

Correlation between the zooplanktonic community and environmental variables in a reservoir from the Northeastern semi-arid

Correlação entre a comunidade zooplanctônica e variáveis ambientais em um reservatório do semi-árido nordestino

Vieira, ACB.¹, Ribeiro, LL.¹, Santos, DPN.² and Crispim, MC.³

¹Programa de Pós-Graduação em Ciências Biológicas, Departamento de Sistemática e Ecologia, Centro de Ciências Exatas e da Natureza, Universidade Federal da Paraíba – UFPB, Cidade Universitária, CEP 58059-900, João Pessoa, PB, Brazil
e-mail: carolgnv@hotmail.com; leonardo.ribeiro@yahoo.com.br

²Laboratório de Ecologia Aquática, Departamento de Sistemática e Ecologia, Centro de Ciências Exatas e da Natureza, Universidade Federal da Paraíba – UFPB, Cidade Universitária, CEP 58059-900, João Pessoa, PB - Brazil
e-mail: darlannobrega@hotmail.com

³Departamento de Sistemática e Ecologia, Centro de Ciências Exatas e da Natureza, Universidade Federal da Paraíba – UFPB, Cidade Universitária, CEP 58059-900, João Pessoa, PB, Brazil
e-mail: cccrispim@hotmail.com

Abstract: Aim: Aquatic environments of the semi-arid regions are submitted to several environmental pressures originated mainly from the irregular and scarce rainy season. Thus, the organisms developed strategies to adapt and remain in the environment, despite alterations of the hydrological regime. In order to comprehend these processes, the present study aimed to evaluate the influence of an atypical rainy year on the zooplanktonic community and the limnological variables and its interrelations in the Taperoá II Reservoir, located in the semi-arid of Paraíba. **Methods:** In this study, 10 samplings were developed from January to December/06, from which data from precipitation rates, temperature, pH, conductivity were taken. Water samples were also taken to analyze nitrogen and phosphate nutrient concentrations; zooplanktonic communities were also analyzed, quantitatively and qualitatively. **Results:** An increase in nutrients was observed during the rainy season. Dissolved oxygen, pH, and alkalinity were low during this season, increasing its values during the dry season. Filter feeder microcrustaceans (cladocerans and calanoid copepods), which were more abundant in January, presented an abrupt decrease in density in the beginning of the rainy season, maintaining its low values until the end of the study. On the other hand, rotifers densities increased and corresponded to more than 80% of the zooplankton density in the end of the study. Thus, despite environmental alterations, rotifers presented higher recovery and re-establishment of its populations. **Conclusion:** From this study, it was concluded that constant alterations in the environmental characteristics, resulting from the irregular pluviometric regime, are the determinant factors in the dynamics of zooplanktonic communities.

Keywords: semi-arid, reservoirs, zooplankton, environmental factors.

Resumo: Objetivo: Os ambientes aquáticos das regiões semi-áridas são submetidos a diversas pressões ambientais originadas principalmente pela irregular e escassa estação chuvosa. Diante desse fato, os organismos desenvolveram estratégias para se adaptar e permanecer no ambiente, a despeito das alterações no regime hídrico. No intuito de compreender esses processos, o presente trabalho teve por objetivo analisar a influência de um ano atípico de chuvas sobre a comunidade zooplanctônica e as variáveis limnológicas e suas inter-relações no Açude Taperoá II, situado no semi-árido paraibano. **Métodos:** Para este estudo foram realizadas 10 coletas de janeiro a dezembro/06, nas quais foram tomadas as medidas de pluviosidade, temperatura, pH, condutividade; amostras de água foram coletadas para análises de nutrientes inorgânicos nitrogenados e fosfatados; a comunidade zooplanctônica foi analisada quantitativamente e qualitativamente. **Resultados:** Observou-se o aumento na concentração dos nutrientes durante a estação chuvosa. Oxigênio dissolvido, pH e alcalinidade mantiveram-se baixos durante esta estação, aumentando seus valores durante a estação seca. Os microcrustáceos filtradores (cladóceros e copépodos calanóides), que tiveram suas maiores densidades registradas no mês de janeiro, apresentaram uma brusca queda com o início da estação chuvosa, mantendo suas densidades baixas até o fim do estudo; em contrapartida, os rotíferos apresentaram crescimento nas suas densidades, respondendo por mais de 80% da densidade zooplanctônica no fim dos estudos; dessa forma, apesar das alterações no meio, os rotíferos tiveram maior poder de recuperação e restabelecimento de suas populações. **Conclusão:** Com este trabalho pode-se concluir que as constantes alterações nas características ambientais, resultantes do irregular regime pluviométrico, são fatores determinantes na dinâmica das comunidades zooplanctônicas.

