# ZOOPLANKTON DISTRIBUTION AND COMMUNITY STRUCTURE IN A BRAZILIAN COASTAL LAGOON

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# ZOOPLANKTON DISTRIBUTION AND COMMUNITY STRUCTURE IN A BRAZILIAN COASTAL LAGOON

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ZOOPLANKTON COMMUNITY
TROPICAL COASTAL LAGOON
*HEXARTHRA* SPP.
*BOSMINOPSIS DEITERSI*
*"DIAPTOMUS" AZUREUS*
CANONICAL CORRESPONDENCE ANALYSIS

ABSTRACT. – Zooplankton temporal and spatial distributions and additional environmental features of a Brazilian coastal lagoon were studied during three years. Despite its proximity to the sea and the occurrence of marine intrusion during the period of study, the lagoon was characterized as a freshwater environment. The zooplankton community consisted of 95 taxa, including holoplanktonic and meroplanktonic forms. Location, macrophyte colonization and river input were found to be key factors determining the distinct features of the zooplankton community. A canonical correspondence analysis revealed that water salinity and conductivity, suspended matter content and water transparency were the main factors behind the temporal differences in the frequency of occurrence and the abundance of the constant and common taxa. Predation pressure by invertebrates and fish probably determines the zooplankton community structure, favouring small-sized cladocerans as well as rotifers with anti-predatory strategies, and may also help explain the spatial distribution of larger zooplankters.

## INTRODUCTION

Many aquatic ecosystems along the Brazilian coast, collectively termed coastal lagoons. These lagoons are characterized by a shallow water column and a location in close proximity to the sea. Recent studies have, however, revealed important differences among these systems related to the origin and morphometry of the water body, marine influence, features of surrounding soils and drainage basins, meteorological events, and anthropogenic influence (Schäfer 1994). Terms such as "salty lagoon", "brackish lagoon", "freshwater lagoon" and "black-water lagoon" emphasizing distinct characteristics of the body of water are commonly used either in popular or in scientific literature. Despite the great variation reported in physical and chemical conditions among the Brazilian lagoons, only few studies describing the aquatic communities of these environments have been made. Today, however, research is necessary given the increasing anthropogenic impacts arising from disordered urban expansion.

Studies of zooplankton composition have so far mainly been conducted in human-influenced lagoons of the Rio de Janeiro State, such as those receiving domestic (Arcifa *et al*. 1994, Branco *et al*. 2007) and industrial sewage (Attayde & Bozelli 1998), whereas only few investigations have been conducted in relatively undisturbed lagoons (Branco *et al*. 2000). The aim of this study was to determine the richness and the temporal and spatial distribution of zooplankton species in Cabiúnas Lagoon. We also wanted to evaluate the relationships between the zooplankton community and some environmental factors.

## MATERIALS AND METHODS

The Cabiúnas Lagoon (22°18'S, 41°42'W) is one of a series of shallow lagoons located in the National Park of Jurubatiba, Municipality of Macaé, State of Rio de Janeiro. It has a surface area of 0.34 km$^2$, a maximum depth of 3.5 m and is separated from the sea by a 50-meter wide sand barrier. A rich aquatic macrophyte community can be found in the lagoon: *Typha domingensis* in the littoral region and *Nymphaea ampla*, *Nymphoides humboldtiana*, *Utricularia foliosa*, *Potamogeton stenostachys*, *Salvinia auriculata*, *Eichhornia crassipes* and *Mayaca* sp. in the central part and arms of the lagoon (Henriques *et al*. 1988). The climate of the region is sub-humid and the mean annual rainfall ranges from 800 to 1200 mm. The typical dry and wet seasons, often encountered in tropical and subtropical regions, are less pronounced here because of the frequent passage of polar fronts throughout the year. The wind action is constant throughout the year and the predominant wind is from Northeast. According to Panosso *et al*. (1998) high values of effective length added to low profundity favours wind action on the water column of the lagoon throughout the year.

Samples for analyses of environmental variables and zooplankton were collected monthly, from May 1992 to February 1993, and every four months, from May 1993 to August 1995, at three sampling stations (Fig. 1). The first station was situated in the limnetic central part of the lagoon, about 200 m from the sand barrier. The second sampling station was located in one of the arms of the lagoon and the third station near the mouth of Cabiúnas River. Measurements of the environmental variables and the collection of water samples for nutrient analysis (APHA 1992) were done at the surface. At each sampling station, zoo-

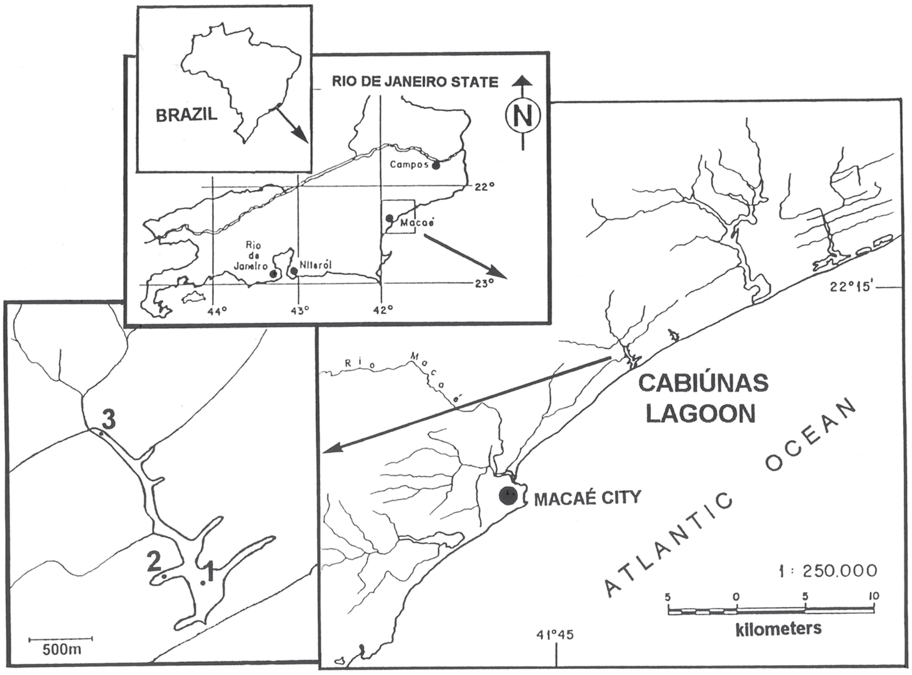


Fig. 1. – Location of the Cabiúnas Lagoon and the sampling stations.

