org.m^{-3})	F.O. (%)	Organism	A.D. (Org.m^{-3})	F.O. (%)
Cnidariana			Copepoda		
Polyps	0.08	1.64	Copepodite	234.00	95.90
Hydroida	1.96	18.85	*Acartia lilijeborgi* Giesbrecht, 1889	13.78	31.15
Liriope tetraphylla (Chamisso & Eysenhardt, 1821)	2.18	16.39	*Centropages* sp	16.83	45.90
Siphonophora Calicophorae	0.81	11.48	*Clytemnestra rostrata* (Brady, 1883)	0.07	1.64
			Corycaeus spp	33.58	68.85
Mollusca			*Eucalanus* sp	3.44	17.21
Bivalvia (Veliger)	6.73	34.43	*Euterpina acutifrons* (Brian, 1921)	1.64	19.67
Gastropoda (Veliger)	1.82	22.95	*Farranula* sp	1.28	7.38
Pteropoda (*Creseis* sp)	1.19	9.84	*Labidocera fluviatilis* F. Dahl, 1894	0.02	0.82
			Macrocyclops sp	0.04	0.82
Annelida (Polychaeta)			*Macrosetella gracilis* (Dana, 1847)	3.91	21.31
Trochophore	2.11	15.57	*Mesocyclops* sp	0.09	1.64
			Microcyclops sp	0.13	2.46
Cladocera			*Oithona oswaldocruzii* Oliveira, 1945	2.65	19.67
Bosmina longirostris (O.F. Müller, 1785)	0.09	1.64	*Oithona ovalis* Herbst, 1955	0.10	1.64
Ceriodaphnia silvestrii *Daday, 1902*	0.69	1.64	*Oithona plumífera* Baird, 1843	1.76	10.66
Evadne spinifera P.E. Muller, 1867	1.07	7.38	*Oncaea* sp	2.80	13.93
Macrothrix triserialis (Brady, 1886)	0.68	1.64	*Paracalanus quasimodo* Bowman, 1971	68.58	62.30
Moina minuta Hansen, 1899	1.60	4.92	*Parvocalanus crassirostris* (Dahl, 1894)	69.94	29.51
Penilia avirostris Dana, 1852	106.81	64.75	*Temora stylifera* (Dana, 1849)	10.21	39.34
Pleopis polyphemoides (Leuckart, 1859)	0.43	4.10	*Temora turbinata* (Dana, 1849)	39.31	45.08
Pseudevadne tergestina (Claus, 1877)	11.05	26.23			
			Chaetognatha		
Amphipoda	0.18	3.28	*Sagitta enflata* Grassi, 1881	1.94	18.03
Hiperiidea	0.84	4.10	*Sagitta híspida* Conant, 1895	1.00	11.48
			Sagitta tenuis Conant, 1896	9.74	52.46
Euphausiacea					
Calyptopis	6.08	23.07	Larvacea		
			Oikopleura dioica (Fol, 1872)	21.23	57.38
Decapoda					
Lucifer faxoni Bonadile, 1915	2.93	21.31	Thaliacea		
Megalopa	0.50	4.10	*Thalia democrática* (Forskal, 1775)	35.8	24.59
Mysis	0.83	9.84	*Weelia cilíndrica* (Cuvier, 1804)	0.21	1.64
Protozoea	1.36	15.57	*Doliolum nationalis* Borgert, 1894	3.09	16.39
Zoea	6.42	47.54			
			Teleostei		
			Egg	2.46	13.11
			Larvae	1.03	16.93

The species which presented the highest average densities and occurrence frequencies were: *Paracalanus quasimodo, Parvocalanus crassirostris, Temora stylifera, T. turbinata* and *Acartia lilijeborgi*. In other groups, *Sagitta tenuis* was the predominant species for the Chaetognatha, *Penilia avirostris* and *Moina minuta* for the Cladocera, *Oikopleura dioica* for the Larvacea, and the zoea stage for the decapod crustacean larvae.