Palavras-chave: semi-árido, reservatórios, zooplâncton, fatores ambientais.

1. Introduction

The zooplankton is one of the most studied and known aquatic communities, due to its importance in the matter and energy dynamics in the aquatic ecosystems and to its sensitivity to environmental changes (Esteves, 1998; Maemets, 1983; Peijer, 1983). Thus, zooplanktonic organisms developed strategies, like cyclomorphosis and the production of resistance forms that allow their permanence in the environment despite these alterations (Willians, 1987; Crispim and Watanabe, 2001; Gannon and Stemberger, 1978).

In Brazil, the northeastern semi-arid presents extreme conditions in climatic terms, with elevated mean temperatures (27-29 °C), strong insolation, and high evaporation rates associated to a low percentage of relative air humidity, and mainly the lower and irregular pluviometric indexes of the country. This region covers an area of *ca.* 700,000 km² that corresponds to 10% of the national territory (Paraíba, 1997). Due to the climate rigidity, a deficit in the hydric budget occurs, which is responsible for the temporary regime of several water bodies of the region (Barbosa, 2002). This high variation of the hydric volume influences directly the dynamics of the ecosystem because it promotes the concentration of the substances present, like salts and nutrients that directly influence the water quality.

In the northeastern semi-arid, some studies about the ecology of the zooplanktonic community were performed. One of the first studies were carried out by Nordi and Watanabe (1978), followed by Moredjo (1998) that evaluated the influence of anthropic activities on the increase of the trophic degree in reservoirs of the region, using the zooplanktonic community as an indicator. From 2000 year, several studies about the zooplanktonic community were performed in Paraíba State, focusing many aspects: the relationship of the zooplanktonic community and the hydrological cycle and water quality (Crispim et al., 2000; Crispim and Watanabe, 2000b; Crispim and Freitas, 2005); the vertical migration and the distribution of the zooplanktonic community in different regions of reservoirs (Silva et al., 2009); the influence of the biomanipulation on the zooplanktonic community structure (Freitas et al., 2007). Also, studies with diapause eggs of rotifers and cladocerans in the dry sediment of Soledade Reservoir were developed by Crispim and Watanabe (2000a, 2001), besides the study of different population dynamics of *Moina minuta* hansen 1899 hatched from ephippia (Crispim et al., 2003). Studies about the zooplanktonic composition in semi-arid reservoirs were also performed by Eskinazi- Sant' Anna et al. (2007) in Rio Grande do Norte State, and by Leitão et al. (2006) in Ceará State.

In environments subject to constant alterations of the water quality, as is the case of the aquatic environments of the semi-arid regions, comprehend the population

dynamics of these organisms and how they respond to these alterations is of fundamental importance to the understanding of the functioning of the ecosystem itself. Therefore, this work aimed to evaluate the correlations of the zooplanktonic community with some environmental variables along a hydrological cycle in Taperoá II Reservoir, semi-arid of Paraíba State.

2. Material and Methods

2.1. Study area

Most of the Northeast region of Brazil is under a semi-arid climate due to wind circulation and geomorphological patterns (Reis, 1976). This region is delimited by the 800 mm-isoet of pluviometric precipitation, and the hydrological cycle features lead most of the water bodies to present a temporary regime (Maltchik, 1999; Vieira, 2000). This region is the most densely inhabited semi-arid area in the world (Ab'Saber, 2003), and the building of surface reservoirs by damming rivers are essential to guarantee water supply through longer periods.

The Taperoá River rises in the Serra do Teixeira, and has its mouth in Epitácio Pessoa Reservoir, Boqueirão, Paraíba, draining an area of 7,316 km², and runs through about eight municipalities. Regional Climate is Köppen's Bsh type: tropical semi-arid with irregular precipitation in autumn-winter; and its bioclimate is 2b: warm subdesertic with tropical trends, reaching from nine to eleven dry months in a year (Feliciano and Melo, 2003). Taperoá River, as well as several water bodies in its basin is temporary, with running water presents only in wet seasons. Meanwhile, reservoirs can keep water for longer periods of time, although they can completely dry.

The Manuel Marcionilo (Taperoá II) Reservoir (Figure 1) is a shallow reservoir, with 5.7 m of depth, and 1.4 m mean depth, which can keep 15,148,900 m³, and occupies an area of 4.6 km² (Barbosa et al., 2002). Water supply and crop irrigation are its main uses (Lacerda, 2003). The trophic degree remains mesotrophic along most part of the hydrological cycle, shifting to eutrophic at the end of dry season (Barbosa et al., 2002), but this depends on precipitation rates.