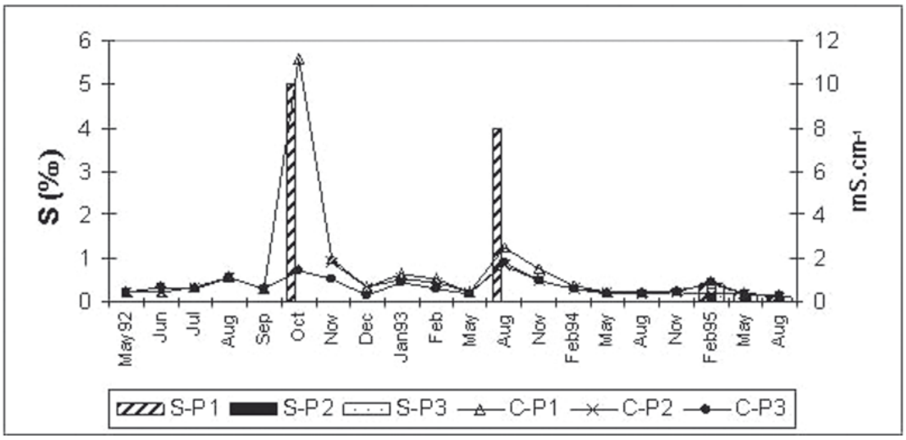


Fig. 2. – Salinity (‰) and water conductivity ($mS.cm^{-1}$) values recorded at the three sampling stations. (S-P = salinity at the sampling station; C-P = conductivity at the sampling station).

plankton samples (ca 100 litres) were collected by vertical hauls, from the bottom to the surface, using a 68 mm-mesh plankton net (diameter 28 cm), and from nine to ten o'clock in the morning. Organisms were counted in triplicate in Sedgewick-Rafter cells.

The density of the constant and common taxa (n = 38) and the values of environmental variables (n = 17), except pH, were log-transformed $x' = \log(x + 1)$ prior to analysis (Pearson Correlation Coefficient and the Canonical Correspondence Analysis (CCA)). The Monte Carlo permutation test was used to test the significance of the axes at p = 0.01 level. Separate CCAs were conducted for each of the three sampling stations (n = 63) using twelve of the seventeen environmental variables (those with higher correlation coefficients with the density of zooplankton species) and a matrix with constant and common taxa. Computer packages used were Statistic vers. 6.0 and Canoco vers. 3.2.

## RESULTS

### *Environmental conditions*

In October 1992 heavy rainfall caused the rupture of the sand barrier. Lagoon water drained into the ocean and a direct exchange between these two systems occurred. Salinity values of 10 ‰ and a water conductivity of 2.5 $mS.cm^{-1}$, indicative of mesohaline conditions, were recorded at station 1 during the sand barrier opening (Fig. 2). Moreover, the marine inflow led to an increase in water transparency, pH and total phosphorus, respectively to 7.2 and 57 $\mu g.l^{-1}$ and a decrease in the chlorophyll-*a* concentration (Figs. 3 & 4).

Despite its location and the marine intrusion, the Cabiúnas Lagoon remains a freshwater environment

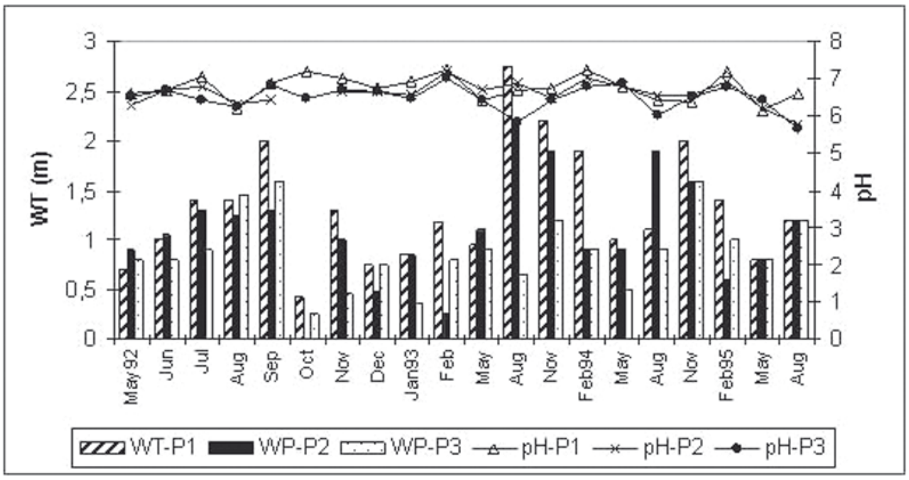


Fig. 3. – Water transparency (m) and pH at the three sampling stations (WT-P = water transparency at the sampling station; pH-P = pH at the sampling station.

