Zooplankton assemblages in eutrophic reservoirs of the Brazilian semi-arid

Eskinazi-Sant'Anna, EM.[a,b]*, *Menezes, R.*[c], *Costa, IS.*[d],
Araújo, M.[d], *Panosso, R.*[d] *and Attayde, JL.*[c]

[a]Departamento de Oceanografia e Limnologia, Centro de Biociências,
Universidade Federal do Rio Grande do Norte – UFRN,
Via Costeira, s/n, Praia de Mãe Luiza, CEP 59014-100, Natal, RN, Brazil
[b]Departamento de Biodiversidade, Evolução e Meio Ambiente, Universidade Federal de Ouro Preto – UFOP,
Campus Morro do Cruzeiro, CEP 34500-000, Ouro Preto, MG, Brazil
[c]Departamento de Botânica, Ecologia e Zoologia, Centro de Biociências,
Universidade Federal do Rio Grande do Norte – UFRN, Campus Universitário, Lagoa Nova, Natal, RN, Brazil
[d]Departamento de Microbiologia e Parasitologia, Centro de Biociências,
Universidade Federal do Rio Grande do Norte – UFRN, Campus Universitário, Lagoa Nova, Natal, RN, Brazil
*e-mail: eskinazi@iceb.ufop.br

Received September 23, 2011 – Accepted April 10, 2012 – Distributed February 28, 2013
(With 6 figures)

Abstract

Species composition, density, and temporal dynamics of zooplankton were studied in six reservoirs in a semi-arid region in tropical northeastern Brazil (Rio Grande do Norte state). All the reservoirs are highly eutrophic, with high contents of total nitrogen (minimum of 1200 $\mu g.L^{-1}$) and total phosphorus (minimum of 10 $\mu g.L^{-1}$), and extremely high algal biomass was registered (surpassing 20 µg Chl *a*.L^{-1}). All the reservoirs showed an enduring condition of high turbidity and phytoplankton assemblages dominated by cyanobacteria. Zooplankton also showed quantitative patterns suggestive of eutrophic conditions, expressed by high densities, mainly in Passagem das Traíras and Sabugi reservoirs. A spatial differentiation in the composition of the zooplankton community was registered. Rotifers (especially *Keratella tropica*, *Brachionus havanensis*, and *Keratella americana*) were the dominant forms in the zooplankton community of Itans, Passagem das Traíras, and Sabugi reservoirs, while calanoid copepods (mainly *Notodiaptomus cearensis*) dominated in the Armando Ribeiro, Gargalheiras, and Parelhas systems. The existence of novel relationships in zooplankton community composition in eutrophic reservoirs in this tropical semi-arid region must be considered in designating zooplankton indicators of eutrophic conditions.

Keywords: reservoirs, semi-arid, zooplankton, eutrophication.

Assembléias zooplanctônicas em reservatórios eutróficos do semiárido brasileiro

Resumo

A composição de espécies, a densidade e a dinâmica temporal do zooplâncton foram estudadas em seis reservatórios de uma região semiárida no nordeste do Brasil (Estado do Rio Grande do Norte). Todos os reservatórios estão altamente eutróficos, com altas concentrações de nitrogênio total (mínimo de 1.200 $\mu g.L^{-1}$) e fósforo total (mínimo de 10 $\mu g.L^{-1}$), e biomassa algal extremamente alta (muitas vezes, superando 20 $\mu g.L^{-1}$ de Chl *a*). Todos os reservatórios apresentaram alta turbidez e assembleias fitoplanctônicas dominadas por cianobactérias. O zooplâncton também apresentou padrões quantitativos sugestivos de condições eutróficas, expressas por altas densidades, principalmente nos Reservatórios Passagem das Traíras e Sabugi. Foi registrada uma diferenciação espacial na composição da comunidade zooplanctônica. Rotíferos (especialmente *Keratella tropica*, *Brachionus havanensis* e *Keratella americana*) foram as formas dominantes na comunidade zooplanctônica dos Reservatórios Itans, Passagem das Traíras e Sabugi, enquanto copépodos Calanoida (principalmente *Notodiaptomus cearensis*) dominaram nos Reservatórios Armando Ribeiro Gonçalves, Gargalheiras e Parelhas. A existência de novas relações na composição da comunidade zooplanctônica em reservatórios eutróficos dessa região semiárida tropical deve ser considerada no estabelecimento de indicadores zooplanctônicos de condições eutróficas.

Palavras-chave: reservatórios, semiárido, zooplâncton, eutrofização.

1. Introduction

Although considered of extreme importance to regional socio-economic development because of their associated multiple uses, many reservoirs of the semi-arid region in northeastern Brazil are eutrophic or hypereutrophic (Bouvy et al., 1999, 2000;; Lazzaro et al., 2003). Cultural eutrophication is one of the most common and complex disturbances undergone by reservoirs worldwide (Carpenter et al., 1998), and once established, it results in a series of changes in the aquatic environment and consequently in their communities.

Drastic changes in the structure of species composition and aquatic food chains occur as eutrophication progresses (Pinto-Coelho, 1998; Rückertand and Giani, 2008). One of the more drastic effects associated with eutrophication is algal blooms dominated by cyanobacteria. During bloom events, the cyanobacteria can form large colonies or aggregates, which are generally unpalatable to the majority of planktonic herbivores because of the direct physical interference with their filtration apparatus (Webster & Peters, 1978; De Bernardi and Giussani, 1990; De Mott et al., 2001). Because of their chemical composition, the cyanobacteria are also considered to be nutritionally deficient as a food for zooplankton (Brett and Müller-Navarra, 1997). In this way, powerful mechanisms including bottom-up effects can profoundly affect the structure and diversity of the zooplankton populations in eutrophic systems, in addition to the changes in water quality.

The zooplankton community is a strategic compartment in the energy flow in aquatic ecosystems and in the maintenance and orientation of the aquatic trophic webs. Its positioning in the food chain, with a high degree of connection with the primary producers, makes it extremely susceptible to structural changes occurring at this trophic level. As a function of their short life cycles, changes in the phytoplankton community are rapidly reflected by the zooplankton, which then comes to indicate the intensity and conditions established during and after the consolidation of these disturbances. All these characteristics make the zooplankton communities key elements for the understanding of the changes occurring in aquatic ecosystems due to eutrophication, particularly in understanding the potential for propagation of these disturbances along the food chains.

In spite of the unquestionable importance of zooplankton for the understanding of ecosystem changes caused by eutrophication, its central role in the aquatic food chain, and its potential as a bioindicator community for environmental quality (Burns and Galbraith, 2007; Pinel-Allou et al., 1995; Dodson et al., 2007), studies on the zooplankton of the reservoirs of the Brazilian semi-arid region are in a very early stage. One of the first studies relating zooplankton and environmental conditions of the reservoirs were conducted by Sousa et al. (2008) and Vieira et al. (2009), who described how variations in water quality can influence the zooplankton composition. In the present study, we aimed to identify the zooplankton structure and composition in eutrophic reservoirs of the state of Rio Grande do Norte in northeast Brazil, and to identify the principal factors that influence the taxonomic and quantitative structure of the zooplankton community in these enriched aquatic systems.

2. Material and Methods

2.1. Study area

This study was conducted in six reservoirs (Armando Ribeiro Gonçalves, Boqueirão de Parelhas, Gargalheiras, Itans, Passagem das Traíras, and Sabugi), located in the Piranhas-Assu drainage basin, in the semiarid region of Seridó (04° to 08° S and 36° to 39° W). Figure 1. This hydrographic basin lies entirely within a semiarid region, with a mean annual rainfall of 500 mm and wide spatial and temporal irregularity in its rainy season. In general, precipitation above 100 mm occurs only from February through May, and the remaining months are marked by an almost complete lack of precipitation. The soil in areas surrounding these reservoirs is shallow and highly susceptible to erosion during the rainy season.

Armando Ribeiro Gonçalves (ARG) reservoir is a large (19,200 ha) and relatively deep (40 m maximum depth) eutrophic reservoir, with a stored water volume above 2 billion m^3 and surrounded by agricultural and urban areas. This system is an important water supply and subject to intense recreational and fishing activity, in addition to impacts from agriculture and urban runoffs. Recurrent algal blooms are observed in the reservoir, including some toxic species, predominantly *Microcystis aeruginosa* and *Planktothrix agardii*.

The medium-sized reservoirs studied were Parelhas (1,327 ha; 26 m maximum depth), Itans (1,340 ha; 23 m maximum depth), Passagem das Traíras (1,005 ha; 25 m depth), and Sabugi (1,260 ha; maximum depth 20 m), all shallow systems. These reservoirs support recreational and fishing activities and are impacted by domestic and agricultural activities. As a consequence, they are facing intense eutrophication, mainly due to diffuse nutrient loading from soil erosion and agricultural and urban runoff. In Sabugi and Passagem das Traíras, hypereutrophic conditions have been reported, and algal biomass (Chl *a*) can surpass 400 $\mu g.L^{-1}$(Costa et al., 2006). Gargalheiras is the smallest reservoir (780 ha), and is also shallow (25 m maximum depth) and eutrophic. The phytoplankton biomass is usually high (>100 $mm^3.L^{-1}$), with the occurrence of sporadic toxic algal blooms of *Microcystis* sp.