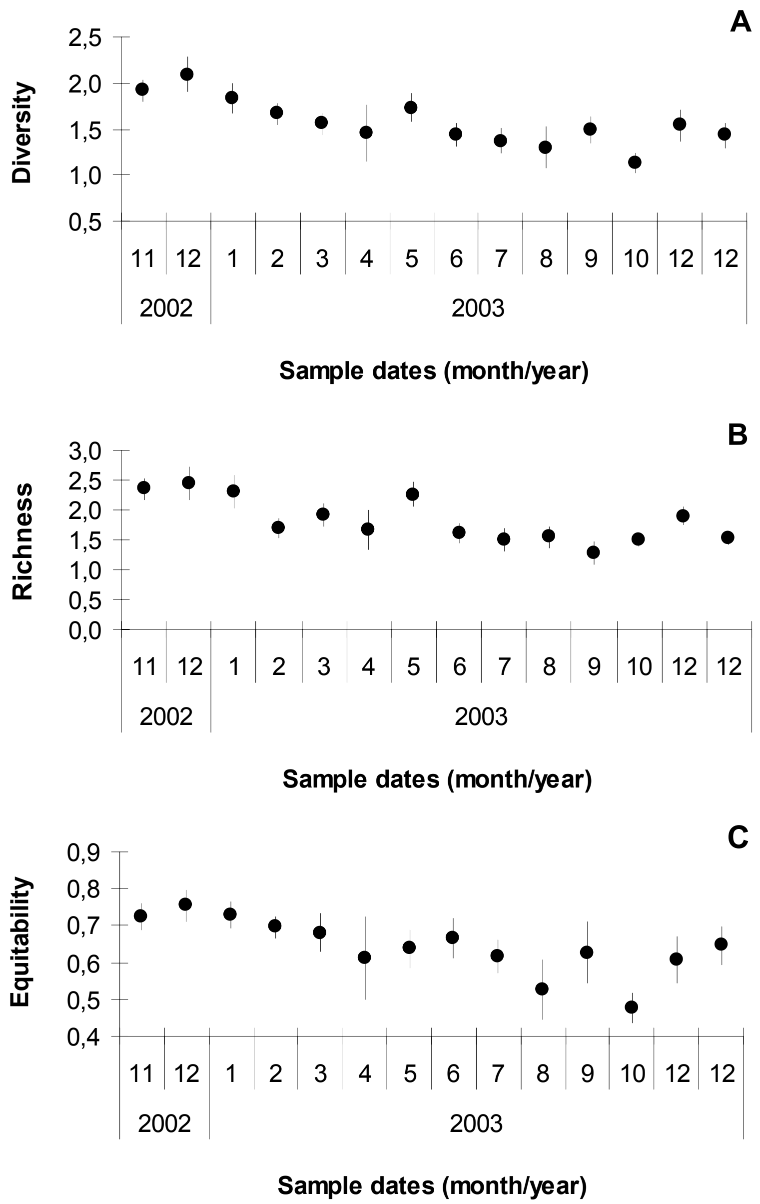


Fig. 7. Average values and standard error for: A – Shannon-Weaver diversity index; B – Margalef richness index and C – Pielou equitability index for each cruise between 2002 and 2003.

As to the specific composition of zooplankton identified in the samples, groups of species were observed with similar abiotic demands, which are imposed by the hydrological conditions (Fig. 8). A typical group of the Itajaí-açu River mouth was that comprised of *Acartia lilijeborgi* and *Oithona oswaldocruzii*, occurring in waters with intermediate temperature but low salinities, particularly in the November 2002 cruise and in the sampling points close to the river mouth.

The dominant species on the adjacent shelf consisted of small copepods presenting *P. quasimodo* with distribution at the upper extremes of temperature and salinity of Tropical Water, while *P. crassirostris* occurred in the lower extreme of the same body of water (Fig. 8). For the species of the *Temora*, *T. turbinata* genus, higher densities were observed in waters with high temperatures, while *T. stylifera* occurred in high densities in waters with higher salinities.

These results were confirmed by the ordering analysis (Fig. 9), despite the low explanation accumulated by the two first axes (31.4%). The first axis was related to the seasonal variation between cruises (high weight for the temperature), while the second axis presented a relationship with the influence of the inflow of the Itajaí-açu River, and consequently, with the salinity of the sampling points.