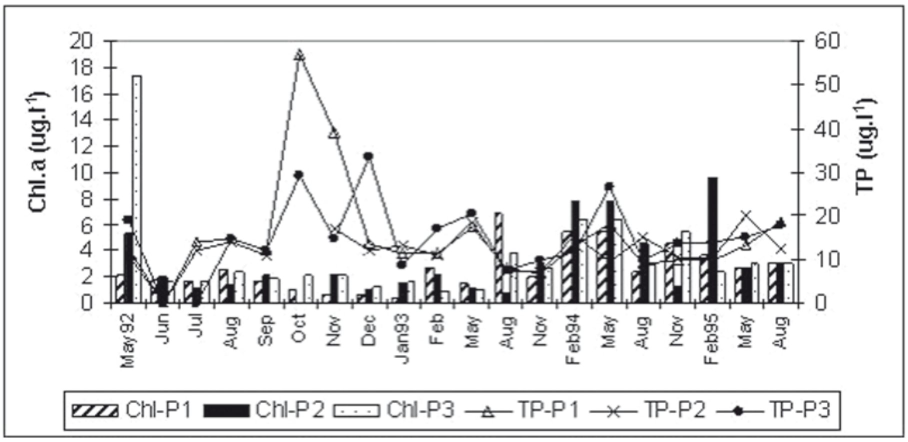


Fig. 4. – Total phosphorus ($\mu g.l^{-1}$) and chlorophyll-*a* ($\mu g.l^{-1}$) concentration at the three sampling stations. TP-P = total phosphorus at the sampling station; Chl-P = chlorophyll-*a* at the sampling station.

(Table I). Traces of salinity were found for several months at station 1 and at all stations in August 1993 as well as in February and May 1995. This is most probably related to storms or high tides, or both, causing seawater inflow over the sand barrier, as there was no direct marine inlet from October 1992 until the end of the 4-year study period.

### *Zooplankton composition and distribution*

The number of taxa identified per sample varied from 6 to 26. Average species richness was 18 at sampling stations 2 and 3, and 16 at sampling station 1. Zooplankton taxa were found during the marine intrusion in October 1992 and in August 1993 when salinity values increased. Total zooplankton abundance ranged from 10,356 to 633,750 individuals per cubic meter (Fig. 5) with a mean value of 99,132. The highest density was found at station 2 in November 1993 due to an increase in the *Brachionus falcatus* population. The lowest zooplankton abundances were observed during the sea-water entrance in October 1992. The zooplankton community consisted of 95 taxa, including 54 Rotifera and 6 Cladocera species in addition to the Chydoridae, which were grouped in one taxonomic unit, 8 species of copepods, larvae of benthic organisms and of insects, Gastrotricha, Nematoda, Ostracoda and fish larvae (Table II).

### *CCA ordination: relation between zooplankton and other variables*

*Sampling station 1:* The two axes of the CCA accounted for 62.4 % of total variation, the first for 41.3 % and the second for 21.1 % (Fig. 6). A conductivity and salinity gradient related to marine inflows appeared to be the most important and represents the first axis of the CCA. This axis also reveals a rise in the total phosphorus concentration due to seawater input and a decrease in the total organic nitrogen concentration. Among the constant taxa, Gastropoda larvae and nauplii forms were those less impaired by high salinity values, as evidenced by their biplot positions. The densities of *Brachionus plicatilis*, Polychaeta larvae and Harpacticoida copepods were higher at high salinity values. Taxa found only at station 1 and only during freshwater conditions, such as *Collotheca* sp. and *Lecane* spp., are positioned on the left side of the biplot.

The second-most important environmental gradient at station 1 was related to the stability of the water column. In a shallow tropical system such stability is related to

Table I. – Average, minimum and maximum values and standard deviation (m) of the environmental variables measured at the three sampling points during the sampling period.

| VARIABLE | P1 | | | P2 | | | P3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | average (s.d.) | min. | max. | average (s.d.) | min. | max. | average (s.d.) | min. | max. |
| **Water temperature (°C)** | 25.3 (2.5) | 22.00 | 30.3 | 25.8 (2.4) | 21.5 | 30.5 | 25.34 (2.51) | 21.2 | 30.7 |
| **Water transparency (m)** | 1.3 (0.5) | 0.4 | 2.7 | 1.1 (0.5) | 0.2 | 2.2 | 0.9 (0.3) | 0.2 | 1.6 |
| **pH** | 6.75 (0.33) | 6.14 | 7.23 | 6.60 (0.32) | 5.79 | 7.19 | 6.48 (0.35) | 5.67 | 7.01 |
| **Total alkalinity (mEq/l)** | 0.30 (0.05) | 0.20 | 0.37 | 0.29 (0.08) | 0.12 | 0.43 | 0.34 (0.12) | 0.14 | 0.61 |
| **Water conductivity (mS/cm)** | 1.30 (2.38) | 0.28 | 11.20 | 0.73 (0.44) | 0.26 | 1.80 | 0.72 (0.40) | 0.28 | 1.80 |
| **Salinity (%o)** | 0.74 (2.36) | 0 | 10.00 | 0.03 (0.07) | 0 | 0.20 | 0.04 (0.10) | 0 | 0.40 |
| **Dissolved oxygen (mg/l)** | 6.24 (1.62) | 2.63 | 8.70 | 6.08 (1.72) | 3.26 | 8.84 | 4.52 (1.49) | 1.22 | 7.40 |
| **Sílica (mg/l)** | 2.80 (1.21) | 0.91 | 5.10 | 2.46 (0.95) | 1.00 | 4.80 | 3.32 (1.28) | 1.00 | 5.60 |
| **Chlorophyll-a (µg/l)** | 2.60 (1.79) | 0.40 | 6.80 | 3.21(2.72) | 0.80 | 9.60 | 3.53 (3.73) | 0.90 | 17.4 |
| **Suspended matter (mg/l)** | 4.91 (6.59) | 0.80 | 31.8 | 3.54 (2.48) | 1.10 | 12.00 | 6.23 (6.13) | 2.10 | 24.7 |
| **Ammonia (µg/l)** | 40.30 (34.49) | 1.60 | 134.00 | 39.60 (39.02) | 1.20 | 151.00 | 41.41(43.66) | 2.10 | 179.00 |
| **Nitrate (µg/l)** | 12.04 (7.69) | 0 | 35.10 | 11.32 (0.65) | 0 | 30.30 | 11.76 (7.25) | 0 | 30.40 |
| **Dissolved organic nitrogen (µg/l)** | 444.7 (144.8) | 200.0 | 750.7 | 471.9 (118.7) | 245.0 | 637.0 | 425.1 (114.6) | 152.0 | 597.0 |
| **Total organic nitrogen (µg/l)** | 559.2 (181.5) | 203.0 | 887.8 | 595.1 (127.1) | 245.0 | 773.0 | 498.1 (121.7) | 202.0 | 706.6 |
| **Total phosphorus (µg/l)** | 15.44 (12.26) | 0 | 57.00 | 12.11(4.49) | 0 | 20.00 | 14.82 (8.46) | 0 | 33.5 |
| **Dissolved phosphorus (µg/l)** | 7.33 (5.37) | 0 | 21.00 | 7.09 (4.66) | 0 | 18.00 | 9.03 (5.21) | 0 | 21.00 |
| **Orthophosphate (µg/l)** | 0.99 (1.85) | 0 | 5.07 | 1.01 (1.81) | 0 | 5.10 | 0.87 (1.58) | 0 | 4.4 |