2.2. Field sampling and laboratory analysis

Sampling was carried out every three months from September 2002 through March 2004, including the dry (December), rainy (March), and transitional seasons (September). Sampling was conducted at two sites: one located in the riverine zone, and the other in the lacustrine zone near the dam. Since no significant differences between the values from riverine and dam areas (ANOVA, N = 50, $p > 0.05$) were observed, we used median values from both sampling points to describe the physical, chemical, and biological parameters.

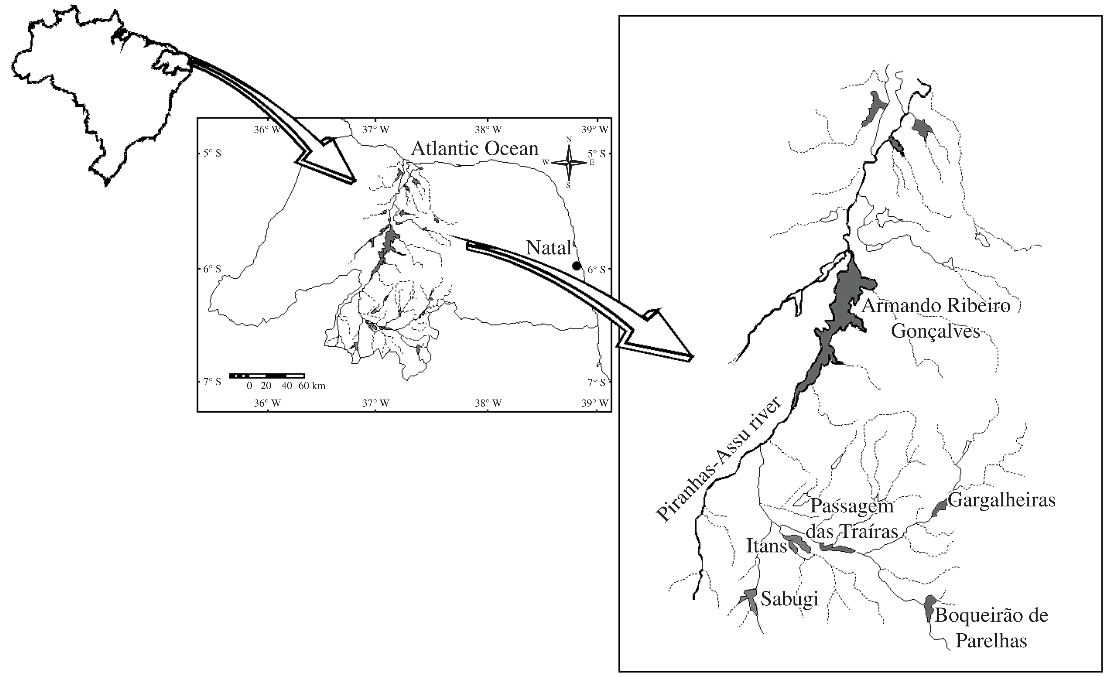

Figure 1. Location of the study area, highlighting the reservoirs Armando Ribeiro Gonçalves, Boqueirão de Parelhas, Gargalheiras, Itans and Passagem das Traíras, state of Rio Grande do Norte, Brazil.

On each sampling date, water transparency was measured using a Secchi disk. From September 2002 to September 2003, limnological features were described from individual water samples collected from the epilimnion and hypolimnion with a Van Dorn bottle (5 L). In December 2003 and March 2004, profiles of temperature, dissolved oxygen, pH, and conductivity were taken at 0.5-m intervals with a multiprobe (Horiba, U23). Nutrients (total phosphorus and total nitrogen) and alkalinity were determined according to APHA (1995). Water samples for Chl *a* were collected in the epi- and hypolimnion, and analyses were done fluorometrically after ethanol extraction (Nusch and Palme, 1975). Hydraulic features of the reservoirs (water retention time) were obtained from the State Secretary of Water Resources (SERHID).

Surface (0.5 m) water samples (250 mL) for phytoplankton counts were taken with a Van Dorn bottle (1 L) and preserved in Lugol solution with acetic acid. Phytoplankton was counted using the inverted-microscope method. In each sample, mean cell dimensions of the phytoplankton were calculated for all species on the basis of measurements of 20-50 individuals, and the biovolume calculated through geometric equations (Rott, 1981). Bacterioplankton samples were obtained from integrated water samples (from the surface and hypolimnion), preserved in 2% formaldehyde (final concentration), and stored in the dark at 4 °C. Bacteria were enumerated at 1000× magnification from DAPI-stained samples (Porter and Feig, 1980), using an Olympus epifluorescence microscope. Bacterioplankton densities were considered only to perform CCA analysis.

Zooplankton samples (in triplicate) were collected with a 68 µm-mesh plankton net towed vertically and equipped with a flowmeter (Hydrobios). All samples were preserved in 4% buffered formaldehyde. Rotifers and copepod nauplii were analysed from subsamples of 1 mL taken with an automatic pipette from a well-mixed whole sample (250 mL) and counted under a microscope in a Sedgwick-Rafter chamber until the coefficients of variation of the most abundant species were lower than 20%. Mesozooplankton abundance (Copepoda, Cladocera, and Ostracoda) was determined from subsamples (5 mL) and analysed under a stereomicroscope. Zooplankton abundance was determined from total counts and expressed as mean abundances for each sampling date.

2.3. Data analysis

For multivariate analyses, mean zooplankton densities and the mean values of environmental variables for each month and reservoir were used to construct the data matrices. Prior to analysis, zooplankton abundances were $\log_{10}(x + 1)$ transformed and environmental variables were standardised. Abundance data and species richness were used to compute the Shannon-Wiener diversity index. The hierarchical cluster and multidimensional scaling (MDS) analyses of similarity between reservoirs were computed on the basis of the Bray-Curtis similarity index using the PRIMER statistical package version 5.0 (Clarke and Gorley, 2001).

A redundancy analysis (RDA) was performed in order to describe the relationships between the abundance of the zooplankton taxa and the observed environmental variables. Species abundance and environmental data often show a highly skewed distribution, and we prevented a few high values from unduly influencing the ordination by transforming all data with the formula $y = \ln (x + 1)$. The redundancy analysis was performed with the software CANOCO version 4. To evaluate the significance of the RDA axes and of the environmental variables which defined these axes, Monte Carlo tests were performed with 999 unrestricted permutations, using the eigenvalues of the axes as test statistics (Ter Braak and Prentice, 1988).

3. Results

3.1. Environmental factors

Water volume of reservoirs, water temperature, pH, dissolved oxygen, alkalinity, total nitrogen, and TN:TP ratios showed conspicuous seasonal differences ($P < 0.05$) in the reservoirs (Table 1). The euphotic depth of the reservoirs was reduced during the entire sampling period, resulting in the nonexistence of seasonal variation in water transparency ($P > 0.05$). Even the deepest reservoir (Armando Ribeiro Gonçalves) showed a low Secchi depth (maximum value of 1.2 m). The depth of the euphotic zone was smaller in Parelhas and Armando Ribeiro Gonçalves reservoirs (minimum 0.5 m). Sabugi and Gargalheiras reservoirs were less affected by temporal fluctuations in transparency (1.0-1.4 m). Table 1.

Water temperature was always high but with a clear seasonal fluctuation: higher during the dry season (October through May) and lower during the rainy season (July through September) ($P < 0.05$). Water temperature exceeded 32 °C in Passagem das Traíras, Itans, and Sabugi reservoirs, and in Armando Ribeiro Gonçalves reached 34 °C in March 2004, during the rainy season. The highest seasonal variation of water temperature was observed in the shallow Itans Reservoir ($P < 0.001$). The pH values also showed a marked seasonal fluctuation, with more alkaline waters during the dry season in all six reservoirs (pH from 7.6 to 9.4). Dissolved oxygen levels did not vary much within reservoirs, but showed vertical variation in all the reservoirs, with the lowest values near the hypolimnion (<4 mg.L^{-1}), although no anoxic conditions were observed. Conductivity was always high, with mean values exceeding 300 µS.cm^{-1}. Armando Ribeiro Gonçalves, Gargalheiras, and Itans reservoirs showed much higher concentrations of nutrients than the other reservoirs. This was especially evident with the high concentrations of total nitrogen (>10,000 µg L^{-1}) during the rainy months. Total phosphorus was also elevated, especially during the rainy season in Gargalheiras, Itans, and Parelhas (> 200 µg.L^{-1}). Water retention time was considerable high for almost all reservoirs, especially at Parelhas (6.22 years), Armando Ribeiro Gonçalves (2.82 years) and Itans reservoirs (2.46 years). Table 1.