Discussion

Due to the type of sampling carried out in this study, which was limited to the surface layer of the water column, the vast majority of cruises

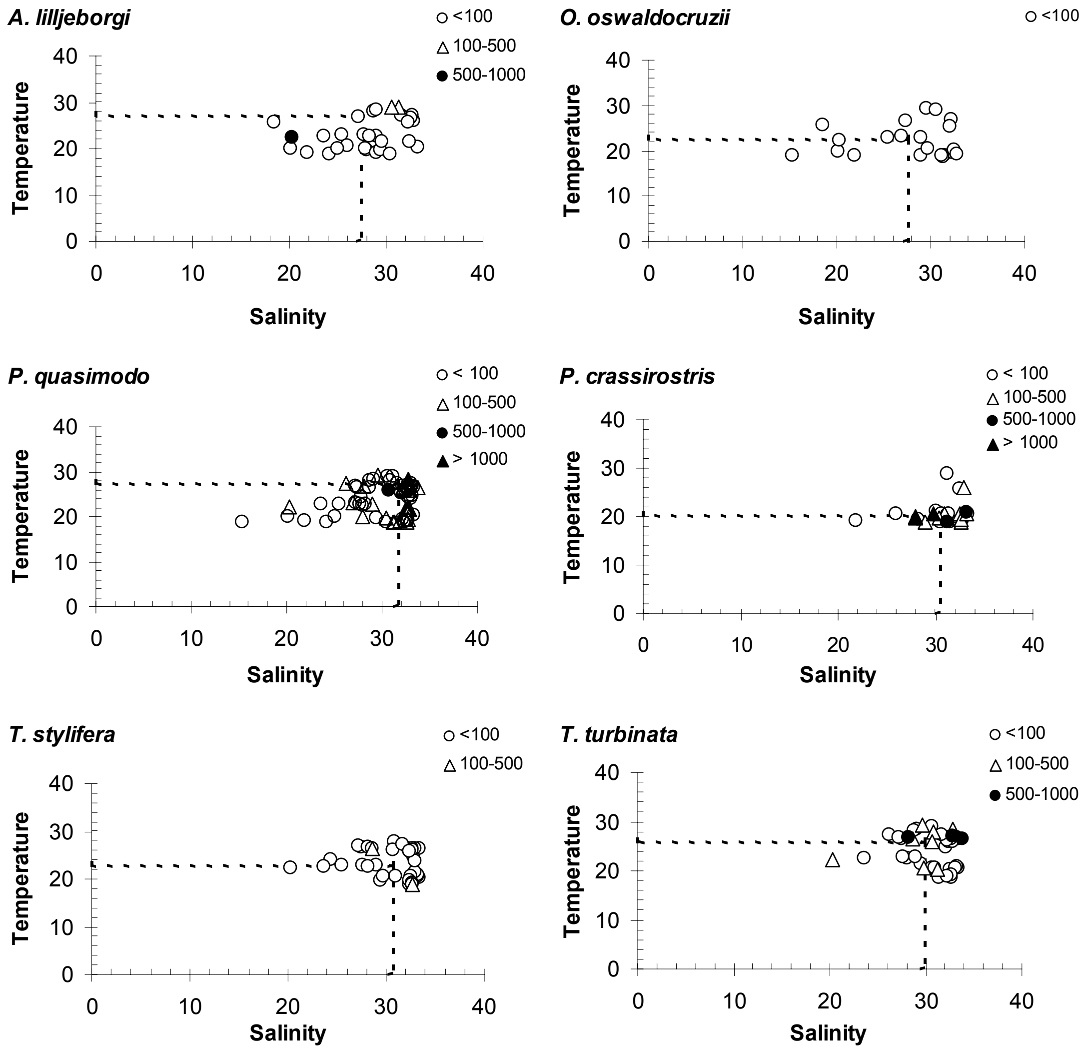


Fig. 8. T-S-Plankton diagram for the main species registered on the adjacent shelf and mouth of the Itajaí-açu River, for the years 2002 and 2003. Captions refer to the intervals of density of the organisms (Org.m^{-3}) and the dotted lines to the average temperature and salinity values for the high density values.