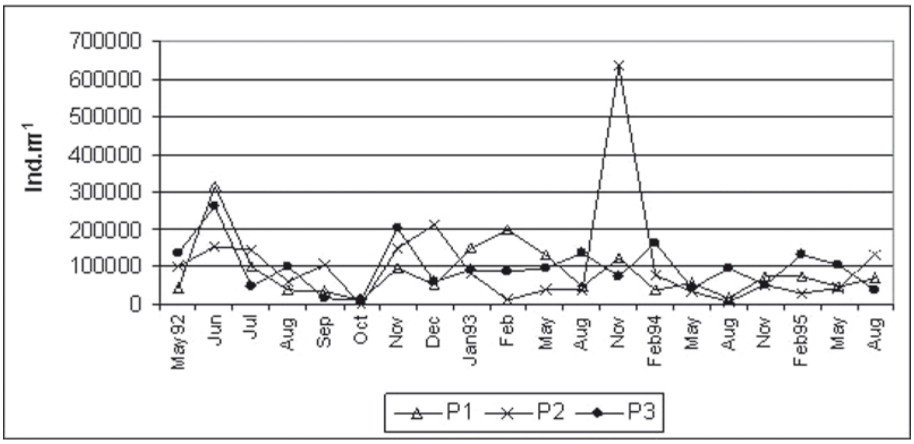


Fig. 5. – Total zooplankton abundance (ind.m$^{-3}$) at the three sampling stations.

high penetration of light and high temperature, leading, as shown by the results, to high chlorophyll-*a* concentrations. Some taxa such as *Conochilus natans*, *Lecane signifera*, *L. leontina*, *Macrochaetus collinsi*, *Testudinella patina*, *Macrothrix superculeata* and *Thermocyclops decipiens* were positively correlated to chlorophyll-*a* values. Increases in ammonium and dissolved oxygen concentrations were associated with water column mixing. An increase in ammonium concentrations seemed to occur when bottom water rich in decaying organic matter prevailed. Changes in most common taxa such as *L. signifera*, *C. natans*, *T. decipiens* and also Chaoboridae larvae were likely associated with water column changes, whereas some constant taxa such as *Brachionus falcatus*, *Hexarthra longicornicula*, *Lecane bulla*, *Bosminopsis deitersi*, *Moina minuta*, *"Diaptomus" azureus* and Gastropoda larvae, found in the central part of the biplot, appeared less affected by such changes.

*Sampling station 2:* The 2 first axes of the CCA of sampling station 2 accounted for 63.3 % of total variability, the first axis for 40 % and the second for 23.3 % (Fig. 7). The intense aquatic macrophyte colonization and constant detritus production characteristic of this station identify suspended matter to be the main environmental factor influencing zooplankton abundance. The rotifers related to high-suspended matter content were *Collotheca* sp., *Synchaeta tremula*, and *Platyonus patulus*. High values of conductivity, total phosphorus, dissolved oxygen, transparency, ammonium and silica appear related to both water column mixing and marine inflow, which may also influence the zooplankton composition in this arm of the lagoon. In contrast to the biplot of station 1, most constant taxa were not centrally located but linked with changes in environmental conditions. The second-most important environmental gradient at station 2 was related to high chlorophyll-*a*, total organic nitrogen concentration and water temperature. *Lecane bulla* and *Polyarthra dolichoptera* are associated with the highest chlorophyll-*a*

Table II. – Mean density (individuals per cubic meter) and frequency of occurrence of the zooplankton taxa during the period of study at the 3 sampling stations.

