

## DISTRIBUTION AND ABUNDANCE OF CLADOCERA (BRANCHIOPODA) IN THE PARAÍBA DO SUL RIVER ESTUARY, RIO DE JANEIRO, BRAZIL

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### ABSTRACT

To characterize the cladoceran community of the Paraíba do Sul River estuary, located in the district of São João da Barra, Rio de Janeiro, Brazil, cladocerans were collected monthly in nine sampling stations from September 2002 until August 2003. Samples were obtained by subsurface tows using a plankton net with a 30 cm opening mouth and 70 micron mesh size, fitted with a mechanical flowmeter. Environmental parameters such as salinity and temperature were also obtained. Seventeen species of Cladocera were identified: *Pseudoevadne tergestina*, *Penilia avirostris*, *Macrothrix triserialis*, *Moina micrura*, *Simocephalus kerhervei*, *Simocephalus vetulus*, *Simocephalus latirostris*, *Simocephalus serrulatus*, *Alona rectangula*, *Alona quadrangularis*, *Bosmina longirostris*, *Bosminopsis deitersi*, *Camptocercus dadayi*, *Ceriodaphnia richardi*, *Diaphanosoma fluviatile*, *Kurzia latissima* and *Pleuroxus similis*. The highest total abundance of Cladocera occurred in April in the marine zone of the estuary. The most abundant species during this period was *Penilia avirostris*. At the mixing and freshwater zones of the estuary, the most abundant species were *Moina micrura*, mainly in January; and *Simocephalus vetulus* and *Bosmina longirostris* during spring. From this scenario, it can be inferred that the cladoceran community of the Paraíba do Sul River estuary presents characteristics of marine, brackish and freshwater environments. Temperature and salinity seem to limit the occurrence and distribution of cladocerans in the estuary.

### RESUMO

O presente estudo teve como objetivo caracterizar a comunidade zooplânctônica de cladóceros no estuário do Rio Paraíba do Sul, localizado no município de São João da Barra, RJ. O zooplâncton foi coletado mensalmente de setembro/2002 a agosto/2003 em nove estações através de arrastos subsuperficiais com uma rede de plâncton com abertura de boca de 30 cm e malha de 70 µm, dotada de fluxômetro mecânico. Foram medidas simultaneamente a salinidade e a temperatura. Foram identificadas dezessete espécies de cladóceros: *Pseudoevadne tergestina*, *Penilia avirostris*, *Macrothrix triserialis*, *Moina micrura*, *Simocephalus Kerhervei*, *Simocephalus vetulus*, *Simocephalus latirostris*, *Simocephalus serrulatus*, *Alona rectangula*, *Alona quadrangularis*, *Bosmina longirostris*, *Bosminopsis deitersi*, *Camptocercus dadayi*, *Ceriodaphnia richardi*, *Diaphanosoma fluviatile*, *Kurzia latissima* e *Pleuroxus similis*. As maiores abundâncias de cladóceros ocorreram no mês de abril na zona marinha do estuário. A espécie mais abundante nesse período foi *Penilia avirostris*. Na zona de mistura e fluvial do estuário, as espécies mais abundantes foram *Moina micrura*, principalmente durante o mês de janeiro; *Simocephalus vetulus* e *Bosmina longirostris* na primavera. Diante desse cenário, pode-se dizer que a comunidade de cladóceros no estuário do Rio Paraíba do Sul apresenta características de ambientes marinhos, estuarinos e límnicos. A salinidade e a temperatura parecem limitar a ocorrência e distribuição dos cladóceros no estuário.

*Descriptors:* Zooplankton; Estuary; Cladocera; Salinity.

*Descritores:* Zooplâncton; Estuário; Cladocera; Salinidade.

### INTRODUCTION

Estuaries constitute an important transition region between terrestrial and marine environments, with rivers as the main thoroughfare for materials from continental leaching to estuaries and coastal zones

(Garrels & Mackenzie, 1971). In general, estuarine waters are biologically more productive than freshwater systems and the adjacent ocean, due to their hydrodynamic circulation characteristics that retain nutrients, stimulate production (Miranda *et al.*, 2002), and produce high auto- and heterotrophic biomass (Nixon, 1981).

Tidal hydrodynamics have a strong effect on the composition and zonation of resident and temporary organisms in pelagic habitats. Combined with river discharge, tides influence the regulation of planktonic population by translocation of individuals from one place to another within and even to the outside of the estuary (Villate, 1997; Wooldridge & Callahan, 2000). Estuarine waters are characterized by high turbidity, turbulence and strong tidal currents, resulting in an environment in which organisms need to show specific adaptations. This, along with the limited exchange with coastal waters, results in the development of a distinct pelagic community (Miller, 1983).

Tidal effects on the regulation of estuarine zooplankton can be especially relevant in small system where strong river discharges occur (Kennish, 1990). Tides are not only responsible for distributional patterns, but also affect the survival of endemic populations through export of water masses and consequent reduction of resident populations (Kennish, 1990).

The neritic populations of areas with coastal, intermediate and freshwater inputs influence the relative development of estuarine systems through salinity variations (Tundisi, 1970; Lansac-Tôha & Lima, 1993; Lopes, 1994). Primary production is transferred to higher trophic levels through mesozooplankton. Estuarine plankton need to be able to respond to great physical-chemical changes in the environment, which influence daily and seasonal distributional patterns, and thus population dynamics. All these environmental and biological factors restrict the variety of zooplankton species in estuaries compared to marine areas, but the high primary productivity levels in estuaries can make these species very abundant (Summerhayes & Thorpe, 1998).