3.2. Phytoplankton biomass (Chl a) and biovolume (mm^3.L^{-1})

The temporal distribution of the phytoplankton biomass showed a bimodal pattern in all the reservoirs, with quantitative peaks at the end of the rainy season, in September. Figure 2. The highest phytoplankton biomass was recorded only in Sabugi reservoir during the dry season (December 2002 and March 2004). In spite of these temporal fluctuations, the reservoirs were eutrophic

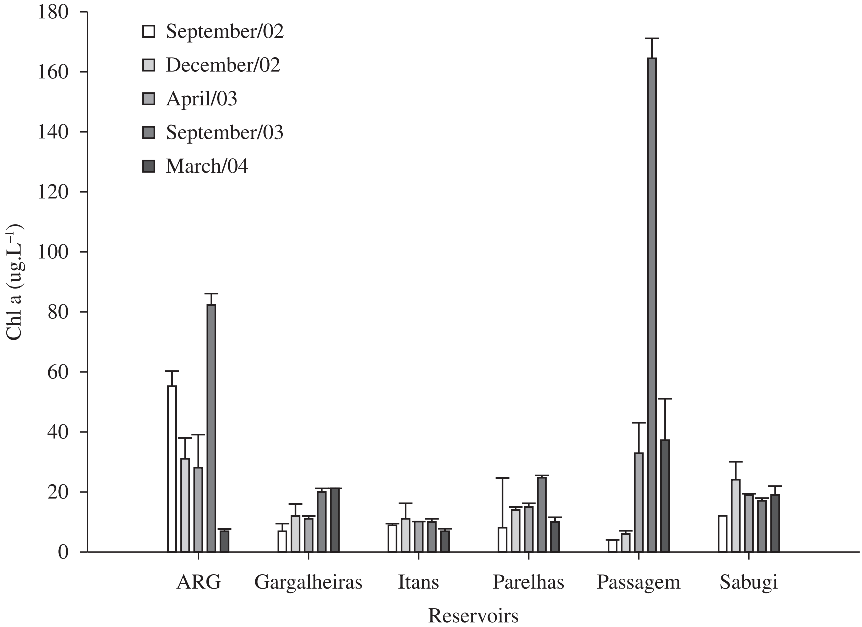

Figure 2. Phytoplankton biomass (Chl *a* µg.L^{-1}) (mean ± SD) in the studied reservoirs, semi-arid region of Rio Grande do Norte state.

Table 1. Summary statistics [mean ± standard deviation (max-min)] for limnological features of studied reservoirs.

Period	Reservoirs	± (m)	Temperature* (°C)	pH*	Oxigen* (mg L^{-1})	Cond (µS cm^{-1})	Alcal* (mg CaCO3 L-1)	Total P (µg L-1)	Total N* (µg L-1)	Water Retention (year)
	ARG	0.8 ± 0.3 (1.2-0.5)	27.3 ± 1.1 (28.0-26.5)	8.6 ± 0.4 (9.4-8.2)	6.8 ± 0.5 (8.6-7.5)	305 ± 17 (328-280)	103.3 ± 6.8 (113.3-93.5)	0.1 ± 0.1 (0.2-0.04)	3.7 ± 0.8 (4.8-2.8)	2.82
D	GAR	0.9 ± 0.4 (1.4-0.5)	28.2 ± 0.0 (28.2)	8.6 ± 0.5 (9.2-8.1)	6.5 ± 0.9 (8.2-8.0)	870 ± 218 (1085-313)	191.3 ± 45.2 (252.3-142.1)	0.1 ± 0.1 (0.3-0.06)	3.6 ± 2.2 (6.7-1.5)	1.01
R	ITA	1.0 ± 0.5 (1.5-0.5)	26.1 ± 0.3 (26.5-25.7)	8.4 ± 0.5 (8.9-7.6)	7.5 ± 1.0 (7.3-6.8)	533 ± 86 (649-432)	150.2 ± 35.7 (201.4-109.8)	0.8 ± 0.9 (2.2-0.1)	3.2 ± 1.8 (5.2-1.5)	2.46
Y	PAR	0.8 ± 0.1 (0.9-0.6)	26.4 ± 1.7 (28.0-24.5)	8.9 ± 0.4 (9.3-8.4)	7.2 ± 1.0 (7.3-7.0)	1257 ± 227 (1560-960)	241.6 ± 53.5 (315.7-187.1)	0.1 ± 0.07 (0.2-0.03)	2.9 ± 1.6 (4.4-1.2)	6.22
	PAT	1.2 ± 0.8 (1.9-0.5)	26.2 ± 1.6 (27.8-24.8)	8.8 ± 0.7 (9.6-8.0)	7.0 ± 0.8 (7.2-6.5)	590 ± 92 (717-476)	135.6 ± 42.4 (205.9-97.3)	0.1 ± 0.06 (0.17-0.02)	2.8 ± 1.1 (4.5-1.7)	0.26
	SAB	1.1 ± 0.1 (1.3-1.0)	26.1 ± 0.9 (27.5-25.2)	8.3 ± 0.7 (8.8-7.6)	7.5 ± 0.4 (7.4-6.9)	336 ± 66 (404-248)	155.1 ± 44.8 (202.5-106.8)	0.08 ± 0.04 (0.12-0.03)	3.6 ± 1.6 (5.0-1.8)	0.65
T	ARG	0.9 ± 0.3 (1.4-0.5)	29.3 ± 2.0 (29.5.0-24.0)	8.6 ± 0.3 (9.0-8.1)	6.5 ± 0.5 (8.4-7.3)	292 ± 91 (313-287)	91.7 ± 5.4 (104.5-91.2)	0.2 ± 0.1 (0.2-0.03)	3.5 ± 0.6 (4.0-2.5)	
R	GAR	0.7 ± 0.2 (1.0-0.5)	27.1 ± 0.4 (28.5-25.2)	7.6 ± 0.4 (9.0-7.6)	6.5 ± 0.2 (6.5-7.1)	742 ± 187 (865-290)	186.2 ± 28.2 (197.4-99.7)	0.1 ± 0.1 (0.2-0.04)	2.7 ± 1.2 (5.8-1.2)	
A	ITA	1.0 ± 0.5 (1.4-0.6)	25.2 ± 0.5 (26.0-25.4)	7.8 ± 0.3 (8.1-7.7)	7.2 ± 0.9 (7.1-6.9)	621 ± 102 (701-235)	138.6 ± 44.2 (198.6-122.5)	0.1 ± 0.2 (0.2-0.1)	3.6 ± 1.2 (4.5-1.2)	
N	PAR	1.0 ± 0.2 (1.0-0.5)	27.6 ± 1.3 (28.0-25.3)	7.2 ± 0.5 (8.7-7.2)	6.8 ± 1.2 (7.2-6.1)	987 ± 245 (1210-389)	189.7 ± 44.5 (277.6-124.5)	0.1 ± 0.06 (0.1-0.02)	2.7 ± 0.9 (3.5-1.0)	
S	PAT	1.3 ± 0.5 (1.7-0.5)	26.1 ± 1.4 (26.7-24.6)	8.4 ± 0.6 (9.1-8.6)	7.2 ± 1.0 (7.2-6.8)	620 ± 100 (707-329)	156.8 ± 35.6 (253.1-108.9)	0.09 ± 0.02 (0.2-0.02)	2.4 ± 1.2 (3.5-1.3)	
	SAB	1.2 ± 0.5 (1.2-0.5)	26.3 ± 0.6 (27.0-24.4)	7.8 ± 0.5 (8.3-7.5)	7.4 ± 0.1 (7.4-7.0)	357 ± 45 (398-112)	133.2 ± 57.7 (165.4-99.8)	0.06 ± 0.02 (0.9-0.03)	3.5 ± 1.5 (4.8-1.2)	

* indicates seasonal differences statistically significant ($P < 0.05$). Abbreviations of the reservoirs: ARG = Armando Ribeiro Gonçalves; GAR = Gargalheiras; ITA = Itans; PAR = Parelhas; PAT = Passagem das Traías; SAB = Sabugi.

Table 1. Continued...

Period	Reservoirs	± (m)	Temperature* (°C)	pH*	Oxigen* (mg L^{-1})	Cond (µS cm^{-1})	Alcal* (mg CaCO3 L-1)	Total P (µg L-1)	Total N* (µg L-1)	Water Retention (year)
R	ARG	0.8 ± 0.1 (1.0-0.7)	30.8 ± 1.9 (34.4-28.5)	7.8 ± 0.5 (8.8-7.2)	8.2 ± 0.5 (8.6-7.4)	301 ± 106 (439-193)	62.8 ± 14.9 (78.5-46.5)	0.09 ± 0.05 (0.17-0.04)	3.7 ± 0.8 (4.8-2.9)	
A	GAR	1.2 ± 0.2 (1.4-1.0)	24.9 ± 5.0 (28.7-18.0)	7.9 ± 0.2 (8.2-7.6)	8.0 ± 0.4 (8.2-7.5)	750 ± 307 (1059-423)	168 ± 25.6 (195.1-142.9)	0.3 ± 0.2 (0.6-0.05)	12.4 ± 2.1 (15.8-9.9)	
I	ITA	0.5 ± 0.3 (0.7-0.2)	29.5 ± 1.3 (31.7-28.0)	7.9 ± 0.1 (8.1-7.8)	7.3 ± 0.2 (7.2-6.9)	388 ± 164 (581-225)	94.4 ± 19.1 (107.3-75.9)	0.2 ± 0.1 (0.3-0.07)	11.3 ± 2.0 (14.0-8.5)	
N	PAR	0.8 ± 0.2 (1.1-0.6)	28.5 ± 1.0 (30.2-27.0)	8.0 ± 0.3 (8.4-7.6)	7.9 ± 1.0 (7.4-6.3)	907 ± 464 (1389-488)	204.7 ± 41.8 (246.2-162.8)	0.2 ± 0.1 (0.09-0.27)	11.4 ± 2.0 (13.6-9.2)	
Y	PAT	0.7 ± 0.3 (0.9-0.3)	30.6 ± 1.4 (32.6-29.0)	8.0 ± 0.4 (8.8-7.6)	8.1 ± 0.4 (8.4-7.5)	497 ± 129 (640-380)	92.4 ± 27.4 (115.4-63.9)	0.08 ± 0.08 (0.26-0.01)	10.4 ± 1.9 (13.1-8.3)	
	SAB	0.9 ± 0.1 (1.0-0.8)	29.8 ± 1.5 (31.4-27.0)	7.4 ± 0.2 (7.6-7.0)	8.0 ± 0.3 (8.1-7.4)	274 ± 111 (389-135)	83.1 ± 20.6 (110.9-68.6)	0.06 ± 0.02 (0.09-0.04)	11.3 ± 1.9 (13.6-8.6)	