| TAXA | % of occur. | average density S1 | S2 | S3 | TAXA | % of occur. | average density S1 | S2 | S3 |
|---|---|---|---|---|---|---|---|---|---|
| ROTIFERS | | | | | *Sinantherina semibullata* | 5.1 | 15 | 16 | 0 |
| *Anuraeopsis fissa* | 1.6 | 0 | 0 | 3 | *Synchaeta tremula* | 13.5 | 49 | 30 | 304 |
| *Ascomorpha ecaudis* | 40.7 | 786 | 642 | 323 | *Synchaeta longipes* | 1.2 | 4 | 0 | 0 |
| *Ascomorpha saltans* | 5.1 | 4 | 701 | 114 | *Testudinella mucronata* | 6.8 | 0 | 21 | 18 |
| *Asplanchna sieboldi* | 8.5 | 19 | 17 | 7 | *Testudinella ohlei* | 3.4 | 6 | 27 | 0 |
| *Brachionus budapestinensis* | 1.4 | 0 | 0 | 4 | *Testudinella patina* | 11.9 | 2 | 64 | 16 |
| *Brachionus caudatus* | 1.6 | 2 | 0 | 0 | *Trichocerca bicristata* | 6.8 | 6 | 0 | 16 |
| *Brachionus falcatus* | 62.7 | 6891 | 28596 | 2571 | *Trichocerca similis grandis* | 3.4 | 117 | 9 | 30 |
| *Brachionus quadridentata* | 1.2 | 0 | 30 | 2 | *Trichocerca elongata* | 8.5 | 0 | 0 | 6 |
| *Brachionus plicatilis* | 15.2 | 587 | 66 | 0 | CLADOCERANS | | | | |
| *Cephalodella forficula* | 1.0 | 3 | 0 | 0 | *Bosminopsis deitersi* | 96.6 | 9368 | 15261 | 20560 |
| *Collotheca* sp. | 28.8 | 152 | 277 | 143 | *Ceriodaphnia cornuta* | 44 | 1642 | 128 | 35 |
| *Collurella obtusa* | 1.4 | 0 | 0 | 9 | *Diaphanosoma birgei* | 50.8 | 6044 | 199 | 239 |
| *Conochilus natans* | 27.1 | 231 | 114 | 734 | *Ilyocryptus spinifer* | 8.5 | 0 | 26 | 2 |
| *Dipleuchlanis propatula* | 8.5 | 4 | 8 | 6 | *Macrothrix superculeata* | 20.3 | 5 | 110 | 18 |
| *Euchlanis dilatata* | 1.6 | 0 | 2 | 0 | *Moina minuta* | 84.7 | 10919 | 1225 | 9945 |
| *Euchlanis incisa* | 3.4 | 0 | 9 | 3 | Chydoridae not identified | 30.5 | 5 | 715 | 19 |
| *Filinia pejleri* | 40.6 | 230 | 3287 | 2634 | COPEPODS | | | | |
| *Gastropus minor* | 35.6 | 544 | 376 | 910 | Calanoida nauplii | 100 | 11238 | 15225 | 21920 |
| *Hexarthra longicornicula* | 88.1 | 14591 | 13793 | 5726 | Cyclopoida nauplii | 100 | 9833 | 16990 | 19557 |
| *Keratella americana* | 1.6 | 0 | 5 | 0 | Harpacticoida nauplii | 1.6 | 0 | 0 | 3 |
| *Keratella cochlearis* | 13.5 | 17 | 52 | 42 | Calanoida copepodids | 100 | 3317 | 3991 | 4714 |
| *Keratella lenzi* | 64.4 | 95 | 1701 | 656 | Cyclopoida copepodids | 93.2 | 1024 | 811 | 860 |
| *Lecane acronycha* | 3.4 | 0 | 0 | 21 | Harpacticoida copepodids | 8.5 | 7 | 2 | 3 |
| *Lecane bulla* | 59.3 | 62 | 339 | 249 | *Acartia liljeborgi* | 1.4 | 1 | 0 | 0 |
| *Lecane cornuta* | 1.8 | 0 | 0 | 13 | *Diaptomus azureus* | 90 | 1748 | 909 | 2434 |
| *Lecane curvicornis* | 6.8 | 0 | 18 | 13 | *Pseudodiaptomus* sp. | 6.7 | 178 | 0 | 40 |
| *Lecane elsa* | 1.6 | 0 | 0 | 9 | *Paracalanus crassirostris* | 6.7 | 4 | 2 | 3 |
| *Lecane leontina* | 44 | 35 | 141 | 90 | *Microcyclops anceps* | 20.3 | 24 | 32 | 83 |
| *Lecane levistyla* | 1.6 | 0 | 7 | 0 | *Oithona oswaldocruzi* | 3.4 | 13 | 0 | 3 |
| *Lecane lunaris constricta* | 8.5 | 0 | 65 | 9 | *Termocyclops decipiens* | 35.6 | 230 | 55 | 78 |
| *Lecane lunaris crenata* | 25.4 | 16 | 102 | 61 | *Tropocyclops prasinus* | 8.9 | 256 | 46 | 52 |
| Lecane proiecta | 1.4 | 0 | 66 | 0 | Harpacticoida not identified | 16.6 | 29 | 7 | 16 |
| *Lecane quadridentata* | 5.1 | 15 | 0 | 5 | OTHERS | | | | |
| *Lecane signifera* | 13.5 | 3 | 23 | 17 | Chaoboridae larvae | 33.9 | 50 | 82 | 63 |
| *Lecane spinulifera* | 1.6 | 0 | 0 | 9 | Chironomidae larvae | 44 | 35 | 184 | 57 |
| *Lecane stenroosi* | 1.2 | 2 | 0 | 0 | Ephemeroptera nymph | 1.6 | 0 | 5 | 0 |
| *Lepadella patella* | 6.8 | 8 | 4 | 6 | Polychaeta larvae | 22 | 863 | 39 | 15 |
| *Macrochaetus collinsi* | 43.4 | 27 | 271 | 60 | Bivalvia larvae | 3.4 | 4 | 0 | 0 |
| *Manfredium eudactylota* | 5.1 | 0 | 7 | 5 | Gastropoda larvae | 91.5 | 5948 | 4534 | 1138 |
| *Monnomata maculata* | 5.1 | 0 | 50 | 0 | Cirripedia nauplii | 3.4 | 17 | 0 | 0 |
| *Mytilina ventralis* | 1.8 | 0 | 18 | 0 | Decapoda zoea | 1.6 | 1 | 4 | 0 |
| *Mytilina* sp | 3.4 | 0 | 11 | 7 | Gastrotricha | 1.6 | 4 | 0 | 0 |
| *Plationus patulus* | 3.4 | 0 | 11 | 3 | Nematoda | 11.8 | 0 | 214 | 24 |
| *Platyas leloupi* | 5.1 | 0 | 2 | 6 | Ostracoda | 3.4 | 0 | 3 | 3 |
| *Polyarthra dolichoptera* | 49.1 | 23 | 457 | 2056 | Fish larvae | 1.2 | 0 | 0 | 3 |

values, *Brachionus falcatus* and *Bosminopsis deitersi* with the highest dissolved oxygen content and conductivity, and *Moina minuta* and adult *"Diaptomus" azureus* with high water transparency.

