Zooplankton community composition and abundance of two Brazilian semiarid reservoirs.

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ABSTRACT: Zooplankton community composition and abundance of two Brazilian semiarid reservoirs. Zooplankton communities from Pacajus and Gavião reservoirs of Ceará state (northeast Brazil) were sampled in dry and rainy periods in order to correlate the composition and abundance of zooplankton species with environmental factors. A total of 32 taxa were identified: 19 of Rotifera, 7 of Cladocera and 6 of Copepoda. In the Pacajus reservoir, 25 species were recorded in the dry period and 24 in the rainy period. In the Gavião reservoir, 10 species were recorded in the dry and 24 in the rainy periods. According to Shannon-Weaver index, the diversity of species was lower during the dry season for both reservoirs, which can be related to the higher trophy status presented by these lakes in that time. There was an evident dominance of Copepoda Cyclopoida over Copepoda Calanoida, mainly caused by high densities of Thermocyclops decipiens, particularly in December/1998. Diaphanosoma spinulosum and Ceriodaphnia cornuta were important among Cladocera, while Keratella and Brachionus were the most conspicuous genera in the Rotifera assembly. The most abundant rotifer species were Keratella tropica, K. americana, Brachionus calyciflorus, B. havanaensis, and Polyarthra vulgaris. Opportunistic species such as T. decipiens, D. spinulosum, C. cornuta, B. calyciflorus, and K. tropica, found in the two studied reservoirs, can be associated with hypereutrophic waters and disturbed environments.

Key-words: reservoirs, zooplankton, bioindicators, water quality, eutrophication, seasonal changes, semiarid, Brazil.

RESUMO: Composição e abundância da comunidade zooplanctônica de dois reservatórios do semi-árido brasileiro. As comunidades zooplanctônicas dos reservatórios Pacajus e Gavião, localizados no Estado do Ceará (nordeste brasileiro), foram coletadas nos períodos seco e chuvoso, com o objetivo de correlacionar a composição e abundância de suas populações com os fatores ambientais. Um total de 32 taxa foram identificados: 19 de Rotifera, 7 de Cladocera e 6 de Copepoda. No reservatório Pacajus, 25 espécies ocorreram no período seco e 24 no período chuvoso, enquanto que no Gavião foram registradas 10 e 24 espécies no período seco e chuvoso, respectivamente. De acordo com o índice de Shannon-Weaver, a diversidade de espécies foi menor durante o período seco para ambos reservatórios, o que pode estar relacionado ao maior grau de trofia apresentado por estes ambientes nesta época. Foi observada a dominância de Copepoda Cyclopoida sobre Copepoda Calanoida, especialmente devido às altas densidades de Thermocyclops decipiens, particularmente em Dezembro/1998. Diaphanosoma spinulosum e Ceriodaphnia cornuta tiveram destaque dentre os cladóceros, enquanto Keratella e Brachionus foram os gêneros mais conspícuos no grupo Rotifera. Os rotíferos mais abundantes foram Keratella tropica, K. americana, Brachionus calyciflorus, B. havanaensis e Poyiarthra vulgaris. Espécies oportunistas tais como T. decipiens, D. spinulosum, C. cornuta, B. calyciflorus e K. tropica, encontradas nos dois reservatórios estudados, podem ser associadas às condições de hipertrofia dos reservatórios investigados.

Palavras-chave: reservatórios, zooplâncton, bioindicadores, qualidade da água, eutrofização, mudanças sazonais, semi-árido, Brasil.

Introduction

The reservoirs of Ceará state (northeast Brazil) are submitted to natural adverse influences caused by the climatic regime, characterized by the pluviometric irregularities, high insolation and evapotranspiration rates during most part of the year. The metropolitan reservoirs in this region are also submitted to impacts of several human activities developed in drainage basins surrounding areas, due to soil uses.

The environmental monitoring is an important process in the ecosystem analysis, having as function to recognize and to follow the resulting changes from transforming activities (Printes, 1996), as the impacts caused by pollution. The allochthonous introduction of forms of energy or substances in the natural aquatic ecosystems causes changes in the physical, chemical and biological aspects of the environment. Aquatic communities and populations can be considered biological indicators of the contamination level of an environment, where the presence or the absence of species can be an indicative of the disturbance of ecosystems (Chapman, 1989). Planktonic communities, living directly under the influence of a specific physical and chemical environment, closely reflect the alterations in water quality. Therefore, the eutrophication affects the specific composition of the zooplankton communities, which can exist associated to different trophic conditions (Sendacz et al., 1985; Rocha et al., 1995).

Few papers have focused on ecological aspects of reservoirs in Ceará state. In order to investigate the seasonal composition and abundance of zooplankton species and to correlate the changes on the communities structure to the trophy degree of the studied systems, a study was conducted in two reservoirs.

Study area

The state of Ceará has almost all of its territory inserted in the Droughts Polygon, where water resources management has a critical role face to unfavorable natural conditions which this area is submitted to. The association of an irregular pluviometric regimen, characterized by rains concentration in a short period of the year; the occurrence of extreme droughts; high evaporation rates and the dominance of crystalline stratum, results in an aggravation of the temporal and spatial water availability (Ceará, 1992).

Pacajus (4°20'S and 38°40'W) and Gavião (3°55'S and 38°35'W) reservoirs are part of the Water Supply System of Metropolitan Region of Fortaleza (Fig. 1),