* indicates seasonal differences statistically significant ($P < 0.05$). Abbreviations of the reservoirs: ARG = Armando Ribeiro Gonçalves; GAR = Gargalheiras; ITA = Itans; PAR = Parelhas; PAT = Passagem das Traías; SAB = Sabugi.

during the entire sampling period, due to the high values of phytoplankton biomass (means above 20 µg Chl L^{-1}). Extreme values were recorded in Armando Ribeiro Gonçalves and Passagem das Traíras (>60 µg Chl.L^{-1}), in September 2003, indicating hypereutrophic conditions. Phytoplankton biovolume showed a conspicuous spatial variation but with no clear seasonal pattern (ANOVA, $p > 0.05$). In Armando Ribeiro Gonçalves, Gargalheiras, and Passagem das Traíras reservoirs, the cyanobacterial biovolume was noticeably high and dominant over other phytoplanktonic forms; in general, the spatial pattern of algal particles in these reservoirs was characterised by large cells (trichomes) and colonies. Chlorophyceae and diatoms showed more prominent biovolume values in Itans, Parelhas, and Sabugi reservoirs (>10 $mm^3.L^{-1}$). Figure 3.

3.3. Spatial and temporal patterns in the zooplankton community

A total of 47 zooplankton taxa were identified, of which 11 were common to all reservoirs (the rotifers Bdelloidea spp., *Brachionus dolabratus*, *B. falcatus*, *F. terminalis*, *Hexarthra* sp, *Keratella lenzi*, and *Keratella tropica*, the cladocerans *Ceriodaphnia cornuta* and *Diaphanosoma spinulosum*, and the calanoid copepods *Notodiaptomus cearensis* and *N. kieferi*). Some zooplankton taxa were only observed in Armando Ribeiro Gonçalves reservoir, including the rotifers *Rotaria neptunia* and *Sinantherina* spp. and the cladoceran *Daphnia gessneri*. Table 2.

Rotifers, mainly represented by *K. tropica*, *Brachionus havanensis*, and *Keratella americana* dominated the zooplankton community in Itans, Passagem das Traíras, and Sabugi reservoirs. *Notodiaptomus cearensis* and cladocerans were the dominant zooplankton forms in Armando Ribeiro Gonçalves, Gargalheiras, and Parelhas.

The temporal fluctuation of the zooplankton density showed a bimodal distribution, with higher values during April and September (dry season), but zooplankton density did not show a statistically significant seasonal difference in the reservoirs ($p > 0.05$). Figure 4. It was therefore difficult to establish a clear seasonal pattern in the zooplankton density. Considering seasonal hydraulic features, all the reservoirs showed stable water levels, since the water retention time was long, except in March

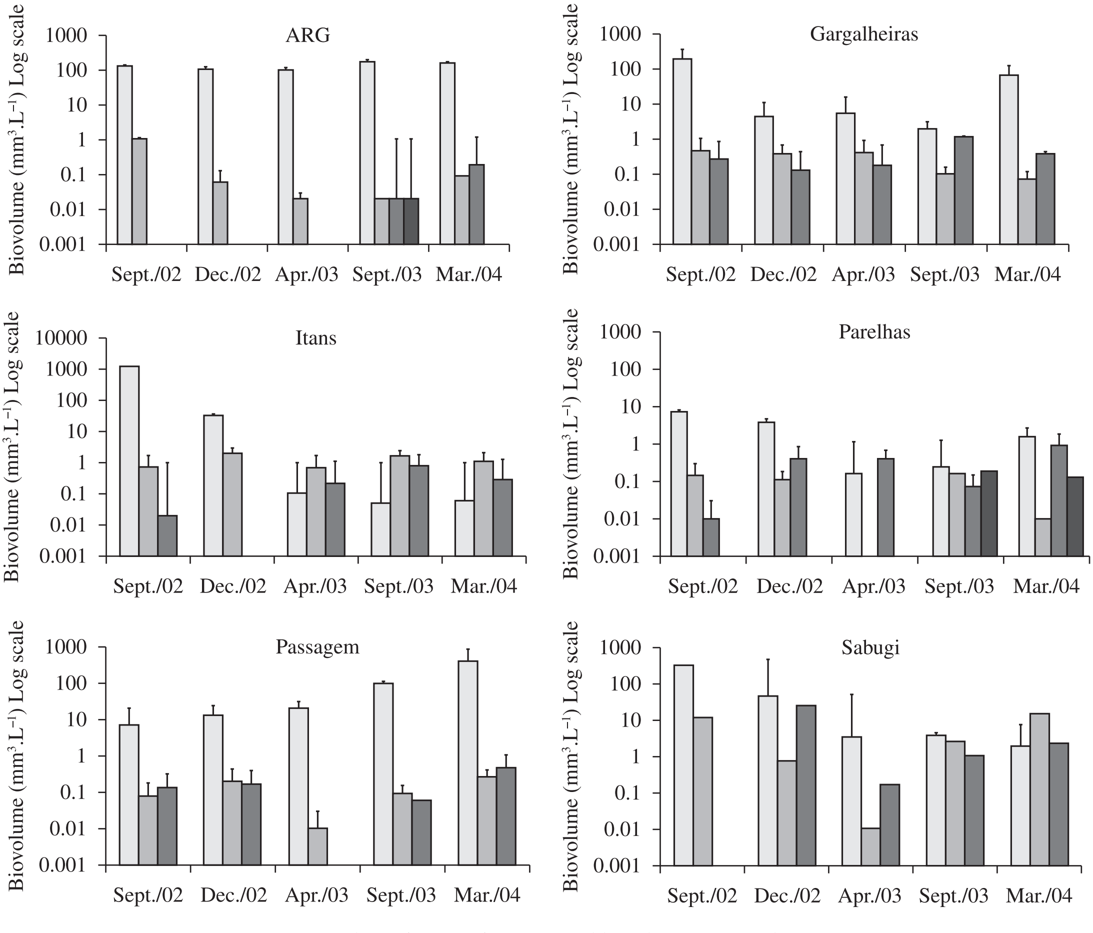

Figure 3. Phytoplankton biovolume ($mm^3.L^{-1}$ – mean ± SD) in the reservoirs of the semi-arid region of Rio Grande do Norte state.

Table 2. Zooplankton *taxa* and density patterns in the reservoirs of Rio Grande do Norte state.

	Armando Ribeiro Gonçalves					**Gargalheiras**				
	Sept./02	**Dec./02**	**Apr./03**	**Sept./03**	**Mar./04**	**Sept./02**	**Dec./02**	**Apr./03**	**Sept./03**	**Mar./04**
ROTIFERS										
Asplanchna sp.										•
Bdelloidea			•	•	•					○
Brachionus angularis Gosse, 1851										
Brachionus calyciflorus Pallas, 1766					○					
Brachionus dolabratus Harring, 1914		•								•
Brachionus falcatus Zacharias, 1898					•			•		
Brachionus havanensis Rousselet, 1911		○	○	○	●					•
Brachionus patulus O.F. Müller, 1786		•		•						
Filinia longiseta (Ehrenberg, 1834)		○	○							
Filinia opoliensis (Zacharias, 1898)					•					
Filinia cf *terminalis* (Ehrenberg, 1834)			•	○	○	○				•
Hexarthra sp.		•	•		•					•
Keratella americana Carlin, 1943	•	•			•					
Keratella cochlearis Gosse, 1851						•			•	•
Keratella lenzi Hauer, 1953										
Keratella sp.										
Keratella tropica Apstein, 1907	○	•			•	•		•		○
Lecane luna (Müller, 1776)							•			
Lecane sp.										
Lepadella spp.				•						
Platyas patulus (O.F. Müller, 1786)										
Polyarthra sp.										
Rotaria neptunia (Ehrenberg, 1830)				•	•					
Sinantherina spp.				•	•					
Tricocherca sp.										
CLADOCERANS										
Bosmina hagmanni Stingelin, 1904										
Ceriodaphnia cornuta Sars, 1906		•	•		○	•	○	○	○	○
Chidoridae										
Daphnia gessneri Herbst, 1967	•			•	•					
Diaphanosoma brevireme Sars, 1901	•		•	•		•	•	•	•	•
Diaphanosoma spinulosum Herbst, 1967	•	•	•	•	○	○	○	○	○	○
Diaphanosoma sp.						•	•	•	•	•
Moina micrura Kurz, 1874										
Moina minuta Hansen, 1899					•					
COPEPODA										
Calanoida nauplii	○	○	○	○	○	○	○	○	○	○
Cyclopoida nauplii	•	•	•	•	•	○	○	○	○	○
Copepodito Calanoida	•	•	○	•	○	○	●	○	○	○
Argyrodiaptomus spp.		•		•	•		○		○	○
Mesocyclops spp.				•	•					
Microcyclops spp.				•						
Notodiaptomus cearensis Wright, 1936	•	•	○	○	○	●	●	●	○	○
Notodiaptomus iheringi (Wright, 1935)		•		•	•	•	•	•	•	•
Notodiaptomus kieferi Brandorff, 1973	•	•		•	•	•	•	•	•	•
Notodiaptomus sp.			•		•	•	•	•	•	•
Thermocyclops decipiens Kiefer, 1929		•			•					
Thermocyclops minutus (Lowndes, 1934)		•	•	○	•		•		•	•

Table 2. Continued...