*Sampling station 3:* The 2 first axes of the CCA accounted for 63.4 % of total data variability, the first for 48.4 % and the second for 15.4 % (Fig. 8). Water transparency influenced by the river input was the main factor explaining zooplankton density. The first axis comprises a gradient of ammonium, silica, conductivity and water transparency. Similar to the CCA results from station 1, the most abundant species are found in the centre of the ordination diagram where they likely have their optima. *Hexarthra longicornicula*, *Brachionus falcatus*, *Keratella lenzi*, *Ascomorpha ecaudis*, *Conochilus natans*, *"Diaptomus" azureus*, *Moina minuta* and *Polyarthra dolichoptera* are positively associated with chlorophyll-*a* values. Phytoplankton growth was probably light-limited, as

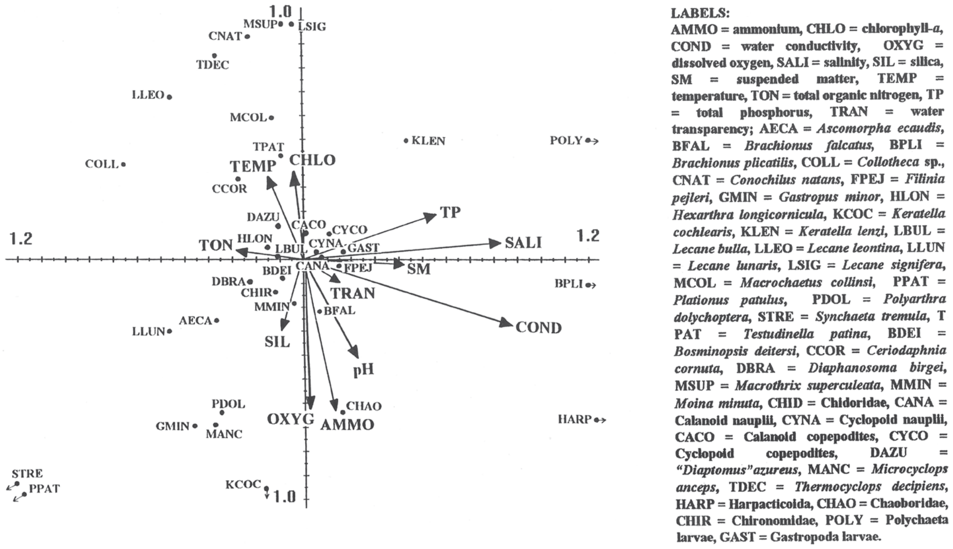


Fig. 6. – CCA ordination biplot of the constant and common species represented by dots and the environmental variables represented by arrows (names abbreviated to four letters; see captions) at sampling station 1.

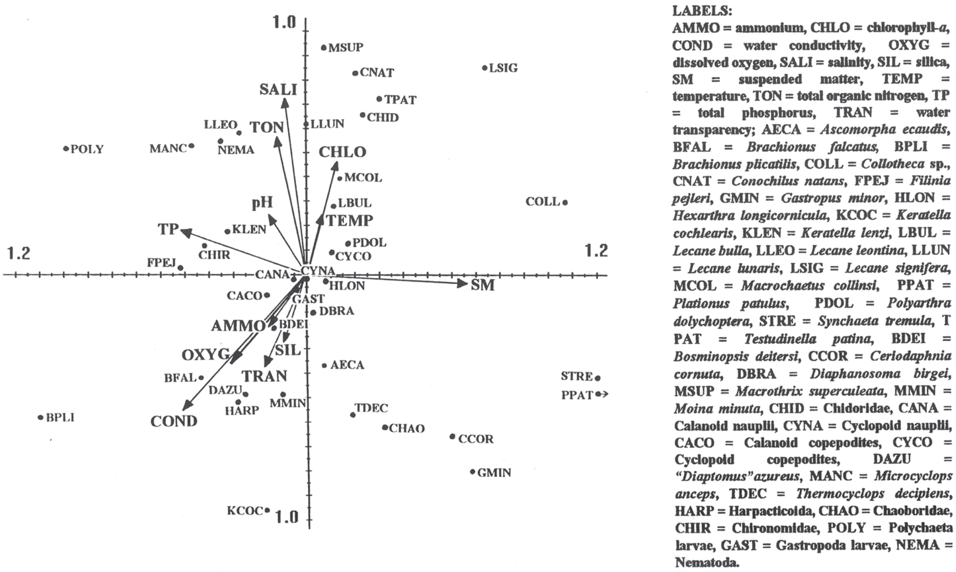


Fig. 7. – CCA ordination biplot of the constant and common species represented by dots and the environmental variables represented by arrows (names abbreviated to four letters; see captions) at sampling station 2.