Cladocerans form a typical limnic group, although some marine species do exist (Elmoor-Loureiro, 1997). They are generally seen as a secondary component of the estuarine zooplankton, even though they may compose a significant fraction of the zooplanktonic community. When abundant, they can be an important food item for planktivorous fish and other zooplanktonic predators, and perform a significant role in production of organic matter (Marazzo & Valentin, 2004).

Studies on cladocerans in other countries are concentrated in lakes (Hobaek *et al.*, 2002) and wetlands (Hann & Zrum, 1997). There are few studies on cladocerans in tropical estuarine regions. Very little is known on the life habits of the cladoceran species found in Brazil (Elmoor-Loureiro, 1997), the majority of studies focusing on limnic environments such as reservoirs and lakes (Sampaio *et al.*, 2002; Santos-Wisniewski *et al.*, 2002; Elmoor-Loureiro *et al.*, 2004) and flooded river plains (Neves *et al.*, 2003;

Serafim Jr. *et al.*, 2003). On marine environments, there are works by Marazzo & Valentin (2000; 2001) and Valentin & Marazzo (2003) at Guanabara Bay; Resgalla Jr. & Montú (1993) on the coast of Rio Grande do Sul State. There is no current work on cladoceran communities of estuaries influenced by large rivers such as the Paraíba do Sul. Therefore, the present study characterizes the cladoceran community of the Paraíba do Sul River estuary, located in the district of São João da Barra, Rio de Janeiro State, and evaluates its distribution in different hydrodynamic and hydrochemical conditions.

## MATERIAL AND METHODS

### Study Area

The Paraíba do Sul River estuary is located between the districts of São João da Barra and São Francisco do Itabapoana (21°37' S and 41°00'W), with a mangrove zone of approximately 8 km<sup>2</sup> (Fig. 1). It is the second largest river in the littoral zone of the southeast area of Brazil, 1,150 km long, and a drainage area of approximately 55,500 km<sup>2</sup>, extending through the states of São Paulo, Minas Gerais and Rio de Janeiro. Its upper part extending from São Fidélis city to the source, is 95 km long with an average declivity of 0,22 m.km<sup>-1</sup>, crossing the Campista low lands, comprising sedimentary soil of fluvial-marine origin, and ultimately discharging into the Atlantic Ocean (Fig. 1). Besides domestic and industrial uses, resources of the river basin are intensively exploited by agriculture, fishing, navigation and for energy generation (CEIVAP, 2001; DNAEE, 1995).

Salinity within the Paraíba do Sul River estuary is regulated by riverine input, tides and coastal currents. The extent of the river plume is determined by several factors such as winds, currents and riverine input (Carneiro, 1998). The rainfall regime in the catchment area of the Paraíba do Sul River shows a period of intense rain activity (November to January) causing floods and a very dry period (July to August). River flow ranges from 155 to 2984 m<sup>3</sup>.s<sup>-1</sup> with the highest flow between December and March, and the lowest from June to October (DNAEE, 1995). These conditions certainly influence the zooplankton, especially during the flood periods.

### Sampling

Sampling was performed monthly during a period of 12 months (September 2002 - August 2003) along the saline gradient of the main estuary channel at 9 sampling locations, 5 within the river plume and 4 in the estuary proper (Fig. 1). All samples were taken during flood tide.