	Itans					Parelhas			
	Sept./02	**Dec./02**	**Apr./03**	**Sept./03**	**Mar./04**	**Dec./02**	**Apr./03**	**Sept./03**	**Mar./04**
ROTIFERS									
Asplanchna sp.	•								
Bdelloidea				•					○
Brachionus angularis Gosse, 1851									
Brachionus calyciflorus Pallas, 1766	•			•	•	•			
Brachionus dolabratus Harring, 1914	•	•	•	•		•			
Brachionus falcatus Zacharias, 1898	•	•	○	○	•	•			
Brachionus havanensis Rousselet, 1911				○					
Brachionus patulus O.F. Müller, 1786									
Filinia longiseta (Ehrenberg, 1834)	○	○		○	•	•			
Filinia opoliensis (Zacharias, 1898)	•			•	•	•			•
Filinia cf *terminalis* (Ehrenberg, 1834)	○	•	•	●	•	•			
Hexarthra sp.	•	○	●	○	•	•	•		○
Keratella americana Carlin, 1943		•			•				
Keratella cochlearis Gosse, 1851					○				
Keratella lenzi Hauer, 1953	•	•			•				
Keratella sp.									
Keratella tropica Apstein, 1907	○		○	○	○				•
Lecane luna (Müller, 1776)									
Lecane sp.		•	•				•		
Lepadella spp.									
Platyas patulus (O.F. Müller, 1786)									
Polyarthra sp.			○	•					•
Rotaria neptunia (Ehrenberg, 1830)									
Sinantherina spp.									
Tricocherca sp.	•								
CLADOCERANS									
Bosmina hagmanni Stingelin, 1904									
Ceriodaphnia cornuta Sars, 1906	○	○	•	•	•	○	○	○	○
Chidoridae									
Daphnia gessneri Herbst, 1967									
Diaphanosoma brevireme Sars, 1901	•	•	•						
Diaphanosoma spinulosum Herbst, 1967	○	○	•		•	○	○	•	•
Diaphanosoma sp.	○	○	•		•				
Moina micrura Kurz, 1874									
Moina minuta Hansen, 1899	○	•	○	•	○	○			○
COPEPODA									
Calanoida nauplii	○	○	●	○	○	○	○	○	○
Cyclopoida nauplii	○	○	○	○	○	○	•	○	•
Copepodito Calanoida	○	○	○	○	○	○	○	○	•
Argyrodiaptomus spp.								•	
Mesocyclops spp.									
Microcyclops spp.									
Notodiaptomus cearensis Wright, 1936	○	•	•		•	○	○	○	•
Notodiaptomus iheringi (Wright, 1935)									
Notodiaptomus kieferi Brandorff, 1973	•	•			•	•	○	•	•
Notodiaptomus sp.									
Thermocyclops decipiens Kiefer, 1929	•			•					•
Thermocyclops minutus (Lowndes, 1934)	•	•	○	•	•	•	•	•	•

Table 2. Continued...

	Passagem Traíras					Sabugi				
	Sept./02	**Dec./02**	**Apr./03**	**Sept./03**	**Mar./04**	**Sept./02**	**Dec./02**	**Apr./03**	**Sept./03**	**Mar./04**
ROTIFERS										
Asplanchna sp.	•			•				•	•	•
Bdelloidea			•						•	•
Brachionus angularis Gosse, 1851										
Brachionus calyciflorus Pallas, 1766	•	•	•	•	•		○	○		•
Brachionus dolabratus Harring, 1914	•	•	•	•	•		○	○		
Brachionus falcatus Zacharias, 1898	•	•		•	•		○	○		•
Brachionus havanensis Rousselet, 1911	•	○	●	○	○	○	○	○	●	●
Brachionus patulus O.F. Müller, 1786										
Filinia longiseta (Ehrenberg, 1834)	•	•		•	•		•	•	•	•
Filinia opoliensis (Zacharias, 1898)					•		•	•		•
Filinia cf *terminalis* (Ehrenberg, 1834)	•	•		•	•	○	○	○	○	○
Hexarthra sp.	•	•		○	○		○	•	○	•
Keratella americana Carlin, 1943	•	•			•		○	○	○	○
Keratella cochlearis Gosse, 1851					○					
Keratella lenzi Hauer, 1953					•		•			•
Keratella sp.										
Keratella tropica Apstein, 1907		○		•	○	○	○	○	●	●
Lecane luna (Müller, 1776)	•									
Lecane sp.		•	•	•			•	•		
Lepadella spp.										
Platyas patulus (O.F. Müller, 1786)	○	•		●						•
Polyarthra sp.								•		•
Rotaria neptunia (Ehrenberg, 1830)										
Sinantherina spp.										
Tricocherca sp.		•								•
CLADOCERANS										
Bosmina hagmanni Stingelin, 1904					○					•
Ceriodaphnia cornuta Sars, 1906	○	○	○	○	○	•	•	○	○	○
Chidoridae	•	•	•							
Daphnia gessneri Herbst, 1967										
Diaphanosoma brevireme Sars, 1901										
Diaphanosoma spinulosum Herbst, 1967	•	○	•	○	○	•	•	○		•
Diaphanosoma sp.										
Moina micrura Kurz, 1874								•		
Moina minuta Hansen, 1899	○	•		•	○		○	○	○	•
COPEPODA										
Calanoida nauplii	○	○	●	○	○	●	○	●	●	○
Cyclopoida nauplii	•	○	○	•	•		•	•	•	•
Copepodito Calanoida	○	○	●	●	○	○	○	○		•
Argyrodiaptomus spp.			•		•					
Mesocyclops spp.										
Microcyclops spp.										
Notodiaptomus cearensis Wright, 1936	○	○	○	○	○	•	•	○		○
Notodiaptomus iheringi (Wright, 1935)							•	•		•
Notodiaptomus kieferi Brandorff, 1973	•			•			○			
Notodiaptomus sp.										
Thermocyclops decipiens Kiefer, 1929								○		○
Thermocyclops minutus (Lowndes, 1934)		•	•	•	•	○	○	○	●	○

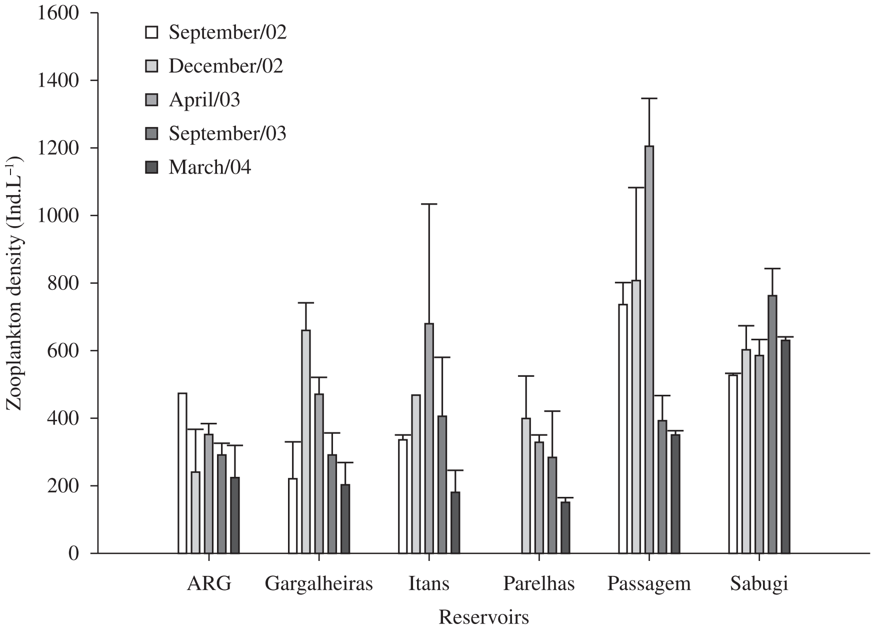

Figure 4. Zooplankton density (Ind.L^{-1} – mean ± SD) in the reservoirs of semi-arid region of Rio Grande do Norte state.

2004, when an unusual peak of rainfall occurred in the region. Zooplankton density also declined abruptly in all the reservoirs at this time.