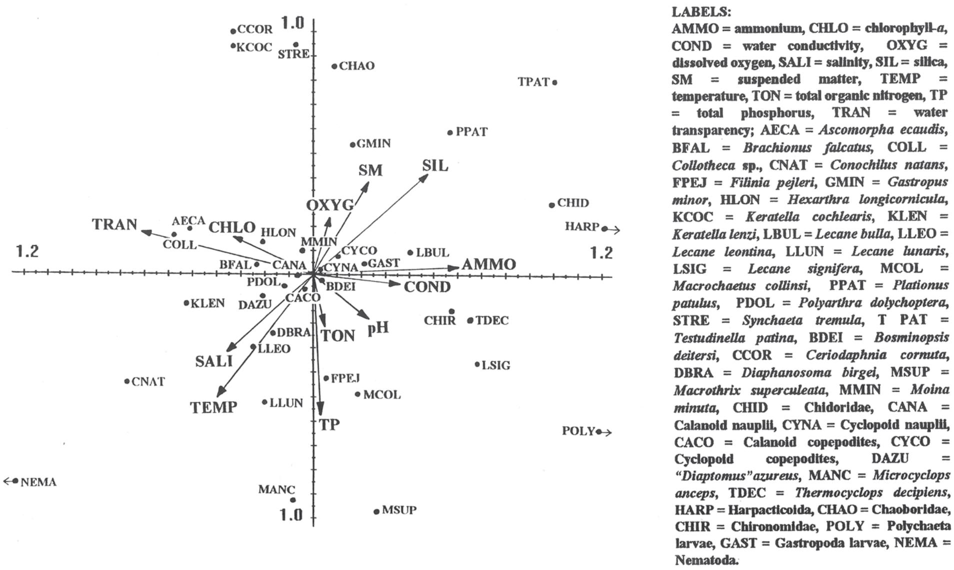


Fig. 8. – CCA ordination biplot of the constant and common species represented by dots and the environmental variables represented by arrows (names abbreviated to four letters; see captions) at sampling station 3.

shown by the positive association of chlorophyll-*a* values with transparency. The second-most important gradient at station 3 seemed to be that of freshwater with oligohaline conditions. The river input contributed with high concentrations of suspended matter, silica, dissolved oxygen and low water temperature, while the lagoon water had a comparatively higher content of total phosphorus, water temperature, salinity, total organic nitrogen and pH. The rotifers *Keratella cochlearis*, *Synchaeta tremula*, *Testudinella patina*, *Gastropus minor*, *Plationus patulus* and Chaoboridae larvae were related to the freshwater input.

## DISCUSSION

Environmental heterogeneity in coastal lagoons is attributed to water column mixing under the effect of tides and winds, the gradient of marine influence and freshwater input, morphometry, plant colonization and human intervention (Attayde & Bozelli 1998, Branco *et al*. 2000, 2006). The spatial and temporal distributions of the different zooplankton taxa in the Cabiúnas Lagoon were probably related to the distinct ecological conditions found at each sampling station.

Considering physical and chemical features, station 1 was situated close to the sand barrier subjected to occasional marine influence and constant wind causing water column mixture. These were the most important factors acting on zooplankton density at this site. The major environmental factor influencing zooplankton abundance at station 2 was suspended matter, possibly associated with the constant production of detritus from macrophytes. Marine influence on the zooplankton was less evident here. The third sampling station was affected by freshwater inflow from the Cabiúnas River and had the highest content of suspended matter. The influence of riverine water with high content of ammonium and silica on the water lagoon with higher values of conductivity and transparency were the main gradients acting on zooplankton abundances.

Marine influence also affected the temporal distribution and density variation of some species. Among the cladocerans, *Bosminopsis deitersi* was found almost year-round and throughout the lagoon, but did not occur during the sand barrier opening in October 1992. However, after this event, *B. deitersi* density was high at all sampling stations, showing fast population recovery. *B. deitersi* has been mentioned as one of the dominant species in brown Amazonian floodplain lakes (Brandorff *et al*. 1982) and in humic coastal lagoons (Branco *et al*. 2000). These last authors suggested that the continuous occurrence of this species in the Comprida Lagoon was likely due to its exploitation as food sources of bacteria and fungi associated to humic compounds. Similarly, we observed high abundances of *B. deitersi* at station 3 where detritus and humic compounds related to high organic and suspended matter input are probably not in short supply.

Besides physical and chemical variables, some biological characteristics of the species and their interactions with other aquatic communities may have influenced taxa occurrence and density. Among the rotifers, *Hexarthra longicornicula* dominated in the Cabiúnas Lagoon, which is the type locality of this species (Turner 1987). *Hexarthra* spp. are frequently found in coastal lagoons characterized by freshwater or oligohaline conditions (Arcifa *et al*. 1994). This genus has special morphological adaptations such as appendages, which reduce the energy costs of maintaining the position in the water column as well as characteristic "jumps", which helps diminish their vulnerability to invertebrate predation. We suggest that the rotifer community in Cabiúnas Lagoon suffers intense predation pressure, which can be supported by the common occurrence of Chaoboridae larvae whose predation on zooplankton increases in the shallow water column.

Table III. – Frequency of occurrence of plankton groups in the stomach contents of dominant fish from marine and freshwater origin in the Cabiúnas Lagoon. (M = marine; F = freshwater; ROT = rotifers; CLAD = cladocerans; CALAN = calanoid copepods; CYCLO = cyclopoid copepods; CHAOB = Chaoborid larvae; CHIRON = Chironomid larvae). Modified from Aguiaro & Caramaschi, 1998.