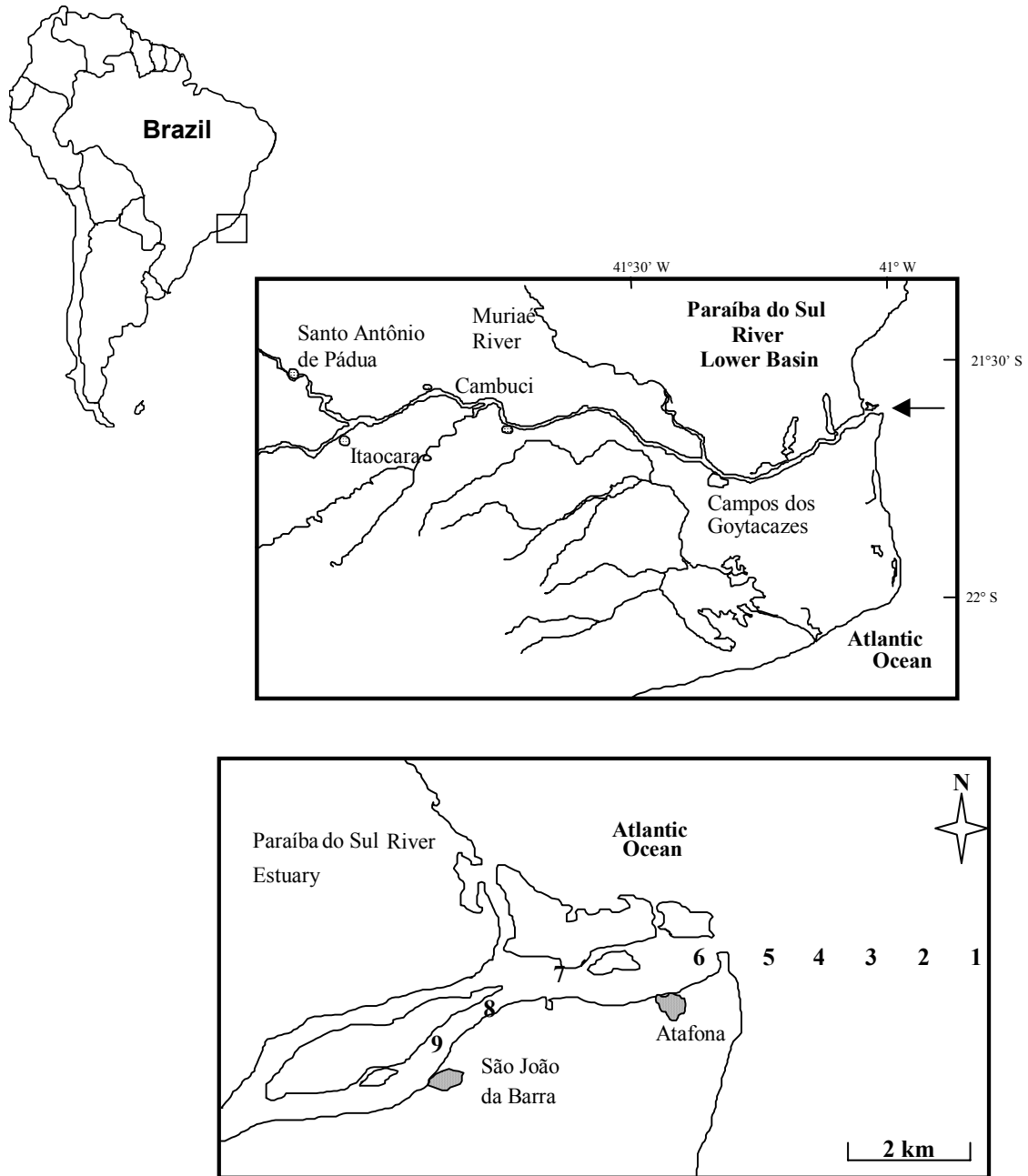


Fig. 1. Map of the study area with the sampling stations.

Samples were collected by sub-surface tows with a plankton net of 30 cm mouth opening and 70  $\mu\text{m}$  mesh size, fitted with a mechanical flowmeter to estimate the amount of water filtered (Elmoor-Loureiro, 1997; Kramer *et al.*, 1994; Omori & Ikeda 1992). Biological material was fixed in an aqueous

solution of 5% formalin, buffered with sodium tetraborate, for later analyses in the laboratory.

For each sample collected, aliquots were taken with a Folsom plankton splitter according to the degree of concentration of the original sample. All individuals within each aliquot were identified and

counted. Species were identified to the lowest taxonomic level according to the literature (Boltovskoy, 1981; 1999; Montú & Gloeden, 1986; Edmondson, 1959; Elmoor-Loureiro, 1997), using a ZEISS Stemi2000 stereoscopic microscope and an Olympus CX41 optical microscope.

#### Environmental Variables

In situ temperature and salinity were measured at the surface and bottom with a portable field multi-sounde YSI65.

#### Statistical Outline

Type I Analysis of Variance (ANOVA) was applied to the environmental parameters (temperature and salinity), total abundance of cladocerans and the density of the most abundant species to test differences between sampling time (temporal patterns) and sampling stations (spatial patterns). To equalize the variance and normalize distributions, all data used in the ANOVA were  $\log_{10}(x+1)$  transformed, but it was not possible to normalize cladoceran abundance. However, ANOVA was performed since this type of

analysis is more robust than non-parametric analyses (Underwood, 1997). Normal data distribution and homogeneity of variances were tested with the Kolmogorov-Smirnov test with a  $p < 0.05$ . When significant differences were detected by the ANOVA, Tukey's Honestly Significantly Different (HSD) test was applied to identify the sources of variation. Analyses were performed using STATISTICA 6.0 software (Statsoft Inc.).

## RESULTS

#### Environmental Variables

Salinity varied from 0.0 at the inner estuary, mainly during the rainy season (January, February and March), to 37.1 at stations located in the estuarine plume during July. Analysis of variance showed significant differences between the sampling locations (Fig. 2). Sampling stations located in the estuarine plume showed salinity values significantly higher than located in the inner estuary (ANOVA  $F = 26.97$ ;  $p = 0.00$ ).

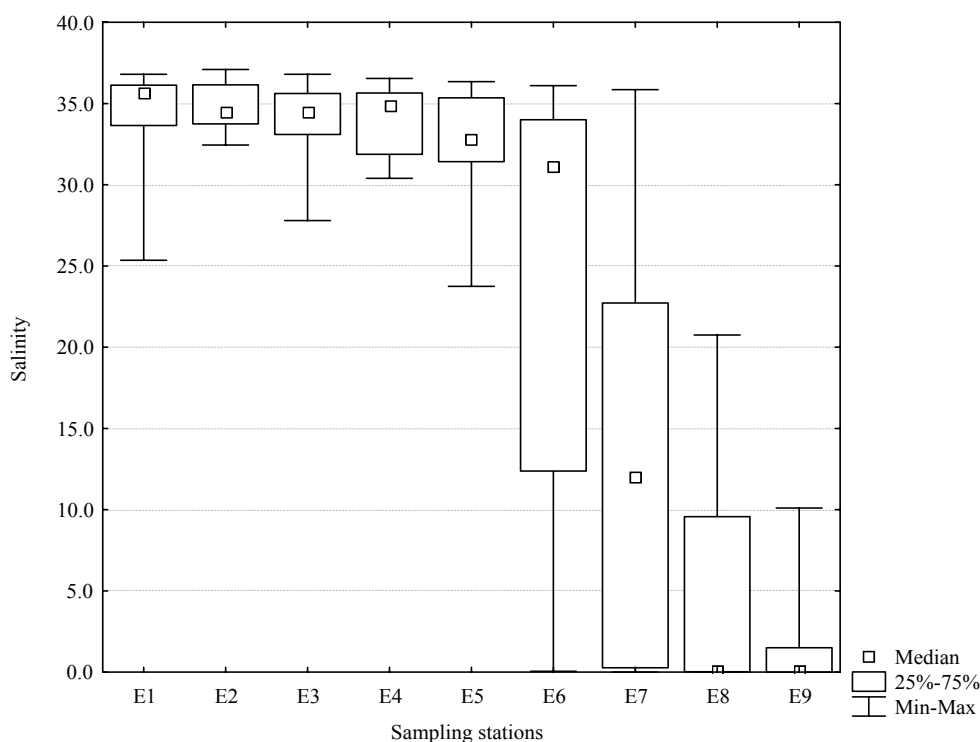


Fig. 2. Average salinity values (n=108) along the sampling stations.