Maximum zooplankton densities (>600 Ind.L^{-1}) were observed in Itans, Passagem das Traíras, and Sabugi reservoirs, while lowest densities were observed in ARG and Parelhas (maximum of 235 Ind.L^{-1} in March 2004). The rotifers *Brachionus falcatus*, *Hexarthra* sp., and *Keratella tropica* were dominant in absolute terms in the Passagem das Traíras, Sabugi, and Itans reservoirs, with densities above 50% of total zooplankton. Cladocera, represented principally by *Ceriodaphnia cornuta* and *Diaphanosoma spinulosum*, also showed high densities (>50% of total zooplankton) in Passagem das Traíras and Itans. Calanoid copepods showed higher densities in Armando Ribeiro Gonçalves and Parelhas reservoirs (>50%), and cyclopoids only showed high values in Sabugi reservoir (>55% of total zooplankton). Figure 5.

4. Spatial Analysis

In the two-dimensional MDS plots, a stress of 0.01 was obtained in the representation of the similarity of the reservoirs. Three groups were spatially separated. Group I was constituted by Sabugi and Passagem das Traíras reservoirs, with highest zooplankton densities (>600 Ind.L^{-1}) and zooplankton dominated by rotifers (mainly *Brachionus falcatus*). The second group included Gargalheiras, Itans and ARG, with zooplankton densities near 400 ind Ind.L^{-1} and a quantitative dominance of selective filter-feeders (copepods over rotifers). Group III isolated Parelhas Reservoir, the only system where cladocerans showed higher densities, and the total zooplankton averaged <300 Ind.L^{-1}.

The first two PCA axes explained 42.0% and 18.7% of the total variance in the species data, respectively. RDA restricts the axes to linear combinations of the environmental variables, and the first two RDA axes explained less, 32.2% and 11.6% of the total variance, respectively. The first two species-environmental correlations were 0.883 and 0.872, indicating that the observed environmental variables accounted for the main variation in the species composition (Figure 6b). Among the observed environmental variables, the biovolume of diatoms (diatom), mean depth (Zm), electrical conductivity (Cond), and water retention time (Tw) explained a significant proportion of the variance of the species data. The RDA results indicated that the first two ordination axes collectively explained 70.7 % of the variance in the species-environment correlations.

Figure 6b illustrates how sites co-vary with environmental variables, and how species co-vary with the sites and their environmental variables. For example, sites 1-5 from ARG Reservoir were characterised by higher mean depth and higher abundances of *N. cearensis*, *Diaphanosoma spinulosum*, and *Brachionus patulus*. Samples from 6-10 from Gargalheiras were associated with higher mean depth and higher abundances of *D. spinulosum*. Samples 16-19 from Parelhas Reservoir were characterised by higher values of electrical conductivity and lower abundances of the rotifers *Brachionus patulus*, *Brachionus havanensis*, and *Keratella tropica*. Samples from 20-24, representing Passagem das Traíras Reservoir, were associated with higher values of conductivity and densities of *Ceriodaphnia cornuta*. Samples 25-29, from Sabugi Reservoir, were characterised by higher values of TN:TP ratios, chlorophyll *a* concentrations, abundance of diatoms, and densities of rotifers and copepod nauplii.

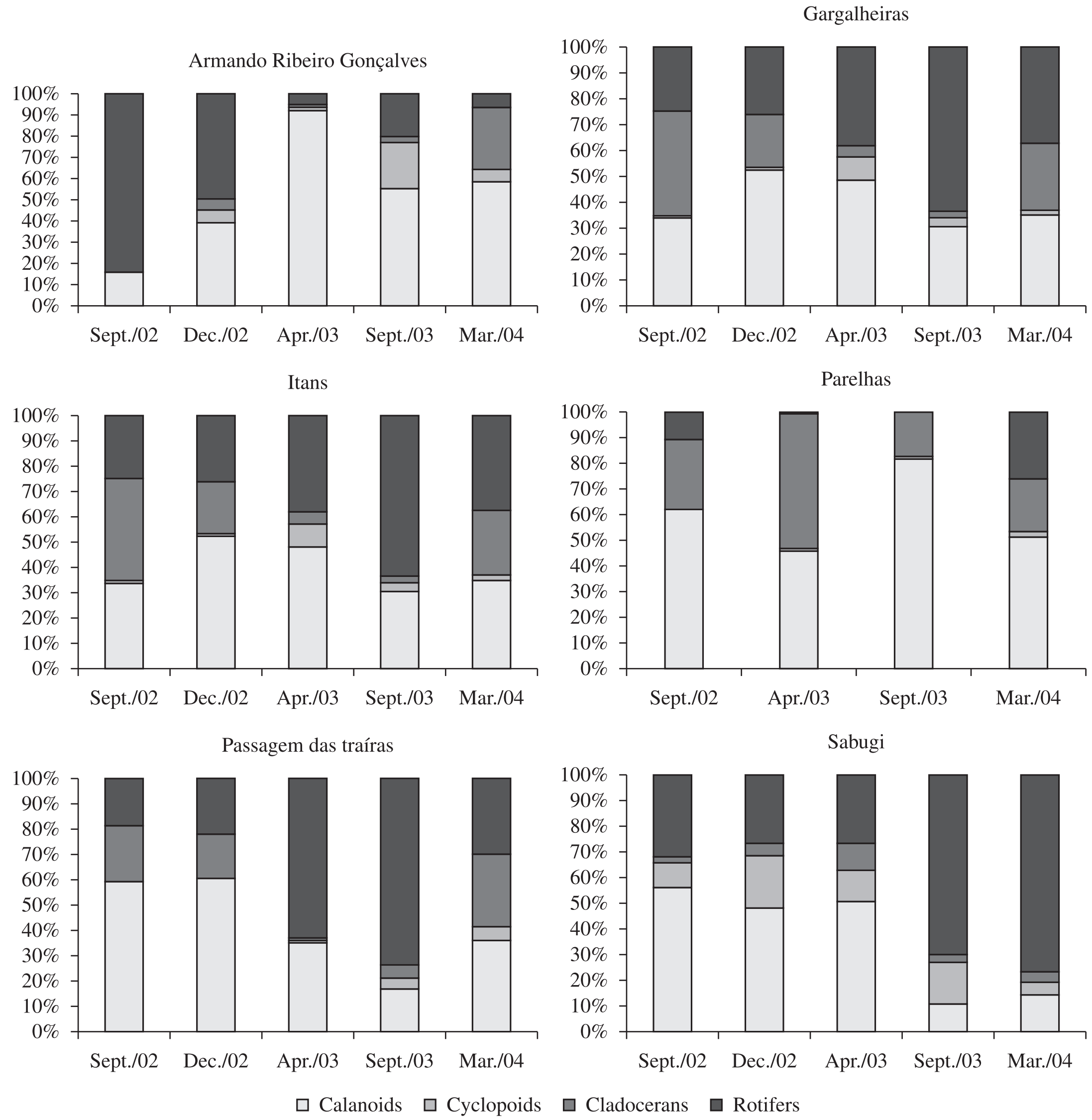

Figure 5. Relative abundance (%) of the zooplankton in the semi-arid reservoirs.

5. Discussion

All six reservoirs studied are facing progressive eutrophication, as a consequence of human activities and also due to natural conditions of the semi-arid climate. These reservoirs differ in many parameters, but all share low transparencies, as a consequence of high turbidity. In tropical semi-arid regions, the droughts and the irregularity of rainfall, responsible for the annual and inter-annual instability of the rains, together with high evaporation rates, shallow soils, and large drainage-basin areas are key factors in controlling water quality and ecological processes in the reservoirs (Sousa et al., 2008).

According to the trophic classification criteria for semi-arid regions, concentrations above 60 ug.L^{-1} of total phosphorus and 12 ug.L^{-1} of Chl *a* are indicative of a eutrophic state (Thornton and Rast, 1993). The Boqueirão Parelhas, Gargalheiras, Itans and Passagem das Traíras reservoirs all showed temporal variation in trophic condition, with Chl *a* concentrations below 12 ug.L^{-1} during September and December, and are classified, during this period, as mesotrophic. During the other sampling periods, all the reservoirs were highly eutrophic, with Chl *a* exceeding 20 ug.L^{-1} and reaching up to 164 ug.L^{-1}.

The frequent changes in trophic state in these reservoirs are an important selective factor for the success of potentially colonising species in such environments. Furthermore, these reservoirs are relatively shallow and turbid, and therefore are highly vulnerable to wind action, which is another important selective factor for their biota. Together with these eutrophic conditions, the high water temperatures and the thermal stability of the water column observed in