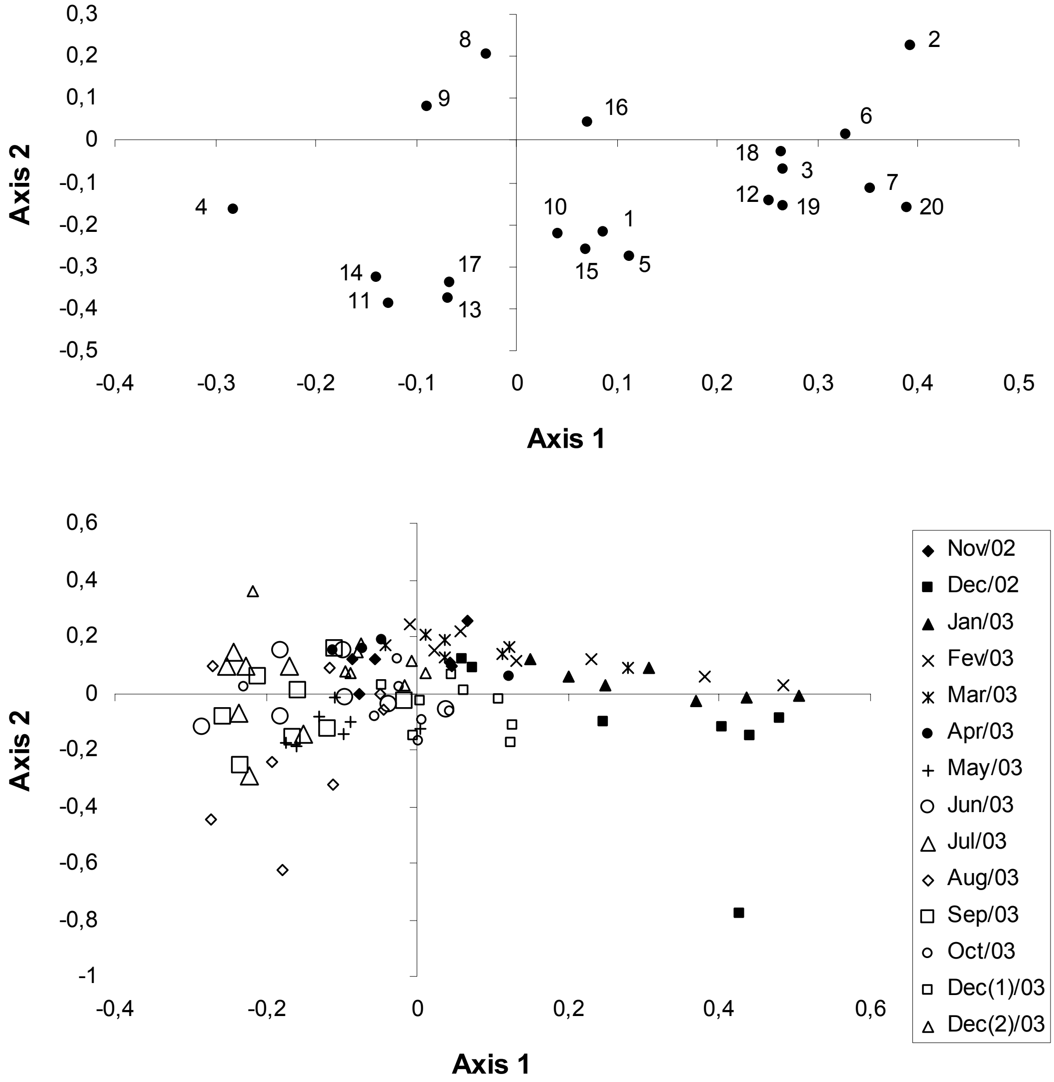


Fig. 9. First and second axis of the principal components analysis (PCA). A: Eight values. Where: 1 – Salinity, 2 – Temperature, 3 – *P. quasimodo*, 4 – *P. crassirostris*, 5 – *T. stylifera*, 6 – *T. turbinata*, 7 – *S. tenuis*, 8 – *A. lilljeborgi*, 9 – *O. oswaldocruzii*, 10 – *L. tetraphylla*, 11 – *P. avirostris*, 12 – *P. tergestina*, 13 – *O. plumifera*, 14 – *E. acutifrons*, 15 – *D. nacionalis*, 16 – *T. democratica*, 17 – *S. enflata*, 18 – *L. faxoni*, 19 – *M. gracilis*, 20 – *S. hispida*. B: Eight vectors with the identification of the samples mouths.

involving summer, autumn and spring were characterized by the Tropical Water of the shelf (SCHETTINI et al., 2005). The indicator species of Tropical Water in these periods were copepods *Paracalanus quasimodo, Parvocalanus crassirostris, Temora stylifera* and *T. turbinata* (BJÖRNBERG, 1981), the cladocera *Pseudoevadne tergestina* and *Evadne spinifera* (RESGALLA; MONTÚ, 1993), the Chaetognatha *Sagitta enflata* and *S. híspida* (RESGALLA JR.; MONTÚ, 1995) and the salpidae (thaliaceas) *Doliolum nationalis* and *Thalia democrática* (ESNAL; DAPONTE, 1999a, 1999b).