Temperature varied from 21.8°C in August to 30.9°C in February (Fig. 3). Through the analysis of variance it was possible to detect significant differences among the sampling months, when

temperature values in the summer were significantly higher than those in winter (ANOVA  $F= 16.30$ ;  $p= 0.00$ ). There were no significant differences between sampling stations (ANOVA  $F= 2.07$ ;  $p= 0.02$ ).

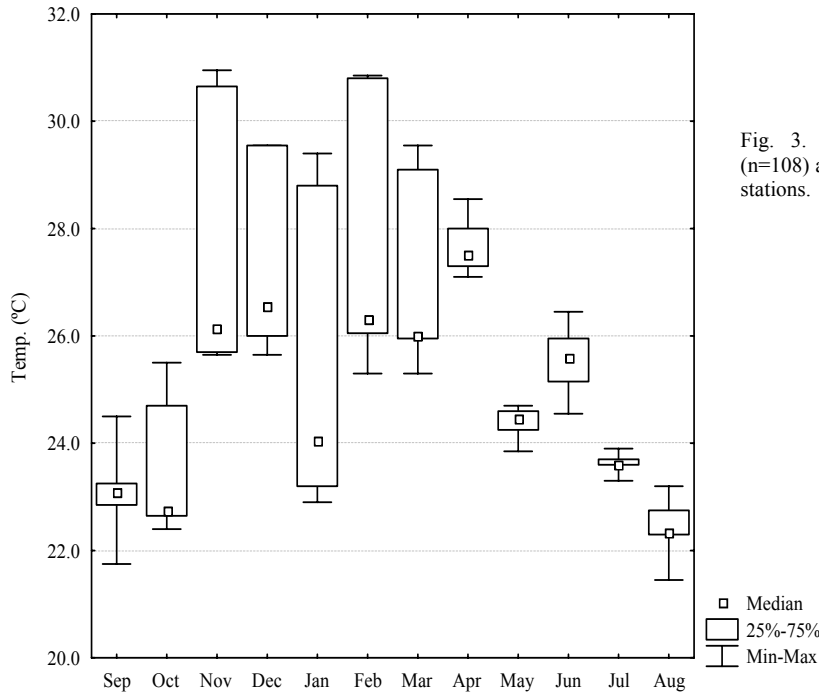
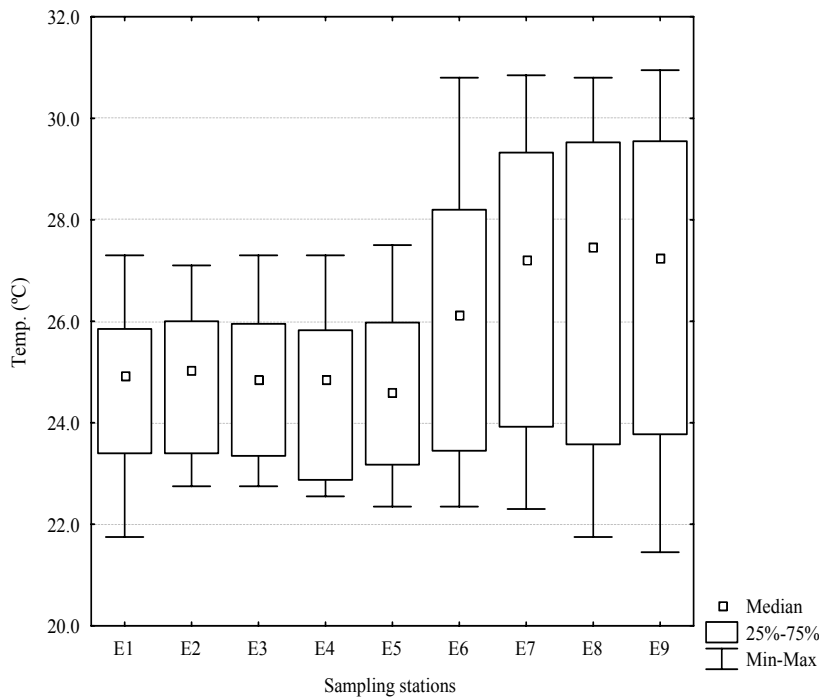


Fig. 3. Average temperature values (n=108) along the months and sampling stations.



## Cladoceran Community

Seventeen species were identified: *Pseudoevadne tergestina*, *Penilia avirostris*, *Macrothrix triserialis*, *Moina micrura*, *Simocephalus Kerhervei*, *Simocephalus vetulus*, *Simocephalus latirostris*, *Simocephalus serrulatus*, *Alona rectangularis*, *Alona quadrangularis*, *Bosmina longirostris*, *Bosminopsis deitersi*, *Camptocercus dadayi*, *Ceriodaphnia richardi*, *Diaphanosoma fluviatile*, *Kurzia latissima* and *Pleuroxus similis*.

Total cladoceran abundance varied from 0 to 17.294 Ind.m<sup>-3</sup>, with significantly higher values in April (ANOVA  $F=2.41$ ;  $p=0.01$ ) at sampling stations located in the marine zone of the estuary (Fig. 4). There were no significant differences in total abundance among stations (ANOVA  $F=0.83$ ;  $p=0.57$ ).