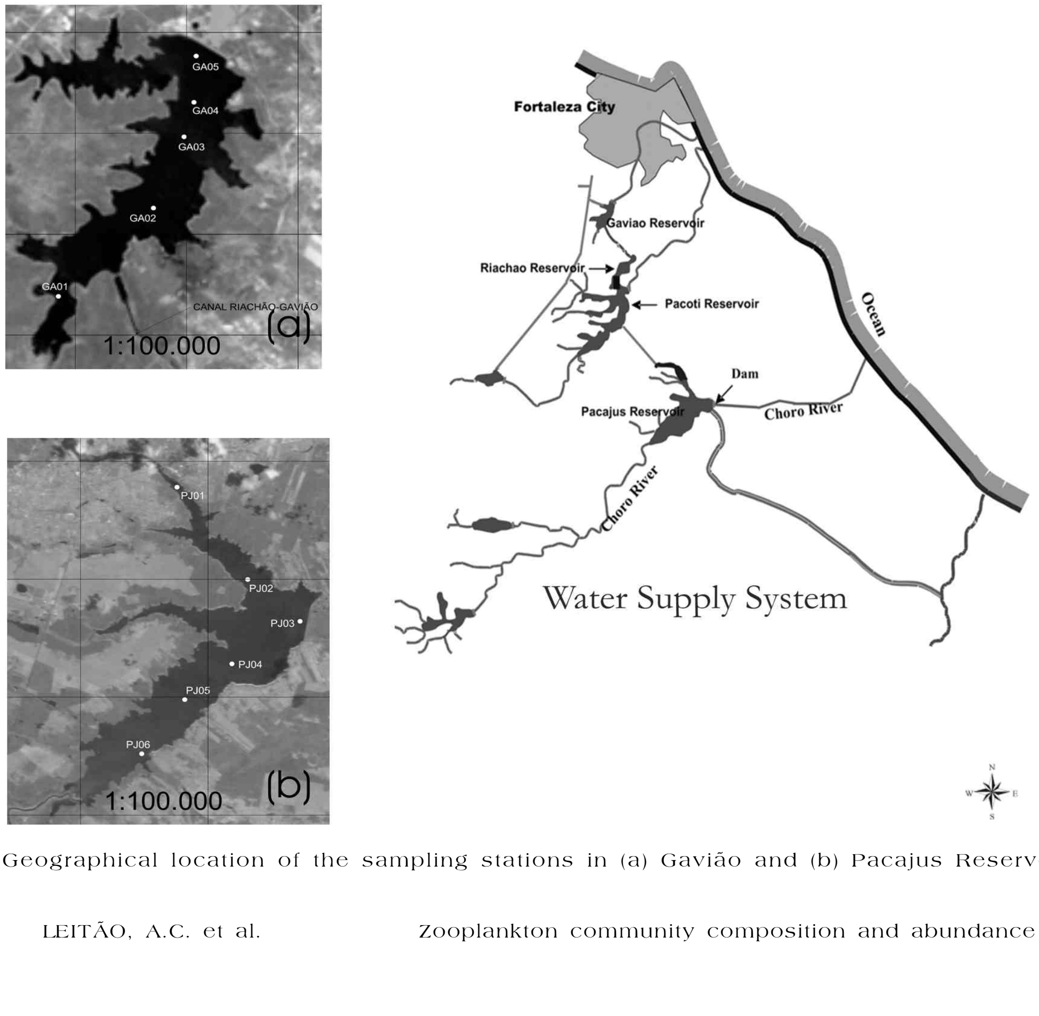


Figure 1: Geographical location of the sampling stations in (a) Gavião and (b) Pacajus Reservoirs.

responsible for supplying the population and also economic activities associated to this area. The Pacajus and Gavião reservoirs have a volume of 240 and 32.9 hm^3, respectively, being considered shallow systems. During the investigated period, the mean depth (Z_m) of the Pacajus and Gavião reservoirs were, respectively, 3.28 m and 4.21 m.

According to the classification of Thornthwaite (1948), the climate of the region is semiarid, characterized by an annual precipitation from 1000.0 to 1600.0 mm in the coast and 800.0 mm in the most occidental part of the basin. In the rainy period, the monthly values can be higher than 300 mm as in March and April (Fig. 2a). The dry period extends from July to December, being characterized by the low values of total precipitation and high monthly values of evaporation. The average temperature may vary from 25.7°C to 27.3°C over a year, and the average annual evaporation is of around 1500.0 mm, falling to 650.0 mm at the highest regions (Fig. 2a and 2b) (Aguiar et al., 2000).

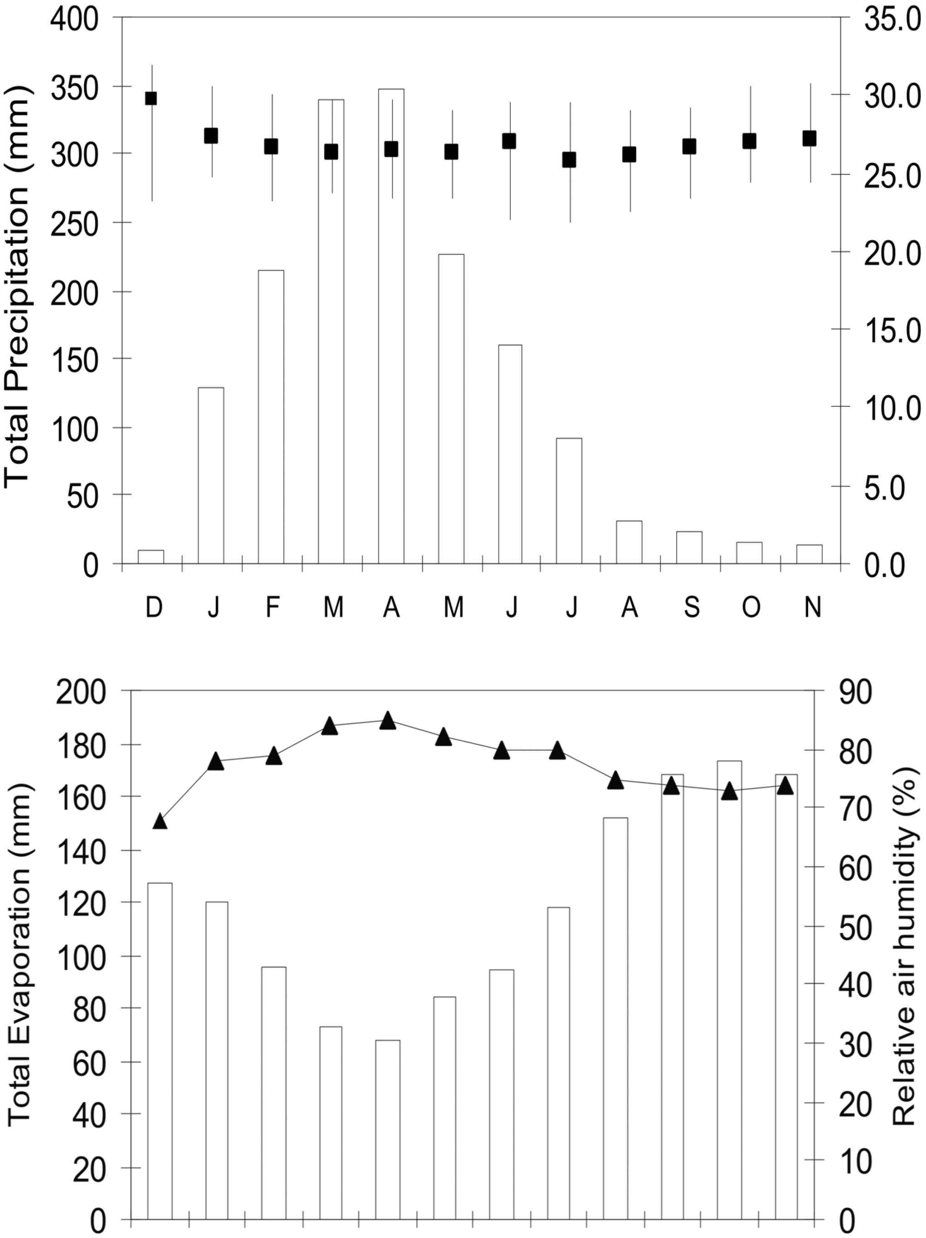


Figure 2: Mean monthly values of meteorological data from 1961 to 1990 at the study area. (a) Rainfall (mm, bars) and temperature (°C, line). (b) Total evaporation (mm, bars) and relative humidity (% , line).