As for the dominant species in the area of study, *P. quasimodo* and *P. crassirostris* are the species which are typical of the Brazilian coast and abundant in waters with low salinity of regions under heavy influence of the continental inflow (ARAUJO, 2006; BJÖRNBERG, 1981). For the species of the genus *Temora*, the replacement of the native species *T. stylifera* for the invasive species *T. turbinata* on the Brazilian coast, has been highlighted by Ara (2002). Also according to this author, the high production of *T. turbinata* (P/B ratio) would explain its higher abundance in relation to the native species.

In this work, on the other hand, the lower tolerance of *T. stylifera* is highlighted in response to variations in salinity, compared with *T. turbinata,* proving itself less competitive in coastal and estuarine waters than the invasive species.

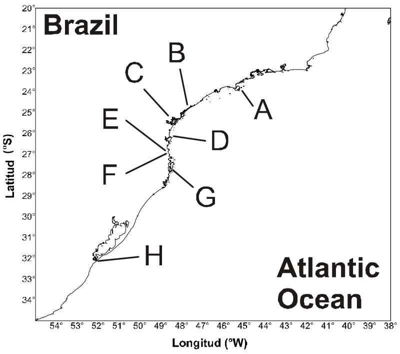
In winter and spring, the high densities of zooplankton may be attributed to the different physical processes which occur on the shelf. In winter, the low salinity of the shelf water, associated with the low flowrate of the river, the low particulate material in suspension, and the presence of *P. polyphemoides* in the samples (RESGALLA JR.; MONTÚ, 1993; MUXAGATA; MONTÚ, 1999) have been attributed to the strong influence of the front of the Plata River (SCHETTINI ET AL., 2005). In the samples from this period, the equitability of species was low, showing the prevalence of *Parvocalanus crassirostris* on the shelf. This species presented an inverse correlation with water temperature, according to ordenation analysis (Fig. 9). As it is a species with wide distribution on the Brazilian coast (NEUMANN-LEITÃO, 1994) its dominance will certainly be more associated with the low salinities of water of the front from the Plata River than with temperature. According to Almeida Prado and Lansac Tôha (1984), *P. crassirostris* presents higher tolerance to low salinity than *P. quasimodo*, and this may be the determining factor in the prevalence of these two species.

For the spring, the low equitability was caused by the prevalence and abundance of *Pelinia avirostris* in the samples from the shelf. This species has frequently been cited for its occurrence in high densities in river mouths, and because of its microdistribution in the initial centimeters of the water column. This behavior may facilitate its accumulation in frontal regions and convergences of waters from different sources (RAMIREZ, 1981).

The influence of the freshwater load from the Itajaí-açu on the shelf was clearly evident where there was a relation between flow rate, lower salinity values, and higher concentrations of suspended matter, in spring 2002 and 2003. The copepods related to the presence of the river plume and the estuarine characteristics associated with this feature, were *Acartia lilljeborgi* and *Oithona oswaldocruzii*, typical species of Brazilian coastal regions (BJÖRNBERG, 1981). *A. lilljeborgi* has been highlighted as the predominant and most frequent species in the Itajaí-açu River plume, with direct responses on the increase in phytoplankton in the river mouth (SCHETTINI et al., 1998; RÖRIG et al., 2003). However, the most prevalent species in this study were the copepods *Paracalanus quasimodo* and *Parvocalanus crassirostris*, typical of areas where the plume loses nutrient and shows a reduction in the size of the phytoplankton cells on the shelf (RÖRIG et al., 2003). The low chlorophyll *a* values observed during the sampling period indicated the low abundance of phytoplankton, and consequently, the predominance of these species of small sized copepods, which probably feed on the more developed microbial loops in the region.

Except for December 2002, practically no relation was observed between the zooplankton densities and the presence of a well-developed plume over the shelf. The previous work by Schettini et al. (1998) observed higher metabolic activity of the zooplankton associated with the Itajaí-açu River plume in deep waters, which may explain the higher density values found, in response to the reproductive increase of the organisms. The sampling level adopted, with the delimitation of the oceanographic stations on a different spatial scale from the saline gradients and limited to the surface of the water column (Fig. 6), may have prevented obtaining a clearer response on the zooplankton community in the Itajaí-açu River plume.