The most abundant species during the study period was *Penilia avirostris*, varying from 0 to 17.294 Ind.m<sup>-3</sup> (Fig. 5). *P. avirostris* was significantly more abundant in February, March and April (ANOVA

$F=5.94$ ;  $p=0.00$ ). Estuarine plume sampling stations showed significantly higher values than stations located in the inner estuary (ANOVA  $F=5.46$ ;  $p=0.00$ ).

Another abundant species was *Moina micrura* which varied from 0 to 3.226 Ind.m<sup>-3</sup> (Fig. 6). It was most abundant in January (ANOVA  $F=4.94$ ;  $p=0.00$ ) and at stations located in the inner estuary (ANOVA  $F=8.22$ ;  $p=0.00$ ), where salinity was close to zero.

*Simocephalus vetulus* was significantly more abundant in October (ANOVA  $F=2.98$ ;  $p=0.00$ ) and varied from 0 to 731 Ind.m<sup>-3</sup> (Fig. 7). Higher abundances occurred at stations located in the inner estuary, mainly at the river portion (ANOVA  $F=7.84$ ;  $p=0.00$ ). *Bosmina longirostris* abundance varied from 0 to 199 Ind.m<sup>-3</sup> and showed significant differences among the months, occurring mainly in October (ANOVA  $F=2.46$ ;  $p=0.01$ ). Higher abundances occurred again at stations located in the inner estuary (Fig. 8), mainly at the river portion (ANOVA  $F=5.01$ ;  $p=0.00$ ).

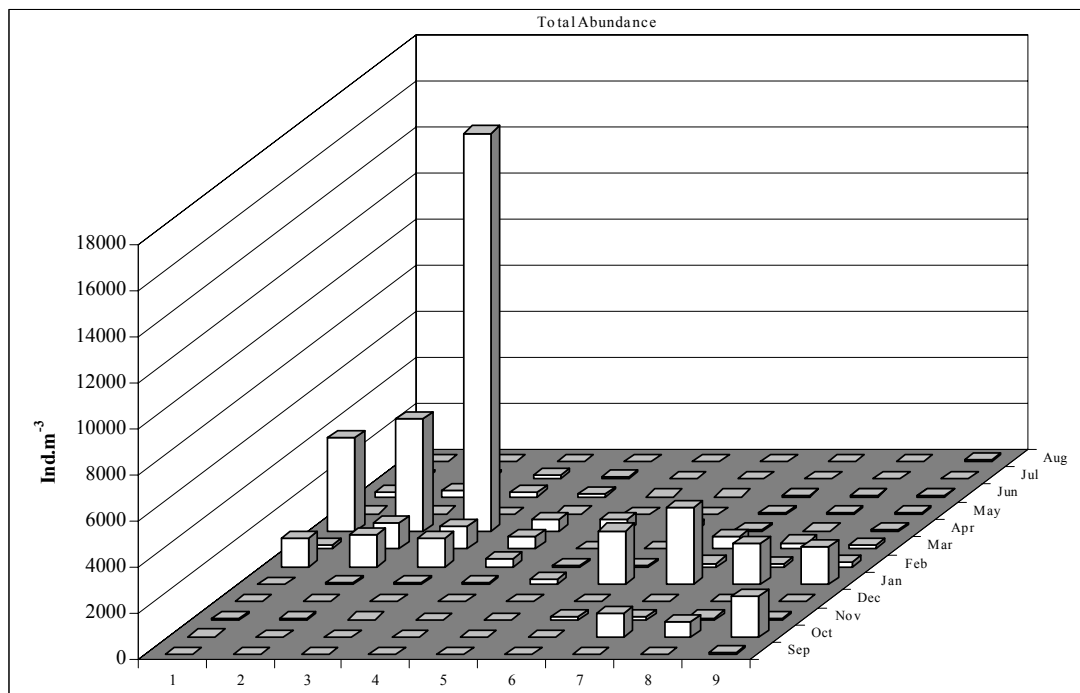


Fig. 4. Total monthly cladoceran abundance (Ind.m<sup>-3</sup>) along the sampling stations (1 to 9).

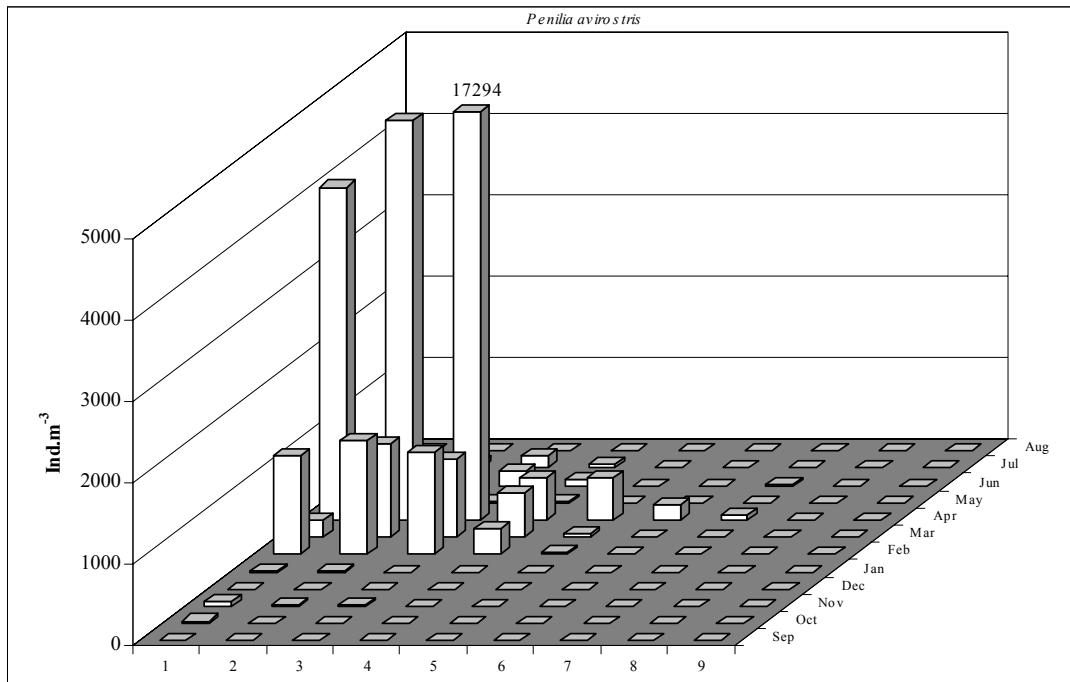


Fig. 5. *P. avirostris* total monthly abundance (n=108) along the sampling stations (1 to 9).