Material and methods

Sampling for qualitative and quantitative analysis of zooplankton was carried out at six stations in the Pacajus reservoir and five stations in the Gavião reservoir, in December 1998 (dry period) and June 1999 (rainy period). Zooplankton samples were collected from the water column by vertical hauls, through a 45 mm mesh net. Collected animals were preserved in 4% formaline solution. Organisms were identified to the greatest possible taxonomic level (genus or species), using an optical microscope and a specialized bibliography. Quantitative analysis of rotifers and nauplii of copepods was performed in a Sedgwick-Rafter chamber, counting between one and five chambers, depending on the abundance, in order to determine the density and relative abundance of all species. Microcrustaceans were counted in reticulated acrylic chambers using sub-samples with at least 300 individuals or the entire sample, depending on the concentrations of organisms. Density of organisms were calculated considering the volume of water filtered and the size of each sub sample, and expressed as numbers of individuals per cubic meter (APHA, 1992). The water temperature, electric conductivity (E.C.), turbidity, pH and dissolved oxygen (DO) were measured at the water column with a multiparametric probe (HORIBA, model U-10, Kyoto, Japan), at regular intervals along the water column. Water samples to total alkalinity, dissolved inorganic phosphorus (DIP), total phosphorus (TP), ammoniacal nitrogen ($NH_{3,4}$), nitrate (NO_3^-) and nitrite (NO_2^-) analysis were collected with a van Dorn bottle in three depths (surface, middle and bottom of the water column), conditioned in acid washed plastic bottles (HCl 10% solution) and kept at -20°C until the analytical determinations according APHA (1992). Samples for dissolved nutrients analysis were filtered onto pre-combusted (500°C) glass fiber filters (Whatman GF/C 47mm, Maidstone, UK). The water transparency (z_{SD}) was estimated using a 30 cm Secchi disk. The chlorophyll a concentrations (corrected to phaeophytin) were determined in samples taken from superficial layer (@30 cm depht) after extraction with 90% acetone solution. The DO saturation concentrations were calculated as described by Straskraba & Tundisi (1999).

Trophy state index was calculated using phosphorous total and chlorophyll a data in according to Toledo et al. (1983) and Toledo (1990). Diversity indices (Shannon & Weaver, 1949) of zooplankton were also calculated.

A Principal Component Analysis (PCA) was carried out to reduce the dimensionality of data. Previously, the variables were log transformed (log (x + 1)), except for pH, in order to stabilize the variance (Legendre & Legendre, 1998). The PCA was carried out with the aid of the software Statistica Version 6.0 (Statsoft. Inc., 2001).

Results

Both reservoirs were characterized by high pH values and electrical conductivity, especially at dry period, when the effects of the evaporative concentration are well evidenced in the systems. High contents of total phosphorus and chlorophyll a were registered in both reservoirs during the whole study (Tab. I). Using monthly mean values of total phosphorus and chlorophyll a, the reservoirs were classified as hypereutrophic and eutrophic for dry and rainy periods, respectively. In June, both reservoirs showed supersaturation in dissolved oxygen (Fig. 3). This situation was observed even below the euphotic zone. At that month, the wind action should have prevailed as the main physical inductive agent of turbulent mixing of the water column, since the inflows to dam were considered nulls. It is worth mentioning that wind action was favored by low mean depth of the reservoirs (Pacajus: 3.4 m; Gavião: 4.2 m). This hypothesis was fortified by conditions of isothermy observed in both reservoirs (Figs. 4a and 4b). However, phytoplanktonic photosynthetic activity should not be neglected as an important component in trophogenic zone oxygenation. The highest oxygen concentrations in superficial layers of the Pacajus reservoir in December can be attributed to high algal biomass (70.48 mg/L). The Pacajus and Gavião reservoirs presented also alkaline waters (pH values ranging from 7.01 to 9.28).

Table II presents the density, relative abundance, richness, and diversity index of zooplankton community at Pacajus and Gavião reservoirs, during December of 1998 and June of 1999. In the dry period, both reservoirs showed lower diversity indexes (usually < 2.5). The Pacajus reservoir presented the highest diversity indexes for both periods, when compared to the Gavião.

A total of 32 taxa were identified in

Table I: Limnological variables (mean ± SD) and Trophic State Indexes (TS) of Pacajus and Gavião reservoirs, during dry (December/1998) and rainy periods (June/1999).

Variables	**Pacajus**		**Gavião**	
	Dec/98	**Jun/99**	**Dec/98**	**Jun/99**
Transparency (m)	0.8 (±0.2)	0.9 (±0.2)	1.3 (±0.6)	0.9 (±0.1)
pH	7.7 (±0.5)	8,0 (±0.4)	8.5 (±0.1)	8.2 (±0.2)
Water Temperature (^{0}C)	29.3 (±0.9)	28.6 (±0.4)	29.3 (±0.3)	32.6 (±0.4)
Dissolved Oxygen (mg/L)	5.92 (±2.36)	8.34 (±3.37)	8.61 (±0.40)	7.46 (±1.34)
Conductivity (mS/cm)	1.22 (±0.11)	0.79 (±0.17)	1.16 (±0.02)	1.13 (±0.07)
Total Alkalinity (mg $CaCO_3$/L)	81.10 (±6.04)	78.11 (±11.85)	57.75 (±12.24)	68.50 (±3.17)
NO_2^--N (mg/L)	3.11 (±0.74)	2.62 (±2.30)	_	1.59 (±0.32)
NO_3^--N (mg/L)	21.71 (±23.13)	2.42 (±1.76)	31.54 (±5.00)	1.63 (±1.38)
$NH_3 + NH_4^+$ (mg/L)	217.46 (±176.34)	296.56 (±84.12)	93.95 (±39.47)	266.52 (±63.10)
PO_4^{3-} - P (mg/L)	11.97 (±18.34)	11.49 (±3.84)	8.29 (±2.34)	13.51 (±3.95)
Total Phosphorus (mg/L)	655.60 (±532.92)	202.02 (±215.32)	420.24 (±443.75)	269.84 (±201.53)
Chlorophyll a (mg/L)	70.48 (±92.63)	16.17 (±9.26)	78.63 (±131.59)	19.37 (±4.07)
TS	89.6 (H)	71.0 (E)	87.1 (H)	74.3 (E)