The zooplankton of the Itajaí-açu River mouth presented a prevalence of the same species as those which occur in the main coastal and estuarine environments of the Southeast and extreme south of Brazil (Fig. 10). The copepod species of the warmer waters, mainly *Oithona oswaldocruzii* and *Paracalanus quasimodo*, indicate that this environment presents greater similarity, in terms of fauna, with the southeastern region. The absence of *Acartia tonsa* in this region, an estuarine species found in colder waters, may be related to the conditions of food availability (PAFFENHOEFER; STEARNS, 1988), and/or the hydrographic conditions of the region. The estuary of the Itajaí-Açu River mouth is a system dominated by the river with high variability in the distribution of salinity, both temporal and spatial, and with less residence time of the water (SCHETTINI, 2002), which may be a limiting factor for the colonization of this species of mixohaline waters. On the other hand, the occurrences of *A. tonsa* in the Bay of Babitonga and in the Baía Sul of the Santa Catarina Island (Florianópolis) suggest that the northern region of the State may present climatic characteristics of the Lagoa dos Patos Estuary, particularly during the winter months.



Region		*Acartia lillijeborgi*	*Acartia tonsa*	*Oithona oswaldocruzii*	*Parvocalanus crassirostris*	*Paracalanus quasimodo*	*Euterpina acutifrons*
A	North	+	-	-	+	+	+
B		+	-	+	+	-	+
C		+	-	+	-	+	+
D		+	+	+	?	?	-
E		+	-	-	?	?	-
F		+	-	+	+	+	+
G	South	+	+	+	+	+	+
H		+	+	-	+	+	+

Fig. 10. Distribution of the main species of copepods in the coastal environments of southeastern and southern Brazil. Where: A – São Sebastião Channel (SP) (De La Rocha,1998), B – Cananéia Estuary (SP) (Montú, 1987), C – Paranaguá Bay (PR) (Montú ;Cordeiro, 1988), D – Babitonga Bay (SC) (Schettini et al., 2002), E – Navegantes Beach (SC) (Rörig et al., 1997), F – Itajaí-açu River mouth (SC) (present work), G – Saco dos Limões inlet Bay (SC) (Resgalla Jr., 2001) ; H – Lagoa dos Patos Estuary (RS) (Muxagata, 1995). (+) present (-) absent and (?) no information.

ACKNOWLEDGEMENTS

The authors would like to thank Anatole Trochimczuk Filho and members of the CTTMar staff who assisted in the field activities. This work is a contribution to the project 'Interaction of the estuary of the Itajaí-Açu River and continental shelf, and its implications on the coastal evolution and biological activity – ITAPLA'. It was carried out with resources provided by the Fundação de Amparo a Pesquisa de Santa Catarina (Santa Catarina Research Support Fund) - FAPESC. We would also like to thank the Conselho Nacional de Pesquisa (National Research Council) (CNPq) for the Grant 307556/2004-2.

REFERENCES

ALMEIDA PRADO, M. S.; LANSAC TÔHA, F. A. The distribution of brackish water Calanoida (Copepoda) along the coasts of Brazil. **Hydrobiologia**, v. 113, p. 147-150, 1984.

ARA, K. Temporal variability and production of *Temora turbinata* (Copepoda: Calanoida) in the Cananéia Lagoon estuarine system, São Paulo, Brazil. **Scient. mar**. v. 66, n. 4, p. 399-406, 2002.

ARAUJO, H. M. P. Distribution of Paracalanidae species (Copepoda, Crustacea) in the continental shelf off Sergipe and Alagoas states, Northeast Brazil**. Braz. J. Oceanogr**. v. 54, n. 4, 173-181, 2006.

BJÖRNBERG, T. S. K. Copepoda. In: BOLTVOSKOY, D. (Ed.). **Atlas del zooplankton del Atlántico Sudoccidental y métodos de trabajo con el zooplancton marino.** Mar del Plata: INIDEP, 1981. p. 587-680. (Publ. esp.).

BOLTOVSKOY, D. **Atlas del zooplancton del Atlántico Sudoccidental y métodos de trabajo con el zooplancton marino**. Mar del Plata: INIDEP, 1981. 936 p. (Publ. esp.).

BOLTOVSKOY, D. (Ed.). **South Atlantic Zooplankton**. Leiden: Backhuys , 1999. 1705 p. 2 v.

BRANDINI, F. P.; LOPES, R. M.; GUTSEIT, K. S.; SPACH, H. L.; SASSI, R. 1997. **Planctologia na Plataforma Continental do Brasil.** Diagnose e revisão bibliográfica**.** Pontal do Sul: **CEMAR/ MMA/ CIRM/ FEMAR,** 1997. 196 p.