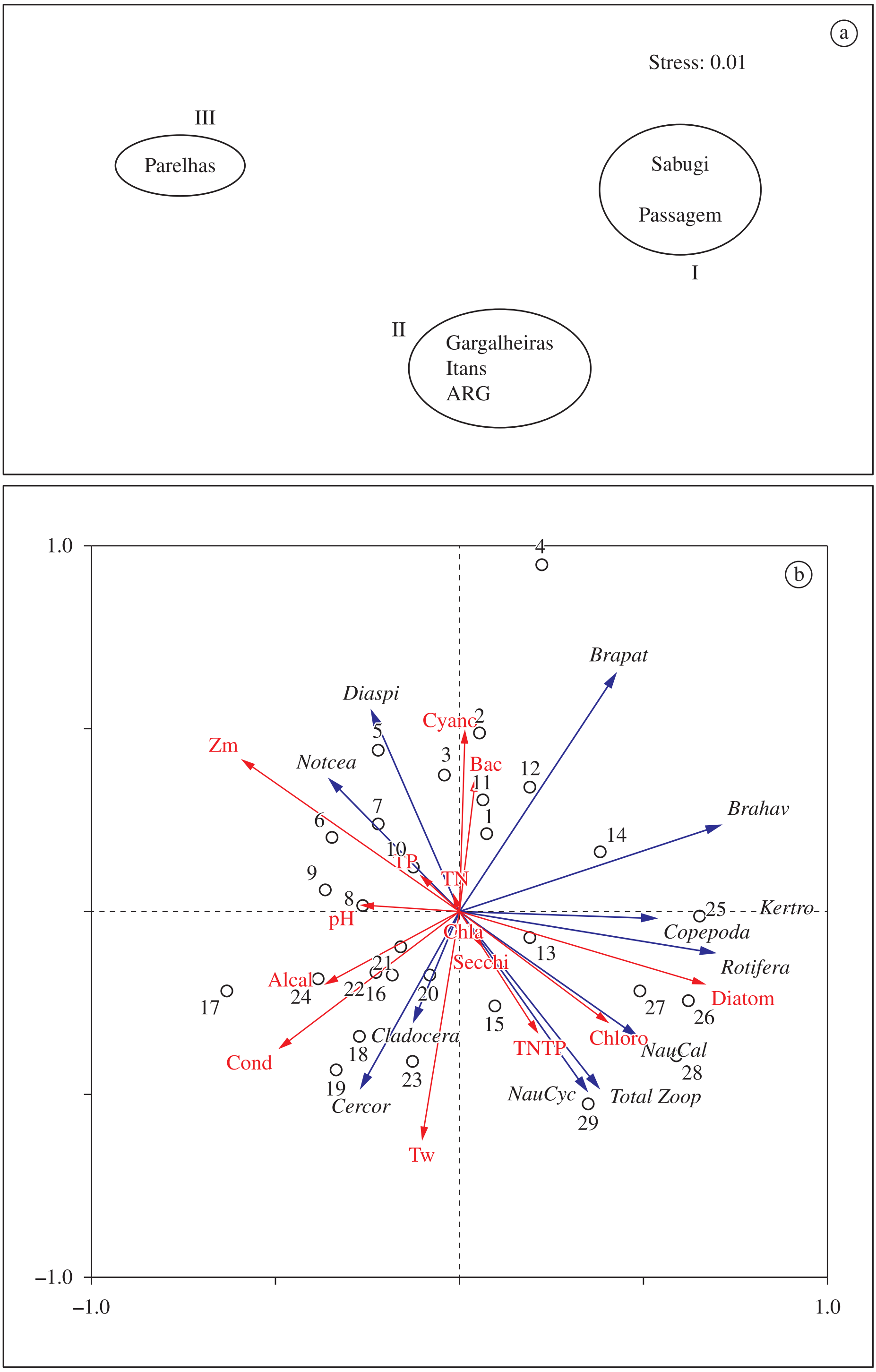

Figure 6. Multidimensional scaling of reservoirs based on zooplankton density composition (a) and ordination diagram by CCA (b) of the zooplankton species and of the sample units of Armando Ribeiro Gonçalves (1-5), Gargalheiras (6-10), Itans (11-15), Boqueirão Parelhas (16-19), Passagem das Traíras (20-24) and Sabugi (25-29) reservoirs. Circles represent the sample units, triangles the species and vectors the environmental variables (CHL, chlorophyll a; Sec, Secchi disk depth; Cond, conductivity; Zm, mean depths; Tw, water time retention; Bac, bacterioplankton; Tn, total nitrogen; TP, total phosphorous; TN:TP, total nitrogen: total phosphorous ratio; Alcal, alcalinidade; pH; Diatom, diatoms; Cyano, cyanobacteria, Brapat, *Brachionus patulus*; Brahav, *Brachionus havanensis*; Kertro, *Keratella tropica*; Diaspi, *Diaphanosoma spinulosum*; Notcea, *Notodiaptomus cearensis*; Cerco, *Ceriodaphnia cornuta*; NauCyc, nauplii of Cyclopoida; NauCal, nauplii of Calanoida; Cladocera; Copepoda; Rotifera; Totalzoop, total zooplankton).

these man-made lakes also favour recurrent algal blooms, which are generally dominated by cyanobacteria of the genera *Microcystis* and *Cylindrospermopsis* (Bouvy et al., 1999). The combined data on chlorophyll concentration and algal biovolume confirms the dominance of large colonies in the studied reservoirs.

It is now known that the dominance of filamentous cyanobacteria in lakes and reservoirs is typically associated with eutrophic conditions. However, it is believed that this dominance may be related more closely to low underwater luminosity, characteristic of eutrophic lakes, than directly to the high nutrient concentrations (Scheffer et al., 1997). Studies in many temperate lakes indicate that dominance by filamentous cyanobacteria is an alternate stable state of phytoplankton communities, since the cyanobacteria are tolerant to low light and increase the water turbidity, augmenting their own competitive advantages. Moreover, the long water residence time, thermal stability of the water column, and high abiogenic turbidity increase the probability that dominance of filamentous cyanobacteria will occur (Scheffer, 1998), this being a characteristic environmental condition of the reservoirs in the semi-arid region of Rio Grande do Norte.

During bloom events, cyanobacteria can form large colonies or aggregates, which are generally unpalatable to the majority of planktonic herbivores (De Bernardi and Giussani, 1990; Gliwicz, 1990). In addition, the presence of certain metabolic compounds considerably limits the grazing of herbivorous zooplankton on these algae particles (Engström-Öst, 2002), and is a decisive factor in shaping the composition of the zooplankton.

The frequent changes in the trophic state, turbidity, and salinity are an important selective factor for the success of the species that are potential colonisers of these environments. As a result of this environmental panorama, profound changes in the pattern of zooplankton species composition are observed during the cyanobacteria blooms, which are a response of the zooplankton community to the patterns of environmental variation and the indicative properties of certain groups of zooplankton species.

The zooplankton community of the six reservoirs studied showed quantitative patterns characteristic of eutrophic environments, with maximum densities close to 1000 org.L^{-1}. No spatial differences in the zooplankton densities were observed, which may be a result of the long water retention time in these reservoirs, a typical characteristic of the systems of the semi-arid region. In this way, in spite of the seasonal variations of the hydrological cycle, the long water retention time favours the establishment of zooplankton populations, contributing to a temporal uniformity in the quantitative patterns of this community.

Itans, Passagem das Traíras, and Sabugi reservoirs are dominated by cosmopolitan rotifers such as *Keratella tropica*, *Brachionus havanensis*, and *K. americana*, species that are generally associated with eutrophic environments dominated by cyanobacteria (Bays and Crisman, 1983; Berzins and Pjeler, 1989). According to Conde-Porcuna et al. (2002), rotifers are less dependent on phytoplankton than are crustacean plankton, which would explain the higher densities observed in these reservoirs. Also, most rotifer species are not very demanding in terms of food quality, being able to feed on detritus and bacteria (Rüttner-Kolisko, 1974), which are extremely abundant in freshwater systems where algal blooms occur.

The reservoirs of the semi-arid region show, in general, longitudinal gradients and temporal variations in trophic state, turbidity, and salinity, which are controlled mainly by the volume of river discharge, external nutrient and sediment load, and by the hydrological balance of precipitation and evaporation (Tundisi, 1994; Freire et al., 2009). Our results revealed that variables that best explained the variation pattern of the zooplankton were the mean depth, hydraulic residence time, conductivity, and the biovolume of diatoms, which are a food of good nutritional quality for the zooplankton. In eutrophic reservoirs, the zooplankton variation does not appear to be associated with the variation in the dominant phytoplankton group (cyanobacteria), probably because of the low nutritional quality of this resource. This would explain the closer association between zooplankton and more-palatable algae such as diatoms and chlorophyceans.

Armando Ribeiro Gonçalves, Gargalheiras, and Parelhas reservoirs showed a different structural pattern of the zooplankton community, distinguished by the dominance of calanoid copepods (especially *N. cearensis*) and cladocerans. This differentiation was previously observed by Sousa et al. (2008), and our results in MDS analysis confirm this taxonomic heterogeneity in the reservoirs.

Studies conducted in several tropical aquatic ecosystems, in the search for zooplankton indicators of eutrophy, have generally described a dominance of cyclopoid over calanoid copepods, as eutrophication becomes established and evolves (Pinto-Coelho et al., 2005). However, our results indicate another structural pattern of zooplankton in eutrophic systems, with the dominance of calanoid copepods.

Studies conducted by Panosso et al. (2003) showed that copepods of the genus *Notodiaptomus* can utilise small colonies and filaments of cyanobacteria for food, which would favour their dominance in eutrophic systems.

The results obtained in the present study indicate new relationships in the composition of the zooplankton community in eutrophic reservoirs of this semi-arid tropical region, which must be considered in designating zooplankton indicators of eutrophic conditions.

Acknowledgements – We thank Edson Santana for helping us with the field work and Dr. Janed Reid for her careful revision of the English version of the manuscript and suggestions. This project received financial support from CNPq (CT-HIDRO nº. 550201/2002-5).

References

American Public Health Association – APHA, 1995. *Standard methods.* 19th ed. Washington: APHA.