E = Eutrophic, H = Hypereutrophic

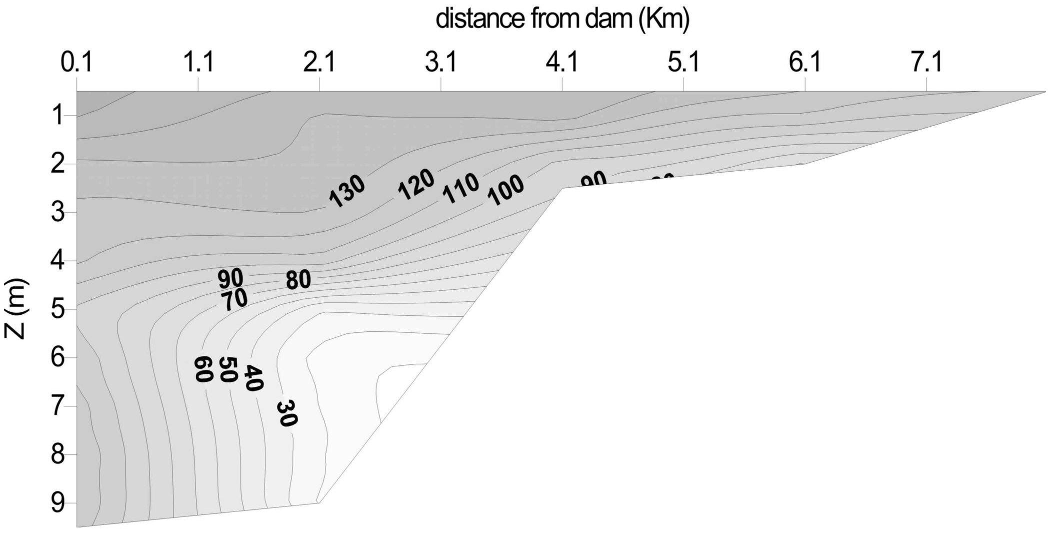
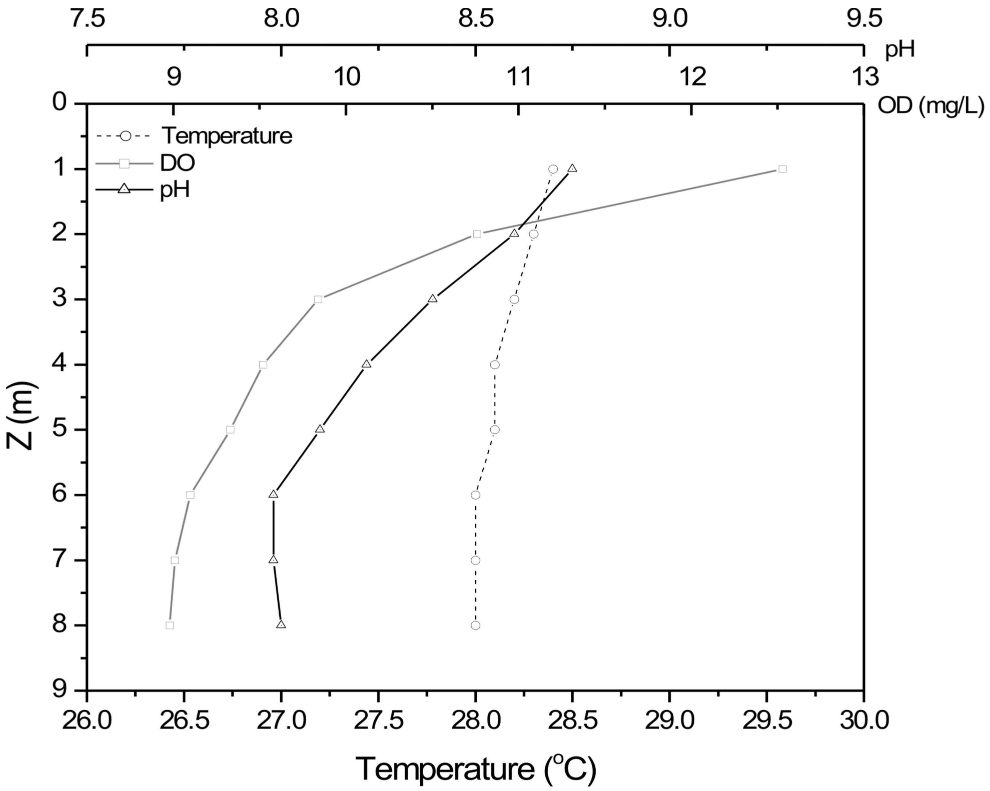


Figure 3: Isopleths of DO (% of saturation) throughout the main longitudinal axis of the Pacajus reservoir in June/1999.



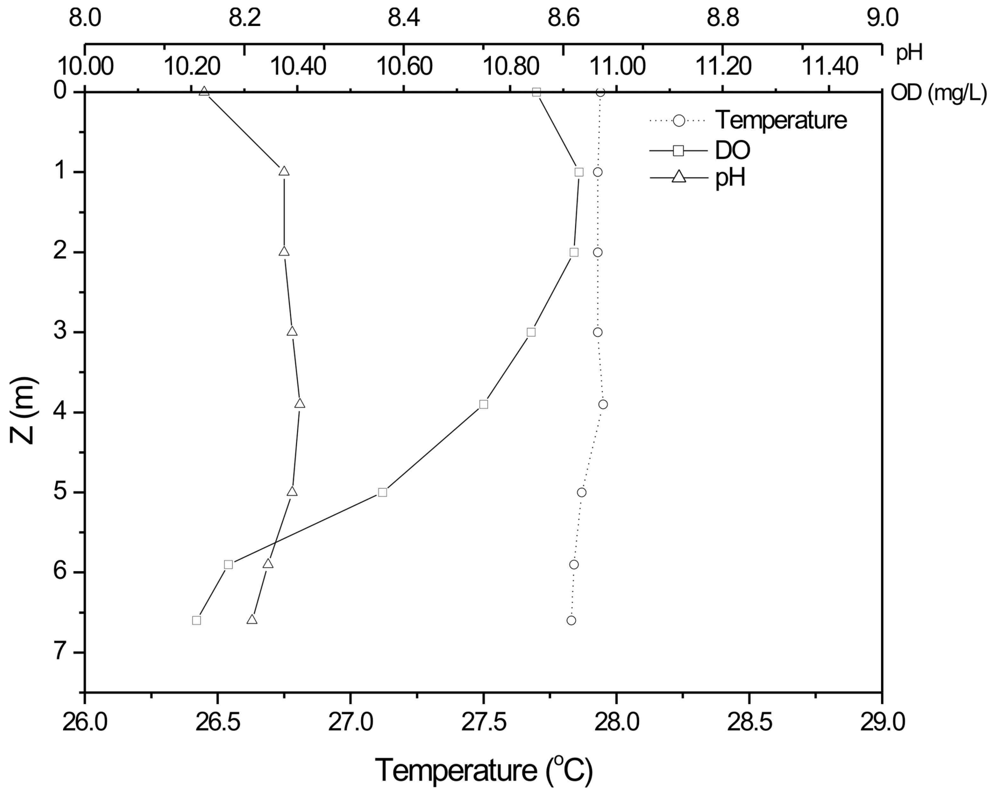


Figure 4: Vertical profiles of water temperature (T), dissolved oxygen (DO) and pH correspondent to dam proximities (deepest region) in (a) Pacajus and (b) Gavião reservoirs in June/1999.

Table II: Density (ind./m³), relative abundance (%), richness (taxa number) and diversity index (bits/ind.) of zooplankton community at Pacajus and Gavião reservoirs, during December of 1998 and June of 1999.

Organisms	**Pacajus**				**Gavião**			
	Dec/98		**Jun/99**		**Dec/98**		**Jun/99**	
	org./m³	**%**	**Org./m³**	**%**	**org./m³**	**%**	**org./m³**	**%**
Copepoda-Calanoida (3)								
Argyrodiaptomus azevedoii	0	0	0	0	298.0	1.9	31.9	0.03
Notodiaptomus cearensis	2347.8	2.2	503.8	0.4	3238.3	20.2	3403.5	2.8
Notodiaptomus iheringi	491.7	0.5	630.4	0.5	4624.6	28.9	2150.2	1.8
Copepoditos (Calanoida)	3101.6	2.9	2280.0	1.8	2781.0	17.4	2938.8	2.4
Nauplios (Calanoida)	6175.9	5.9	7666.0	6.1	2202.7	13.8	9637.7	8.0
Total	12117.0	11.5	11080.2	8.8%	13144.5	82.2	18162.1	15.0
Copepoda-Cyclopoida (3)								
Mesocyclops longisetus	34.7	0.03	52.9	0.04	16.8	0.1	796.5	0.7
Thermocyclops decipiens	1992.0	1.9	426.3	0.3	90.7	0.6	8109.6	6.7
Thermocyclops minutus	383.9	0.4	7582.0	6.0	0	0	4304.1	3.6
Copepoditos (Cyclopoida)	6728.2	6.4	14080.4	11.2	178.9	1.1	12848.5	10.6
Nauplios (Cyclopoida)	16157.5	15.4	58198.2	46.3	1856.9	11.6	64566.6	53.4
Total	25296.3	24.0	80339.8	63.9	2143.3	13.4	90625.3	75.0
Cladocera (7)								
Alonella sp	0	0	0	0	0	0	43.6	0.04
Ceriodaphnia cornuta cornuta	0	0	0	0	23.8	0.1	0	0
Ceriodaphnia cornuta rigaudi	128.0	0.1	176.6	0.1	585.8	3.7	17.3	0.01
Daphnia gessneri	0	0	0	0	63.3	0.4	0	0
Diaphanosoma spinulosum	913.7	0.9	595.7	0.5	0	0	13.9	0.01
Machrotrix flabelligera	0	0	0	0	0	0	450.0	0.4
Moina micrura	90.3	0.1	0	0	0	0	0	0
Total	1132.0	1.1	772.3	0.6	672.9	4.2	524.8	0.4
Rotifera (19)								
Brachionus angularis	1542.2	1.5	2209.6	1.8	0	0	17.3	0.01
Brachionus budapestinensis	0	0	2729.6	2.2	0	0	0	0
Brachionus calyciflorus	13436.6	12.8	3978.1	3.2	0	0	1158.4	1.0
Brachionus caudatus	2.7	0.003	611.1	0.5	0	0	0	0
Brachionus falcatus	1027.0	1.0	559.3	0.4	0	0	103.8	0.09
Brachionus havanaensis	2861.5	2.7	4056.6	3.2	0	0	4570.2	3.8
Brachionus patulus	77.3	0.1	180.8	0.1	0	0	105.9	0.09
Brachionus rubens	747.3	0.7	413.1	0.3	0	0	0	0
Brachionus rubens	747.3	0.7	413.1	0.3	0	0	0	0