CARVALHO, J. L. B.; SCHETTINI, C. A. F.; RIBAS, T. M. Estrutura termohalina do litoral centro norte catarinense. **Notas Téc. Facimar**, v. 2, p. 181-197, 1998.

DE LA ROCHA, C. L. **Estrutura anual da comunidade zooplanctônica nas águas da Praia do Segredo (São Sebastião-SP).** Dissertação (Mestrado), Instituto de Biociencias, Universidade de São Paulo, 86 p. 1998.

EL MOOR-LOUREIRO, L. M. A. **Manual de identificação de Cladóceros Líminicos do Brasil**,. Brasilia, DF: Editora Universa, 1997. 155 p.

ESNAL, G. B.; DAPONTE, M. C. Doliolida. In: BOLTOVSKOY, D. (Ed.). **South Atlantic Zooplankton**. Leiden: Backhuys, 1999a. p. 1409-1421.

ESNAL, G. B.; DAPONTE, M. C. Salpida. In: BOLTOVSKOY, D. (Ed.). **South Atlantic Zooplankton**. Leiden: Backhuys , 1999b. p. 1423-1444.

GAPLAN. **Atlas de Santa Catarina.** Rio de Janeiro: Aerofoto Cruzeiro, 1986.

HAURY, L. R.; PIEPER, R. E. Zooplâncton: Scales of biological and physical events. In: SOULE, D.F.; KLEPPEL, G. S. (Ed). **Marine Organisms as Indicator**. New York: Springer-Verlag, 1988. p. 35-72.

LE FÈVRE, J. Aspects of the biology of frontal systems. **Adv**. **mar**. **Biol**., v. 23, p. 163-299, 1986.

MANN, K. H.; LAZIER, J. R. N. **Dynamics of marine ecosystems:** Biological-physical interactions in the oceans. 3rd ed. New York: Blackwell Publishing, 2005. 512 p.

MONTÚ, M. Estuário do sistema lagunar de Cananéia, complexo da Baía de Paranaguá e Lagoa dos Patos. In: SIMPÓSIO SOBRE ECOSSISTEMAS DA COSTA SUL E SUDESTE BRASILEIRA, 1, 1987, Cananéia, São Paulo, São Paulo. **Memórias...** São Paulo: Academia de Ciências do Estado de São Paulo, 1987. v. 3, p. 176-193.

MONTÚ, M.; CORDEIRO, T. A. Zooplâncton del complejo estuarial de la Bahía de Paranaguá. I. Composición, dinámica de las especies, ritmos reproductivos y acción de los factores aqmbientales sobre la comunidad. **Nerítica,** v. 3, n. 1, p. 61-83, 1988.

MONTÚ, M.; LOEDEN, I. M. Atlas dos cladóceros e copépodas (crustácea) do estuário da lagoa dos Patos (Rio Grande, Brasil). **Nerítica**, v. 1, n. 2, p. 1-134, 1986.

MUXAGATA, E. **Influência da dinâmica na composição, distribuição e abundância do holo e meroplâncton no canal de Rio Grande (Lagoa dos Patos-RS, Brasil)**. Rio Grande: Univ. Rio Grande, 1995. 74p. (Monografia).

MUXAGATA, E.; MONTÚ, M. A. Os cladoceros da plataforma continetal sudeste brasileira: distribuição, densidade e biomassa (Inverno de 1995). **Nauplius**, v. 7, p. 151-172, 1999.

NEUMANN-LEITÃO, S. Resenha literária sobre o zooplâncton estuarino no Brasil. **Trabhs. Oceanogr**., **Univ. Fed. Recife**, v. 23, p. 25-53, 1994.

O'DONNELL, J. Surface fronts in estuaries: a review. **Estuaries**, v. 16, n. 1, p. 12-39, 1993.

OMORI, M.; IKEDA, T. **Method in marine zooplankton ecology**. New York: Jonh Wiley & Sons , 1984. 332 p.

PAFFENHOEFER, G. A.; STEARNS, D. E. Why is *Acartia tonsa* (Copepoda: Calanoida) restricted to nearshore environments? **Mar. Ecol. Prog. Series**, v. 42, p. 33-38, 1988.

PIELOU, E. C. **The interpretation of ecological data**: A primer on classification and ordination. New York: Wiley Intersci., 1984. 263 p.