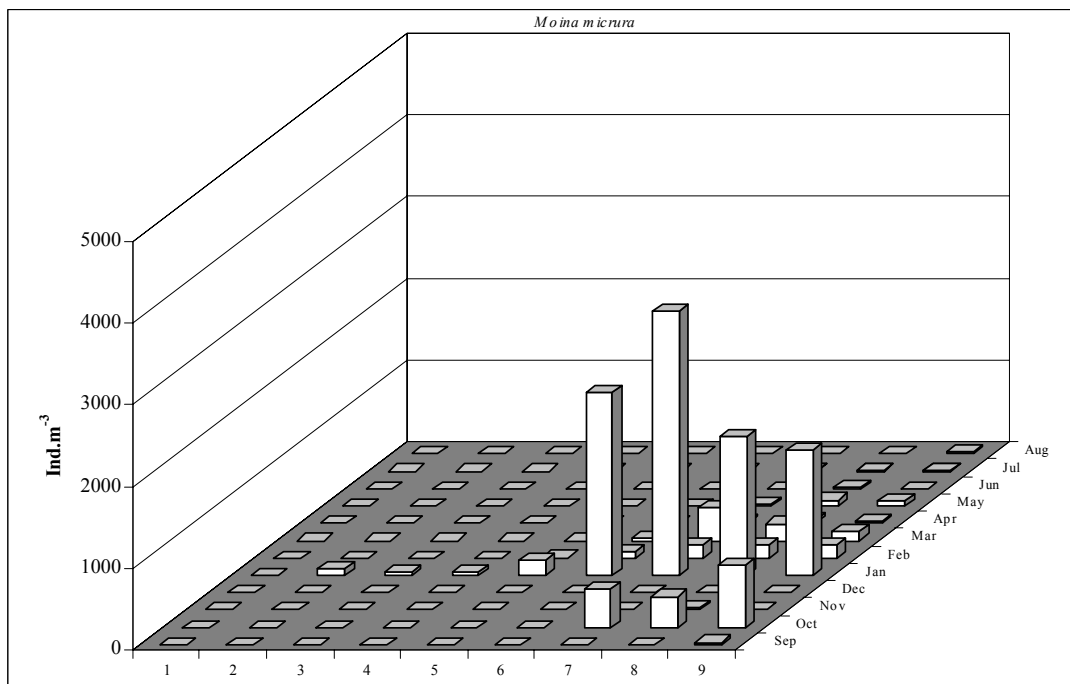


Fig. 6. *M. micrura* total monthly abundance (n=108) along the sampling stations (1 to 9).

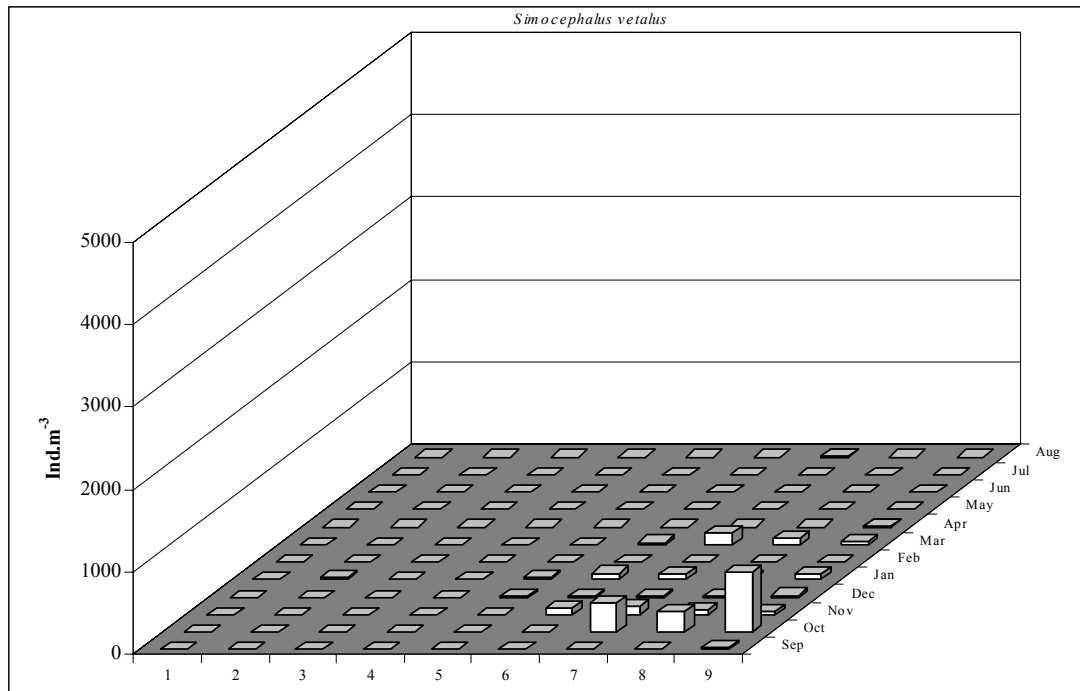


Fig. 7. *S. vetulus* total monthly abundance (n=108) along the sampling stations (1 to 9).