Table II: Cont.

Epiphanes macrourus	406.2	0.4	899.4	0.7	0	0	86.5	0.07
Filinia longiseta	1754.2	1.7	997.3	0.8	0	0	4.5	0.004
Hexarthra intermedia	3482.6	3.3	1754.4	1.4	25.4	0.2	342.2	0.3
Keratella americana	4778.8	4.5	4167.5	3.3	0	0	26.7	0.02
Keratella lenzi	22.0	0.02	0	0	0	0	0	0
Keratella tropica	28145.5	26.7	8093.5	6.4	7.9	0.05	3699.2	3.1
Lecane sp1	50.4	0.05	189.3	0.2	0	0	114.2	0.09
Lecane sp2	105.1	0.1	0	0	0	0	54.0	0.04
Poliarthra vulgaris	8174.6	7.8	2498.9	2.0	0	0	1270.5	1.1
Testudinella sp	0	0	51.5	0.04	0	0	9.0	0.01
Total	66707.5	63.4	33491.9	26.6	33.3	0.2	11562.4	9.6
Total of organisms	105252.8		125684.2		15994.0		120874.6	
Richness	25		24		10		24	
Diversity index (H)	2.06		2.55		1.13		2.18	

samples collected from the Pacajus and Gavião reservoirs, in both studied periods (6 species of Copepoda, 7 species of Cladocera, and 19 species of Rotifera). 27 species composed the zooplanktonic community of the Pacajus, 25 species registered in the dry (December/1998) and 24 species registered in the rainy periods (June/1999). At the Gavião, the zooplanktonic community was composed by 26 species, 10 species occurring in the dry and 24 species in the rainy period.

During the dry period, the Gavião reservoir presented the lowest total zooplankton density throughout the study (15,94 ind./m^3), showing low richness of species (10 species) and a reduced index of diversity (H = 1.13 bits/ind.). The composition was mainly determined by the Rotifera group, while a decrease in the abundance of Cyclopoida copepods was observed. At this time, the Calanoida copepods reached the highest relative abundance (82.2%) of the whole study. However, at Pacajus reservoir, Rotifera presented the highest values of relative abundance (63.4%) and density (66,77 ind./m^3).

Copepoda was represented by six species, three of Calanoida (Notodiaptomus cearensis, Notodiaptomus iheringi and Argyrodiaptomus azevedoi) and three of Cyclopoida suborders (Mesocyclops longisetus, Thermocyclops decipiens, and Thermocyclops minutus). The species that occurred at highest densities, for both Pacajus and Gavião reservoirs, were N. cearensis, N. iheringi, T. decipiens and T. minutus. T. minutus was not found in the Gavião reservoir during the dry period and A. azevedoi did not occur in the Pacajus reservoir in any time. T. decipiens was the most abundant species among the Cyclopoida group for the majority of the zooplankton samples. The association between the genera Thermocyclops and Mesocyclops was observed in both studied reservoirs, and M. longisetus was found in low densities.

The dominance of Copepoda Cyclopoida over Copepoda Calanoida was observed in both studied reservoirs, except in the Gavião during the dry period. In the rainy season, both reservoirs presented relative abundance above 60.0% for Copepoda Cyclopoida. In this period, the group was mainly represented by high abundance of nauplii, reaching 46.3% and 53.4% of the total zooplankton, for Pacajus and Gavião reservoirs, respectively.

Principal Component Analysis considering physical and chemical data, besides the densities of main species and immature forms of Cyclopoida for both reservoirs in June, extracted three statistically significant factors, which explained 72.0% of the total variability. Axis I extracted 34.07% of the variance and was correlated well with T. decipiens and variables related to trophic state of reservoirs (Fig. 5). However, this association was more evident examining axis III (15.11%) (Fig. 6). Axis II (22.77%) was formed mainly by positive contribution of T. minutus, species more abundant in that period, $NH_{3,4}$ and copepodid, in opposition to negative contributions of temperature and eletric conductivity (E.C.) June was mainly characterized by reduction in E.C. values in relation to December.

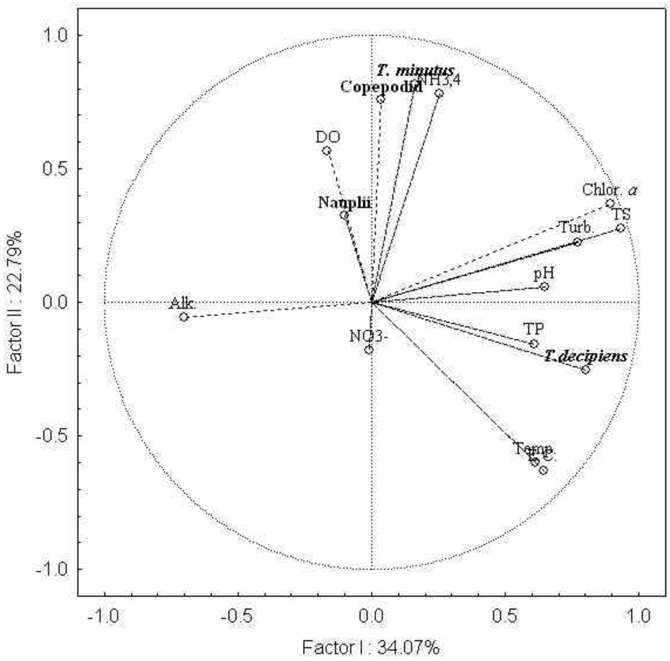


Figure 5: Ordination (I x II) of environmental factors and densities of T. decipiens, T. minutus and Nauplii and Copepodid of Cyclopoida for the two reservoirs in June/1999. (DO: dissolved oxygen, Turb: turbidity, E.C.: electric conductivity, TP: total phosphorus, DIP: dissolved inorganic phosphorus, Chlor. a: Chlorophyll a, Alk: total alkalinity, $NH_{3,4}$: ammoniacal nitrogen, TS: Trophic State).