BAYS, S. and CRISMAN, TL., 1983. Zooplankton and trophic state relationships in Florida lakes. *Canadian Journal of Fisheries and Aquatic Science*, vol. 40, p. 1813-1819. http://dx.doi.org/10.1139/f83-210

BERZINS, B. and PJELER, B., 1989. Rotifer occurrence and trophic degree. *Hydrobiologia*, vol. 182, p. 171-180. http://dx.doi.org/10.1007/BF00006043

BOUVY, M., FALCÃO, D., MARINHO, M., PAGANO, P. and MOURA, A., 2000. Occurrence of Cylindrospermopsis (Cyanobacteria) in 39 Brazilian tropical reservoirs during the 1998 drought. *Aquatic Microbial Ecology*, vol. 23, p. 13-27. http://dx.doi.org/10.3354/ame023013

BOUVY, M., MOLICA, R., DE OLIVEIRA, S., MARINHO, M. and BEKER, B., 1999. Dynamics of a toxic cyanobacterial bloom (*Cylindrospermopsis raciborskii*) in a shallow reservoir in the semi-arid region of Northeast Brazil. *Aquatic Microbial Ecology*, vol. 20, p. 285-297. http://dx.doi.org/10.3354/ame020285

BRETT, MT. and MÜLLER-NAVARRA, DC., 1997. The role of highly unsaturated fatty acids in aquatic food-web processes. *Freshwater Biology*, vol. 38, p. 483-500. http://dx.doi.org/10.1046/j.1365-2427.1997.00220.x

BURNS, CW. and GALBRAITH, LM., 2007. Relating planktonic microbial food web structure in lentic freshwater ecosystems to water quality and land use. *Journal of Plankton Research*, vol. 29, p. 127-139.

CARPENTER, SR., CARACO, NF., CORRELL, DL., HOWARTH, RW., SHARPLEY, AN. and SMITH, V.H., 1998. Nonpoint pollution of surface waters with phosphorous and nitrogen. *Ecological Applications*, vol. 8, p. 559-568. http://dx.doi.org/10.1890/1051-0761(1998)008[0559:NPOSWW]2.0.CO;2

CLARKE, KR. and GORLEY, RN., 2001. *Primer v5*: user manual/tutorial. Plymouth: Primer-E Ltd.

CONDE-PORCUNA, JM., RAMOS-RODRÍGUEZ, E. and PÉREZ-MARTÍNEZ, C., 2002. Correlations between nutrient limitation and zooplankton populations in a mesotrophic reservoir. *Freshwater Biology*, vol. 47, p. 1463-1473. http://dx.doi.org/10.1046/j.1365-2427.2002.00882.x

COSTA, IA., AZEVEDO, SMFO., SENNA, PA., BERNARDO, RR., COSTA, SM. and CHELLAPPA, NT., 2006. Occurrence of toxin-producing cyanobacteria blooms in a Brazilian semiarid reservoir. *Brazilian Journal of Biology*, vol. 66, p. 211-219. PMid:16710515. http://dx.doi.org/10.1590/S1519-69842006000200005

DE BERNARDI, R. and GIUSSANI, G., 1990. Are blue-green algae a suitable food for zooplankton? An overview. *Hydrobiologia*, vol. 200-201, p. 29-41. http://dx.doi.org/10.1007/BF02530326

DE MOTT, WR., GULATI, RD. and VAN DONK, E., 2001. *Daphnia* food limitation in three hypertrophic Dutch lakes: evidence for exclusion of large bodied species by interfering filaments of cyanobacteria. *Limnology and Oceanography*, vol. 46, p. 2054-2060. http://dx.doi.org/10.4319/lo.2001.46.8.2054

DODSON, SI., EVERHART, WR., JANDL, AK. and KRAUSKOPF, SJ., 2007. Effect of watershed land use and lake age on zooplankton species richness. *Hydrobiologia*, vol. 579, p. 393-399. http://dx.doi.org/10.1007/s10750-006-0392-9

ENGSTRÖM-ÖST, J., 2002. *Effects of cyanobacteria on plankton and planktivores*. Walter and Andréé de nottbeck foundation scientific reports. no. 24. Academic dissertation.

FREIRE, RHF., CALIJURI, MC., and SANTAELLA, ST., 2009. Longitudinal patterns and variations in water quality in a reservoir in the semiarid region of NE Brazil: responses to hydrological and climatic changes. *Acta Limnologica Brasileinsia*, vol. 21, p. 251-262.

GLIWICZ, ZM., 1990. Food thresholds and body size in cladocerans. *Nature*, vol. 343, p. 638-640. http://dx.doi.org/10.1038/343638a0

LAZZARO, X., BOUVY, M., RIBEIRO-FILHO, RA., OLIVEIRA, VS., SALES, LT., VASCONCELOS, ARM. and MATA, M., 2003. Do fish regulate phytoplankton in shallow eutrophic Northeast Brazilian reservoirs? *Freshwater Biology*, vol. 48, p. 649-668. http://dx.doi.org/10.1046/j.1365-2427.2003.01037.x

NUSCH, EA. and PALME, G., 1975. Biologische Methoden für die Praxis der Gewässeruntersuchung. *Gewasser und Abwasser*, vol. 116, p. 562-565.

PANOSSO, R., CARLSSON, P., KOZLOWSKY-SUZUKI, B., AZEVEDO, SMFO. and GRANÉLI, E., 2003. Effect of grazing by a neotropical copepod, *Notodiaptomus*, on a natural cyanobacterial assemblage and on toxic and non- toxic cyanobacterial strains. *Journal of Plankton Research*, vol. 25, p. 1169-1175. http://dx.doi.org/10.1093/plankt/25.9.1169

PINEL-ALLOU, B., NIYONSENGA T. and LEGENDRE, P., 1995. Spatial variation and environmental components of freshwater zooplankton structure. *Ecoscience*, vol. 2, p. 1-19.

PINTO-COELHO, RM., 1998. Effects of eutrophication on seasonal patterns of mesozooplankton in a tropical reservoir: a 4-year study in Pampulha Lake, Brazil. *Freshwater Biology*, vol. 40, p. 159-173. http://dx.doi.org/10.1046/j.1365-2427.1998.00327.x

PINTO-COELHO, RM., BEZERRA-NETO JF. and MORAIS, CA., 2005. Effects of eutrophication on size and biomass of crustacean zooplankton in a tropical reservoir. *Brazilian Journal of Biology*, vol. 65, p. 325-338. PMid:16097736.

PORTER, GK. and FEIG, YS., 1980. The use DAPI for indentifying and counting aquatic microflora. *Limnology and Oceanography*, vol. 25, p. 943-948. http://dx.doi.org/10.4319/lo.1980.25.5.0943

ROTT, E., 1981. Some results from phytoplankton counting intercalibrations. *Schweizerische Zeitschrift Für Hydrologie*, vol. 43, p. 34-62.

RÜCKERTAND, GV. and GIANI, A., 2008. Biological interactions in the plankton community of a tropical eutrophic reservoir: is the phytoplankton controlled by zooplankton? *Journal of Plankton Research*, vol. 30, p. 1157-1168. http://dx.doi.org/10.1093/plankt/fbn065

RÜTTNER-KOLISKO, A., 1974. Plankton rotifers. Biology and taxonomy. *Die Binnengewiisser* v. 26, part 1. 146 p.

SCHEFFER, M., 1998. *Ecology of Shallow Lakes*. Chapman and Hall. 357 p.

SCHEFFER, M., RINALDI, S., GRAGNANI, A., MUR, LR. and VANNES, EH., 1997. On the dominance of filamentous cyanobacteria in shallow, turbid lakes. *Ecology*, vol. 78, p. 272-82. http://dx.doi.org/10.1890/0012-9658(1997)078[0272:OTDOFC]2.0.CO;2

SOUSA, W., ATTAYDE, JL., ROCHA, ES. and ESKINAZI-SANT'ANNA, EM., 2008. The response of zooplankton assemblages to variations in the water quality of four man-made lake sin semi-arid northeastern Brazil. *Journal of Plankton Research*, vol. 30, p. 699-708. http://dx.doi.org/10.1093/plankt/fbn032

TER BRAAK, CJF. and PRENTICE, IC., 1988. A theory of gradient analysis. *Advances in Ecological Research*, vol. 18, p. 272-330.

THORNTON, JA. and RAST, W., 1993. A test of hypotheses relating to the comparative limnology and assessment of eutrophication in semi-arid man-made lakes. In STRASKRABA, Y., TUNDISI, JG. and DUNCAN, A. (Eds.). *Comparative Reservoir Limnology and Water Quality Management*. London: Kluwer Academic Publishers. p. 1-24.

TUNDISI, JG., 1994. Tropical South America: Present and Perspectives. In: MARGALEF, R. (Ed.). *Limnology Now*, *a Paradigm of Planetary Problems*. Amsterdam: Elsevier. p. 353-424.

VIEIRA, ACB., RIBEIRO, LL., SANTOS, DPN. and CRISPIM, MC., 2009. Correlation between the zooplanktonic community and environmental variables in a reservoir form the Northeast semiarid. *Acta Limnologica Brasiliensia*, vol. 21, p. 349-358.

WEBSTER, KE. and PETERS, RH., 1978. Some size-dependent inhibitions of larger cladoceran filterers in filamentous suspensions. *Limnology and Oceanography*, vol. 23, p. 1238-1245. http://dx.doi.org/10.4319/lo.1978.23.6.1238