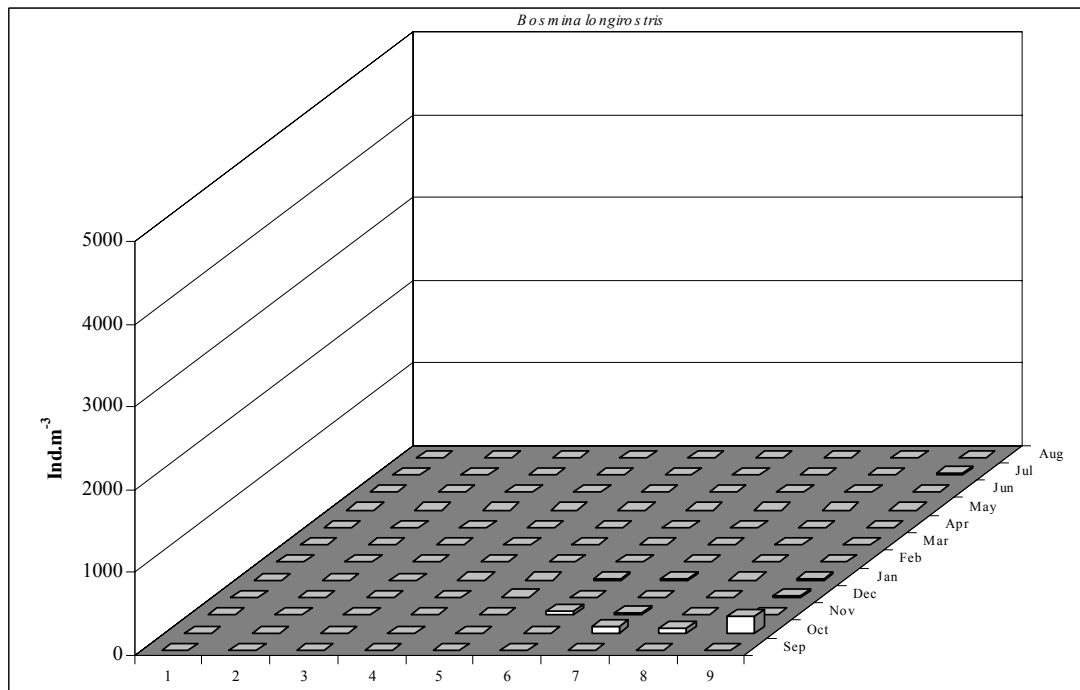


Fig. 8. *B. longirostris* total monthly abundance (n=108) along the sampling stations (1 to 9).



## Environmental Variables x Cladoceran Community

*P. avirostris* occurred mainly at stations located in the estuarine plume, where salinity values were higher and during the warmer months (Fig. 2). *M. micrura*, *S. vetulus* and *B. longirostris* had their highest abundances at stations located in the inner estuary. Also, *M. micrura* occurred mainly during the warmer months (Fig.3).

## DISCUSSION

The species of cladocerans (Table 1) found in the study area are typical of marine and estuarine environments (Coelho-Botelho *et al.*, 1999; Lopes, 1996; Montú, 1980; Nogueira *et al.*, 1999; Valentin &

Marazzo, 2003; Marazzo & Valentin 2004), but most are from freshwater environments (Elmoor-Loureiro, 1997; Elmoor-Loureiro *et al.*, 2004; Hann & Zrum, 1997; Montú, 1980; Neves *et al.*, 2003; Santos-Wisniewski *et al.*, 2002; Sampaio *et al.*, 2002; Serafim Jr. *et al.*, 2003).

The cladoceran community at the Paraíba do Sul River estuary showed an intermediate species richness between freshwater and marine environments. In freshwater, the species number is greater, since 26 species were found in lakes of reservoirs by Sampaio *et al.* (2002); in rivers, 30 species were found by Neves *et al.* (2003) and 63 species by Serafim Jr. *et al.* (2003). The results of the present study are expected since this is a transitional environment.

Table 1. Cladoceran species occurrence at the Paraíba do Sul river estuary in Brazil (Elmoor-Loureiro, 1997; Marazzo & Valentin, 2000; 2001; Montú. & Gloeden, 1986).

<i>Species</i>	<b>Environment</b>	<b>Location</b>
<i>Pseudoevadne tergestina</i>	Estuarine, marine	Rio de Janeiro, Rio Grande do Sul
<i>Penilia avirostris</i>	Estuarine, marine	Rio de Janeiro, Rio Grande do Sul
<i>Moina micrura</i>	Freshwater, estuarine	Alagoas, Pernambuco, Minas Gerais
<i>Macrothrix triserialis</i>	Freshwater	Pará, Mato Grosso, Pernambuco
<i>Simocephalus kerhervei</i>	Freshwater	São Paulo
<i>Simocephalus latirostris</i>	Freshwater	Amazonas, Pernambuco
<i>Simocephalus vetulus</i>	Freshwater	Pernambuco, Rio Grande do Sul
<i>Simocephalus serrulatus</i>	Freshwater	Minas Gerais, São Paulo
<i>Alona rectangularis</i>	Freshwater	Roraima, Mato Grosso, Minas Gerais
<i>Alona quadrangularis</i>	Freshwater	Pará, São Paulo
<i>Bosmina longirostris</i>	Freshwater	Maranhão, Distrito Federal, São Paulo
<i>Bosminopsis deitersi</i>	Freshwater, estuarine	Acre, Mato Grosso, Rio Grande do Sul
<i>Camptocercus dadayi</i>	Freshwater, estuarine	Piauí, Rio Grande do Sul
<i>Ceriodaphnia richardi</i>	Freshwater	São Paulo
<i>Diaphanosoma fluviatile</i>	Freshwater, estuarine	Amazonas, Rio Grande do Sul, Pará
<i>Kurzia latissima</i>	Freshwater, estuarine	Pará, São Paulo, Rio Grande do Sul
<i>Pleuroxus similis</i>	Freshwater, estuarine	Rio Grande do Sul