| TROPHIC GUILD | species | origin | frequency of occurrence | | | | Reference |
|---|---|---|---|---|---|---|---|
| | | | ROT | CLAD | CALAN | CYCLO | |
| macrophagous | *Centropomus mexicanus* | M | 0 | 0.4 | 0 | 0.2 | Aguiaro & Caramaschi 1998 |
| carnivores | *Oligosarcus hepsetus* | F | 0 | 0 | 0 | 0.2 | Aguiaro & Caramaschi 1998 |
| | *Rhamdia* sp. | F | 0 | 0.2 | 0 | 0 | Aguiaro & Caramaschi 1998 |
| microphagous | *Eucinostomus argenteus* | M | 0 | 0.27 | 0.47 | 0.26 | Branco *et al.* 1997 |
| carnivores | *Platanichthys platana* | M | 0.3 | 0.7 | 0.84 | 0.07 | Aguiaro *et al.* 2003 |
| | *Astyanax bimaculatus* | F | 0 | 0.4 | 0 | 0 | Aguiaro & Caramaschi 1998 |
| | *Geophagus brasiliensis* | F | 0 | 0.4 | 0.2 | 0.2 | Aguiaro & Caramaschi 1998 |
| omnivorous | *Parauchenipterus striatulus* | F | 0 | 0.3 | 0 | 0 | Aguiaro & Caramaschi 1998 |
| | *Hyphessobrycon bifasciatus* | F | 0 | 0.6 | 0.5 | 0.3 | Coutinho *et al.* 2000 |
| | *Hyphessobrycon luetkeni* | F | 0 | 0.8 | 0 | 0.2 | Aguiaro & Caramaschi 1998 |
| | *Poecilia vivipara* | F | 0 | 0.6 | 0 | 0 | Aguiaro & Caramaschi 1998 |
| detritivorous | *Cyphocarax gilbert* | F | 0.2 | 0 | 0 | 0 | Aguiaro & Caramaschi 1998 |

Moreover, all constant rotifer species found in Cabiúnas Lagoon are either capable of rapid skipping movements (e.g. *Hexarthra* and *Polyarthra*) or have a lorica with spines (e.g. *Brachionus falcatus* and *Keratella* spp.) providing protection against visual predators.

Predation can also explain differences in the horizontal distribution of the larger zooplankters in the Cabiúnas Lagoon. Few studies conducted so far on fish feeding habits in the Cabiúnas Lagoon have stressed the importance of larger zooplankton components as a food source for many fish species. Aguiaro & Caramaschi (1998) identified the trophic guilds of macrophagous, microphagous carnivores, omnivorous and detritivorous, and showed that dominant fish from marine and freshwater origins, including juveniles, usually included cladocerans, copepods and insect larvae in their diet (Table III). One of the two microphagous carnivores (*Platanichthys platana*) consumed all groups of the zooplankton and cladocerans and calanoid copepods were found in 70 and 84 % respectively of the stomachs analysed. All fish consumed cladocerans, except for *Oligosarcus hepsetus*, the larger microphagous carnivores present in the lagoon.

Furthermore, cladocerans and copepods dominated in the diet of smaller individuals of *Hyphessobrycon bifasciatus*, whereas larger individuals fed mainly on filamentous algae and plant debris (Coutinho *et al*. 2000). According to Jeppesen *et al*. (1994), higher fish biomass may be sustained in shallow lakes by additional alternative food sources. Therefore, a higher predation pressure on zooplankton may be maintained in shallow rather than in deep lakes.

Several studies have focused on the influence of submerged macrophytes on the zooplankton-fish interactions concluding that aquatic vegetation can act as a valuable zooplankton refuge from fish predation (Lauridsen & Lodge 1996, Jacobsen *et al*. 1997, Stansfield *et al*. 1997). However, Jeppesen *et al*. (1998) found a relatively poor refuge effect of macrophytes for zooplankton due to aggregation of sticklebacks (*Gasterosteus aculeatus*) and *Neomysis* in a brackish lake. The high density of fish among the macrophytes in the Cabiúnas Lagoon may also prevent aquatic vegetation from acting as an effective zooplankton refuge. According to Reis *et al*. (1998), the juveniles of most fishes and small-sized species are caught only among macrophytes, whereas very few individuals are found in the open areas. Therefore, macrophytes in the Cabiúnas Lagoon may not function as an effective refuge for larger zooplankton. Intense predation pressure on large-sized zooplankton within macrophyte beds, and reduced predation in limnetic zones, might explain the lower density of larger zooplankters at station 2 and their higher densities at stations 1 and 3. *Moina minuta* was a cladoceran commonly found in the lagoon, as well as the calanoid copepod *"Diaptomus" azureus*, considered constant in the zooplankton community. Both species had an evident lower frequency of occurrence at station 2.

Among the meroplanktonic forms, only Gastropoda larvae were constantly found in the Cabiúnas Lagoon. Larvae of benthic fauna are the most common meroplankton in the zooplankton community in coastal lagoons around the world (Lam-Hoai 1991). Their density was lowest at station 3, probably due to the impact of suspended matter on veliger forms. The density of Gastropoda larvae was low during the sand barrier opening in October 1992, but afterwards their abundance increased mainly at sampling station 1. Similarly, a large increase in the number of *Heleobia australis* veligers was the most notable event detected after a sand barrier opening to the zooplankton community in the Imboassica Lagoon (Branco *et al*. 2006). This is also the dominant gastropod in the benthic community of the Cabiúnas Lagoon.

## CONCLUSION

Water salinity and conductivity, suspended matter content and water transparency were recognised as the main factors influencing the abundance of constant and common zooplankton species in the Cabiúnas Lagoon. The results have significantly elucidated the dynamics of the zooplankton community in response to environmental changes, such as a marine entrance in the lagoon. Biotic interactions also helped explain the zooplankton distribution. The Cabiúnas Lagoon is intensively colonized by macrophytes, and the zooplankton community is dominated by rotifers and small cladocerans (e.g. *Bosminopsis deitersi*) that probably endure predation by other invertebrates. Larger organisms such as large-sized cladocerans and copepods are, instead, preyed upon by fish within the plant beds. Thus, fish predation pressure can be suggested as a contributory factor to the observed differences in the distribution of the larger micro-crustaceans.

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