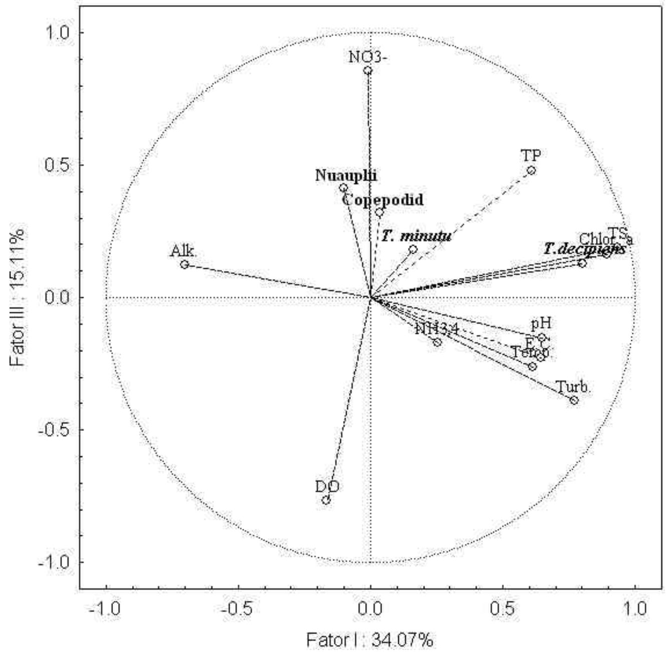


Figure 6: Ordination (I x III) of environmental factors and densities of T. decipiens, T. minutus and Nauplii and Copepodid of Cyclopoida for the two reservoirs in June/1999. (DO: dissolved oxygen, Turb: turbidity, E.C.: electric conductivity, TP: total phosphorus, DIP: dissolved inorganic phosphorus, Chlor. a: Chlorophyll a, Alk: total alkalinity, $NH_{3,4}$: ammoniacal nitrogen, TS: Trophic State).

Copepoda Calanoida were more abundant in Gavião reservoir, overcoming Cyclopoida in December, when species of this group reached lowest densities during the investigated period.

Rotifers constituted 63.4% of the total composition of zooplankton species in the Pacajus reservoir in December and 24.6% in June. In the Gavião reservoir, Rotifera presented a lower relative abundance (0.2% in December and 9.6% in June), when compared to the Pacajus. The Gavião reservoir showed the lowest density (33.3 ind./m^3) for Rotifera in December, with only 2 species (Hexarthra intermedia and Keratella tropica) occurring at very low densities (25.4 and 7.9 ind./m^3, respectively).

The most conspicuous genera were Keratella and Brachionus (3 and 8 species respectively). The most abundant species were K. tropica, K. americana, B. calyciflorus, B. havanaensis and Polyarthra vulgaris. K. tropica reached the highest density values in the Pacajus in both periods (28,145.5 and 8,093.5 ind./m^3, respectively) and a maximum relative abundance (26.7%) was found in December. B. havanaensis and K. tropica were the most abundant species for the Gavião reservoir in June.

The PCA, considering environmental factors data and rotifers densities from both reservoirs at dry period (December) explained 75.44% of total variance, with the first axis representing 47.43%. The second axis (28.01%) was correlated positively with pH and DO, and negatively with rotifers, total alkalinity, PID, NO_3^- and TP (Fig. 7).

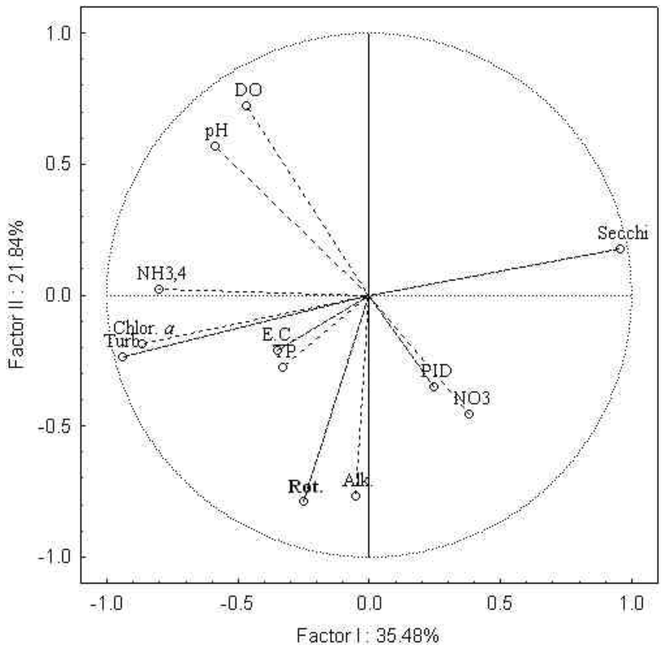


Figure 7: Ordination (I x II) of environmental factors and Rotifera density for the two reservoirs, considering the whole study period (DO: dissolved oxygen, Turb: turbidity, E.C.: electric conductivity, TP: total phosphorus, DIP: dissolved inorganic phosphorus, Chlor. a: Chlorophyll a, Alk: total alkalinity, $NH_{3,4}$: ammoniacal nitrogen, Rot: Rotifera).

Cladocera group presented low richness and densities. At Pacajus only three species of Cladocera were found compared to six in Gavião reservoir. Diaphanosoma spinulosum showed dominance in the Pacajus in both periods, occurring in 100% of the samples and highest densities in December. Ceriodaphnia cornuta rigaudi and Macrothrix flabelligera were the most abundant species of Cladocera in the Gavião reservoir in December and June (87.0% and 85.6%, respectively). The latter species was only found in one single sample in this reservoir, in the rainy period.

PCA considering data from physical and chemical variables, besides the total densities of Rotifera, Copepoda and Cladocera groups corresponding to December in Pacajus reservoir showed an inverse relation between Cladocera and variables associated with trophic state (Fig. 8). In that time, when the reservoir was classified as hypereutrophic, Cladocera reached lowest densities.

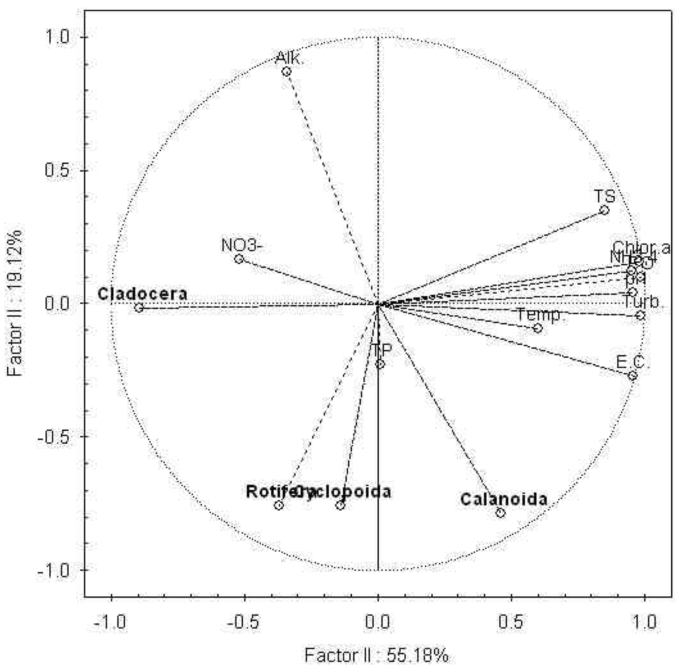


Figure 8: Ordination (I x II) of environmental factors and total densities of Rotifera, Copepoda and Cladocera for the Pacajus reservoir in December/1998 (DO: dissolved oxygen, Turb: turbidity, E.C.: electric conductivity, TP: total phosphorus, DIP: dissolved inorganic phosphorus, Chlor.a: Chlorophyll a, Alk: total alkalinity, $NH_{3,4}$: ammoniacal nitrogen, TS: Trophic State).