Most of cladoceran species recorded in the present study occurred in the warmer and wet months. Salinity seems to limit the occurrence and distribution of cladocerans in the Paraíba do Sul River estuary. Since the majority of the species are from freshwater, these appear in higher quantities in the estuary during the periods of high river water input, when salinity values approach zero at the inner portion of the system (e.g. *Moina micrura*). Lansac Tôha & Lima (1993), working in the Una do Prelado River estuary (São Paulo State) observed that coastal species were found in the inner portion of the estuary during the high tide, but freshwater species invaded the estuary during low tide, especially during the rainy season. Associated to low salinity, high temperature must also be considered (Lansac Tôha & Lima 1993; Montú, 1980).

High abundance of cladocerans in the coastal region was related to the occurrence of *Penilia avirostris*, most abundant during fall. Although it is a marine species, it can penetrate the estuary during the flood tide during periods of low freshwater input. This species is an important component of the zooplankton in coastal and estuarine waters like in the coast off Rio de Janeiro state in certain periods of the year, along with other species such as *Pseudoevadne tergestina* and *Pleopis polyphemoides* (Coelho-Botelho *et al.*, 1999; Nogueira *et al.*, 1999; Marazzo & Valentin, 2004), and is an important contributor to secondary production (Marazzo & Valentin, 2004). However, *Penilia avirostris* may disappear from the plankton at certain periods (Valentin & Marazzo, 2003). In Guanabara Bay, Marazzo & Valentin (2001) observed that *Penilia avirostris* reached its maximum density during fall and disappeared in the winter and spring, as recorded in the present study.

The highest abundance of *Moina micrura* during summer is due to the higher freshwater input during this period, which blocks the entrance of salty waters into the estuary. Consequently this species does not seem to be able to survive in brackish waters in the Paraíba do Sul River estuary, despite being considered an euryhaline-limnetic species, occurring in other environments with salinities from 0-31.5 (Montú, 1980). This is another cladoceran species that may occur in several types of freshwater bodies (Elmoor-Loureiro *et al.*, 2004; Montú, 1980), a good indicator of the trophic state of the environment (Sampaio *et al.*, 2002). In Brazil, it has been recorded in the states of Alagoas, Pernambuco, Mato Grosso do Sul, Minas Gerais, Rio Grande do Sul and in the Distrito Federal (Elmoor-Loureiro, 1997).

Although *Simocephalus vetulus* is a typical freshwater species, its presence in oligohaline waters during spring shows a certain tolerance to brackish waters. This species occurs frequently in wetlands (Hann & Zrum, 1997), abundant in the summer in

areas close to macrophytes. It has been recorded in the states of Pernambuco and Rio Grande do Sul (Elmoor-Loureiro, 1977). The same occurred with *Bosmina longirostris*, which was recorded in brackish waters during spring. This species seems to be also abundant in wetlands during spring (Hann & Zrum, 1997); lakes (Elmoor-Loureiro *et al.*, 2004) and rivers (Serafim Jr. *et al.*, 2003). It is also a good indicator of the trophic state of lakes, particularly of eutrophic environments (Sampaio *et al.*, 2002). It is cosmopolitan, present in the states of Maranhão, São Paulo, Rio Grande do Sul, Minas Gerais and Distrito Federal (Elmoor-Loureiro, 1997).

*Penilia avirostris* abundance peaks in the fall may be associated with the stability of the salinity values in the water column and the elevated temperature values. The same happens to *Simocephalus vetulus* and *Bosmina longirostris*, where their presence in the estuary during spring shows that temperature is probably a controlling factor. *Moina micrura* however, has its occurrence limited to the presence of saline waters in the estuary. The composition and abundance of zooplankton communities can be influenced by several physical, chemical and biological factors (Neves *et al.*, 2003; Sampaio *et al.*, 2002). Temperature can cause changes in community composition as well as density. Temperature controls reproductive rates, species population size and metabolism (Sampaio *et al.*, 2002) all of them the most important factors determining seasonal distribution of marine cladocerans (Marazzo & Valentin, 2004). Other factors such as salinity, dissolved oxygen, tidal currents, can also affect the occurrence and distribution of cladocerans in estuarine environments (Valentin & Marazzo, 2003; Marazzo & Valentin, 2004), salinity being one of the key factors determining the distribution of species of different origin (Montú, 1980). Based on salinity data, it can be concluded that the only species presenting truly estuarine characteristics was *Penilia avirostris*. This species is typically marine and can penetrate the estuary during the periods of low freshwater input into the flood tide, as observed by Lansac Tôha & Lima (1993) at the Una do Prelado River estuary (SP). In periods of high freshwater input, the estuary is invaded by freshwater species such as *Moina micrura*.

## CONCLUSIONS

Cladoceran community of the Paraíba do Sul River estuary shows characteristics of marine, estuarine and freshwater environments. Salinity and temperature limit the occurrence and distribution of the cladocerans in the estuary. Seventeen species of cladocerans have been identified in the Paraíba do Sul River estuary. Highest abundances occur during the

month of April at the marine zone of the estuary, dominated by *Penilia avirostris*. In the mixture and riverine zone of the estuary the most abundant species has been *Moina micrura*, especially during January, and its occurrence is limited to the presence of saline waters. *Simocephalus vetulus* and *Bosmina longirostris* occur mainly in the spring in oligohaline waters.

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