PIOLA, A. R.; CAMPOS, E. J. D.; MÖLLER JR., O. O.; CHARO, M.; MARTINEZ, C. Subtropical shelf front off eastern South América. **J. geoph**. **Res**., v. 105(C3), p. 6565-6578, 2000.

RAMIREZ, F. C. Cladócera. In: BOLTVOSKOY, D. (Ed.). **Atlas del zooplankton del atlantico sudoccidental y métodos de trabajo con el zooplancton marino**. Mar del Plata: INIDEP, 1981. p. 533-541. Publ. esp.

REID, J. W. Chave de identificação para as espécies continentais sulamericanas de vida livre da Ordem Cyclopoida (Crustácea, Copépoda), **Bolm Zool., Univ. São Paulo**, v. 9, p. 17-143, 1995.

RESGALLA JR., C. Estudo de impacto ambiental sobre a comunidade do zooplâncton na enseada do saco dos limões, baía sul da ilha de Santa Catarina, Brasil. **Atlântica**, v. 23, p. 5-16, 2001.

RESGALLA JR., C.; MONTÚ, M. Cladóceros marinhos da plataforma continental do Rio Grande do Sul-Brasil. **Nauplius**, v. 1, p. 63-79, 1993.

RESGALLA JR., C.; MONTÚ, M. Quetognatos de la plataforma continental del sur de Brasil. **Inv. Mar. CICIMAR**, v. 10, n. 1-2, p. 23-41, 1995.

RÖRIG, L. R.; RESGALLA JR.; C.; PEZZUTO, P. R.; ALVES, E. S. ; MORELI, F. Análise ecológica de um processo de acumulação da diatomácea *Anaulus* sp. na zona de arrebentação da Praia de Navegantes (Santa Catarina, Brasil). **Oecol. Bras**., v. 3, p. 29-43, 1997.

RÖRIG, L. R.; RESGALLA JR., C.; SCHETTINI, C. A. F. Estrutura da assembléia planctônica através do estuário e da pluma do rio Itajaí-Açu. **Rer. Estud. ambient., Blumenau**, v. 5, n.1, p. 76-94, 2003.

SCHETTINI, C .A. F. Caracterização física do Estuário do Rio Itajaí-açu, SC. **Rev. Bras. Recursos Hídricos**, v. 7, p. 123-142, 2002.

SCHETTINI, C. A. F.; KUROSHIMA, K. N.; PEREIRA FILHO, J.; RÖRIG, L. R.; RESGALLA JR., C. Oceanographic and ecological aspects of the Itajaí-açu river plume during a high discharge period. **An. Acad. Bras. Ciênc**., v. 70, n. 2, p. 335-351, 1998.

SCHETTINI, C. A. F.; RESGALLA JR., C.; PEREIRA FILHO, J.; SILVA, M. A. C.; TRUCCOLO, E. C.; RÖRIG, L. R. Variabilidade temporal das características oceanográficas e ecológicas da região de influência fluvial do rio Itajaí-açu. Braz. **J. Aquat. Sci. Technol., v.** 9, n. 2, p. 93-102, 2005.

SCHETTINI, C. A. F.; TRUCCOLO, E. C.; RESGALLA JR.; C.; RORIG, L. R.; KUROSHIMA**,** K. N**.** O sistema estuarino da baía da Babitonga. In: KNIE, J. L. W. (Ed.). **Atlas ambiental da região de Joinville** - Complexo hídrico da baía da Babitonga. p. 113-118. 2002.

TROCHIMCZUK FILHO, A.; SCHETTINI, C. A. F. Avaliação da dispersão espacial da pluma do estuário do rio Itajaí-Açu em diferentes períodos de vazão fluvial. **Notas Téc. Facimar**, v. 7, p. 83-96, 2003.

VALENTIN, J. L.; GAETA, S.; SAPCH, H. L.; MONTÚ, M. A.; ODEBRECHT, C. Diagnóstico ambiental oceânico e costeiro das regiões sul e sudeste do Brasil. Volume 4. Oceanografia Biológica: Plâncton. PETROBRÁS, 1994.

WISEMAN JR., W. J.; GARVINE, R. W. Plumes and coastal currents near large river mouths. **Estuaries**, v. 18, n. 3, p. 509-517, 1995.

(Manuscript received 02 October 2007; revised 19 December 2007; accepted 14 April 2008)