Discussion

In the northeast of Brazil, the seasonal pulses of precipitation and wind seem to be the most important forces driving the metabolism of the reservoirs, presenting in their great majority, low depths. External and internal load of suspended material, the last process specially favored by shallowness of the reservoirs, can reduce light penetration in the water column and, as consequence, the optical quality and the phytoplanktonic primary production, determining the quantity and quality of food for the zooplankton community (Bozelli, 1992). Water eutrophication affects also the specific composition of zooplankton through changes in the water quality and phytoplanktonic assemblage, determining different communities associated to different trophic levels (Sendacz et al., 1985). Moreover, the temporal variation in the density of the planktonic organisms may be influenced by operational regime of reservoirs, which determines mainly the magnitude of change on the water residence time. According to Rocha et al. (1999), rotifers, protozoans and nauplii copepods are more susceptible to losses by outflow during periods of low water residence times, especially in rapidly flushed reservoirs.

For many water bodies located in Ceara State zooplankton has never been studied before, and there are no previous records on species composition. This is the case for both reservoirs investigated in the present study. The results obtained revealed that the zooplankton assemblage is composed by species quite representative of the planktonic microinvertebrate Neotropical fauna. It is worth mentioning that new record of species was not found in this preliminary research. The species recorded are also of wide distribution, occurring from near the Equator to the far South region of Brazil (Rocha et al., 1995). The calanoids species found, A. azevedoi, N. cearensis and N. iheringi, are widely distributed in Brazil (Matsumura-Tundisi, 1986). However, the mesh opening chosen (45 mm) for sampling zooplanktonic organisms at the investigated reservoirs certainly had a decisive influence on the results, even this kind of net plankton is especially selective for the micro-zooplankton, while the mesozooplankton, including Cladocera and Copepoda, are underestimated. Therefore, the results should be analyzed considering this limitation, which must be corrected in future researches.

Total richness of species was quite similar in both reservoirs. However, there were differences regarding the main taxonomic groups (Rotifera, Cladocera and Copepoda). The number of species of Cladocera and Rotifera in the open waters of the studied reservoirs was low. Such characteristics also were registered by Newmann-Leitão et al. (1989) in a reservoir located in Pernambuco state (northeast of Brazil).

The richness of species in Pacajus reservoir did not show significant difference between the rainy and dry periods, whereas in the Gavião, species richness varied, being much reduced at the dry period. At this reservoir, a greater reduction in density of Copepoda nauplii was found, as well as in rotifers and adults of Cyclopoida. During the dry period, the Gavião waters showed the highest pH (8.5 ± 0.1) and electrical conductivity means (1.6 ± 0.02 mS/cm), besides high nutrient status and algal biomass. These intrinsic characteristics observed at Gavião may be pointed out as possible growing limiting factors to zooplankton. Although rotifers are considered opportunistic organisms (Allan, 1976; Aoyagui et al., 2003), with high capacity of adaptation to ecological disturbances, some species can be particularly sensible to pH changes. Pennak (1953) found a low number of Rotifera species associated to alkaline waters of freshwater ecosystems in United States. A similar situation was observed by Mourão (1989) in alkaline lakes (popularly known as "salinas") in Pantanal (Mato Grosso, Brazil), where a low number of Rotifera species was registered, and sometimes just one (B. calyciflorus). These particular changes in density and richness community may be attributed primarily to the water quality characteristics, such as high pH and electrical conductivity values, besides the trophic status of the hypereutrophic reservoirs at that time. Several other factors such as different feeding preferences associated with competitive advantages in grazing a specific phytoplankton assemblage could be attributed to the changes in zooplanktonic community, although these data were unavailable. Differences in filtration and assimilation rates for different algae may be associated with differences in nutrient content, cell morphology and edibility (Tavares & Matsumura-Tundisi, 1984). Unpalatability is considered an algal defense mechanism and can be expressed as unmanageability, toxicity and undigestibility (Porter, 1977).

Patalas (1972) and Gannon & Stemberger (1978), studying different ecological aspects of planktonic microcrustaceans in the Great Lakes in the United States, observed that Cyclopoida copepods were relatively more abundant in eutrophic waters than Calanoida copepods. Sendacz & Kubo (1982) associated the absence of Calanoida copepods to eutrophic conditions in reservoirs of São Paulo state. The dominance of Cyclopoida over Calanoida in most of the analysed samples in this study can be associated to the high level of eutrophication of these water systems. In June, Copepoda Cyclopoida dominated the zooplankton communities in both reservoirs, occurring in high densities (› 60%), with nauplii representing › 45% of the total zooplankton. The rainy period is a good time for the reproduction of those organisms, a period characterized by rain and strong winds. Disturbances caused by these forcing functions may induce changes on the metabolism of the reservoirs, promoting great food availability to zooplankton through external and internal loads from inflows and sediments resuspension.

The PCA, considering data from Cyclopoida and Calanoida and environmental factors, showed the influence of the mixing conditions of water column in June, inducing the dominance of Cyclopoida. The strong winds, typical of this period, caused the oxygenation of the whole reservoir, even below the euphotic zone. The turbulent mixing mechanism may induce the sediment resuspension in lakes and reservoirs, altering, indirectly, the underwater climate and optical quality to primary producers. Another aspect to be considered is the influence of internal load of suspended material on the quantity and quality of food for zooplankton community (Bozelli, 1992; Rodríguez & Matsumura-Tundisi, 2000). The probable resuspension of sediments in June may have favored not only the increase of turbidity values towards bottom, but also the greater availability of food. We should consider that Calanoida and Cyclopoida have different feeding preferences. Calanoida are filter-feeding and Cyclopoida capture alimentary particles. Esteves and Sendacz (1988) suggested that cyclopoids can ingest portions of filamentous and colonial algae, which may be inadequate as a food resource for the calanoids. Most Calanoida are herbivorous, feeding on algae, whereas Cyclopoida tend to be more omnivorous, feeding additionally and even preferentially on other planktonic and also benthic microinvertebrates (Dussart & Defaye, 1995). According to Fernando et al. (1990), Thermocyclops species are generally considered herbivorous or sometimes carnivorous, while Mesocyclops species are considered carnivorous or detritivorous.

The Thermocyclops sp. and Mesocyclops sp. were pointed out as a typical association in tropical waters (Hutchinson, 1967). Arcifa (1984) and Sampaio et al. (2002) found this association in most of the reservoirs in São Paulo state, and noticed that M. longisetus was not usually abundant.

T. minutus and T. decipiens are usually found occurring together in several reservoirs in Brazil (Matsumura-Tundisi et al., 1981; Reid & Pinto-Coelho, 1994; Tundisi & Matsumura-Tundisi, 1994; Silva, 1998; Henry & Nogueira, 1999; Güntzel, 2000), although seasonal changes of dominance have been observed for both species (Rocha et al., 1995; 1999; Sampaio et al., 2002). Rietzler (1995), studying the population dynamics and the life cycle of both species, found that T. decipiens has competitive advantages over T. minutus. The latter species is usually found to be dominant in oligotrophic waters (Matsumura-Tundisi & Tundisi, 1976; Sendacz et al., 1985; Güntzel, 2000). In the present study, T. minutus occurred at high densities in the rainy period, when changes in eutrophic conditions were observed. On the other hand, T. decipiens was the most abundant species of Cyclopoida group in most of the samples. This fact can be related to trophic status of the reservoirs, classified as hypereutrophic and eutrophic, in dry and rainy periods, respectively. According to Reid (1988), T. decipiens tends to be a numerically dominant species among planktonic crustaceans in the reservoirs of Brazil, being considered an indicator species of disturbed and nutrient-enriched environments (Sampaio et al., 2002). Freire & Pinto-Coelho (1986) also observed a correlation between T. decipiens and the eutrophic state of Vargem das Flores reservoir in Minas Gerais state, which occurred in high densities in regions next to the domestic sewage disposal. The same was observed by Newmann-Leitão et al. (1989) in Apipucos reservoir, and by Newmann-Leitão & Nogueira (1987) in fishery ponds, in the northeast of Brazil. Rietzler & Espíndola (1998) analysed the gut content of T. decipiens and verified ingestion of a high percentage of organic detritus besides consumption of colonies of Cyanophyceae (mainly Microcystis). This advantage permits to this species to dominate at eutrophic conditions.

The increase of Cladocera densities has already been recognized as an indicator of eutrophication in lakes (Gannon & Stemberger, 1978; Magadza, 1980). However, some species may present different responses associated to the trophic gradient. Sendacz (1984) found high densities of Diaphanosoma sp in the Billings reservoir (São Paulo, Brazil), which did not occur with Daphnia gessneri, attributing this fact to the great adaptation to live in eutrophic environments. The Diaphanosoma genus was well represented in several other eutrophic reservoirs in São Paulo state (Zago, 1976; Sendacz et al., 1985). The highest density of D. spinulosum at the Pacajus reservoir can be associated to hypereutrophic conditions in the dry period. Freire & Pinto-Coelho (1986) reported an association between Ceriodaphnia sp. and the trophic conditions of a reservoir in Minas Gerais state, and found high densities of this genus living in eutrophic waters. Rossa et al. (2001) found the highest densities of C. cornuta on the littoral region of two lakes in the central-west of Brazil that were directly related to water transparency and electrical conductivity. In this study, a peak of C. cornuta (C. cornuta cornuta + C. cornuta rigaudi) occurred in Gavião reservoir, at the dry period, time during which the waters showed the greatest transparency (1.3 m) and high values of electrical conductivity (1.16 mS/cm).

Rotifers were more abundant in the Pacajus reservoir, when compared to the Gavião one, being the dominant group in the dry period. In this period, the lake reached the highest trophy index. Low oxygen dissolved concentrations and high values of pH and electrical conductivity accompanied the peak for Rotifera and the drought conditions of the reservoir. According to Rodríguez & Matsumura-Tundisi (2000), rotifers are considered opportunistic organisms found in high density in most reservoirs. Several species of Rotifera present a large capacity to adjust to environmental changes caused by climate conditions, by water physical and chemical changes, and even by biological interactions. Crispim & Watanabe (2000) found resting eggs of rotifers in dry sediments of Soledad dam, located in a semiarid region in Paraiba State. The researchers stressed the formation of diapause stages as one of the strategies of this zooplanktonic group to survive under adverse conditions. According to Ruttner-Kolisko (1974) and Shiel (1979), tropical lakes are characterized by the predominance of Brachionus, a genus very adapted to the eutrophic waters (Sládecek, 1983). In Brazil, many authors already pointed out the predominance of Brachionus in eutrophic conditions (Sendacz et al., 1985; Freire & Pinto-Coelho, 1986; Paranaguá & Newmann-Leitão, 1980; Paranaguá & Newmann-Leitão, 1982). Newmann-Leitão et al. (1989) found B. calyciflorus and Brachionus falcatus as the most representative species in an eutrophic reservoir in Pernambuco state. Infante (1982) also mentioned these two species as eutrophic indicators in a lake in Venezuela. Some species of rotifers registered in the present work need special attention in order to detect potential bioindicators, such as B. calyciflorus and K. tropica, since that B. calyciflorus is tolerant to high levels of organic pollution, giving rise to high density populations in wastewater treatment plants, such as stabilization ponds (Sladecek, 1983; Bohrer, 1995) and K. tropica is associated with high trophic state (Duggan et al., 2001)

In the Pacajus reservoir, the greater abundance of rotifers was associated with the highest chlorophyll a concentrations in December. Aoyagui et al. (2003) found great density of rotifers associated to high primary productivity during the dry period. The importance of quality and quantity of food availability for Rotifera has been discussed in several ecological studies that focus on plankton (Bonecker & Lansac-Tôha, 1996; Garcia et al., 1998). These studies pointed out a correlation among the abundance of Rotifera and the variation of chlorophyll a in the water bodies. The large numbers of rotifers normally found during the low water period suggest that the pulses caused by water level fluctuations may have influence on its density (Hardy, 1980; Lansac-Tôha et al., 1993).

Although the PCA had highlighted a possible relation between the nutritional status of the reservoirs and the rotifers dominance during the dry period, especially at the Pacajus reservoir, further studies are necessary to clarify the role of Rotifera with environmental factors in a seasonal scale.

Reservoirs operational routines affect the hydrodynamic aspects of the reservoirs, as well as the possible influence on density and composition of zooplanktonic community. According to Porter (1977), grazing preferences throughout the season changes, as the species composition of the phytoplankton does. Therefore, we have no studies with focus on ecological interactions between phyto- and zooplankton in these reservoirs. Unpublished data from Company of Water Management of the Ceará state – COGERH, indicated the dominance of the Cyanobacteria group at Gavião reservoir in July 2002, with a predominance of Cylindrospermopsis raciborskii and Planktothrix agardii (9,100 cel./mL and 252,000 cel./mL, respectively). Data from Pacajus reservoir were not available. Both species are recorded like potentially toxic, able to produce hepato- and neurotoxins, causing damage to humans, other mammals and aquatic biota (AWWARF, 1995; Charmichael, 1994; Charmichael, 1997; Chorus & Bartram, 1999). Although the evidence of the potential effects of cyanotoxins on zooplankton from numerous studies in laboratory is complex and inconsistent, it appears that cyanobacteria may exhibit a deleterious effect on zooplankton (Chorus & Bartram, 1999). However, the effect may be highly variable between genera and species. Several studies have suggested that clone and species differences between zooplankton susceptibilities to toxic cyanobacteria may lead to selection pressures in favor of resistant strains or species in water bodies where toxic cyanobacteria occur frequently (DeMott et al., 1991; Laurén-Määtta et al., 1997).

Although the present study has contributed to increase the knowledge of the zooplankton species occurring in water bodies in Ceará state, ecological studies on zooplankton communities are still lacking for the most of the water sources at northeast region of Brazil. Such additional information is necessary to obtain a better understanding of the responses of the zooplankton community to man-induced modifications of the water quality and its consequences to the aquatic biotic, mainly in these peculiar systems, located in a typically semiarid region.

Conclusion

Brazilian semiarid is characterized by several droughts, which cause extreme changes on water resources. Water eutrophication becomes pronounced in the dry season, altering hydrological and biological processes. The results showed that severe water conditions caused important changes in the zooplankton community. Zooplankton populations presented a strong variation in diversity, density and species composition between periods, mainly in Gavião reservoir. T. decipiens, D. spinulosum, C. cornuta, B. calyciflorus, and K. tropica showed high tolerance to seasonal variations of water quality, being found high densities associated to hypereutrophic conditions.

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