2.2. Sampling and data analysis

Daily pluviometric data were collected by the Programa de Monitoramento em Tempo Real da região Nordeste (Proclima), a partnership between the Centro de Previsão do Tempo e Estudos Climáticos (CPTEC/INPE) and the Superintendence for the Development of the Northeast Region (SUDENE).

Water and zooplankton samples were collected in the littoral zone, from January to December/06, usually between 10:00 and 12:00. Water temperature (Incoterm digital thermometer), pH (Handlab ph-meter), and electri-

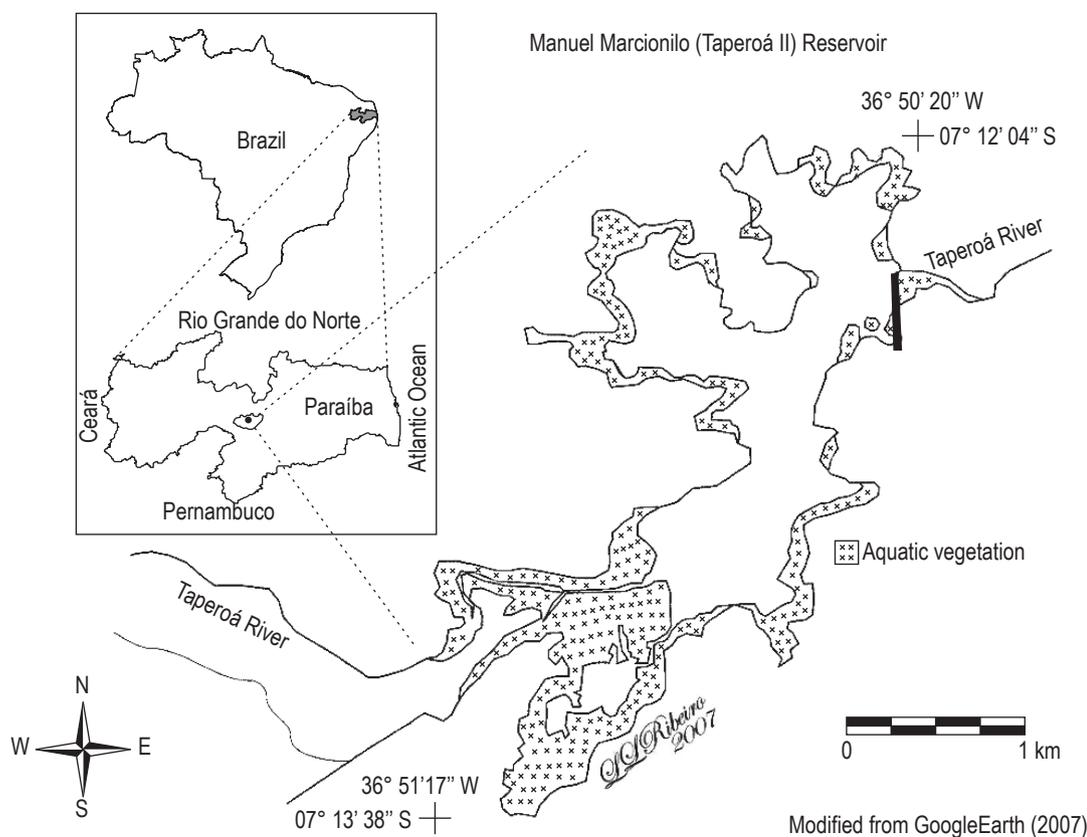


Figure 1. The Manuel Marcionilo (Taperoá II) Reservoir, Taperoá, Paraíba, Brazil.

cal conductivity (Tecnal electric conductivity-meter) were obtained in the field.

Inorganic nutrients were analyzed according to the Standard Methods (Clesceri et al., 1998) for N-ammonia (phenate reaction), N-nitrite (colorimetric method), N-nitrate (cadmium reduction), reactive soluble phosphate (ascorbic acid method), and total phosphorus (permanganate digestion and ascorbic acid method). Dissolved oxygen was analyzed by the modified Winkler's method (Golterman et al., 1978). A trophic state index (TSI) was calculated based on Carlson (1977) functions, modified by Toledo Jr. et al. (1983) to tropical environments.

A Principal Component Analysis (PCA) was performed to ordinate the samples collected along the hydrological cycle of 2006, based on the multidimensional universe of registered environmental data. Data were previously checked out for normality by the non-parametric test Kolmogorov-Smirnov (Sokal and Rohlf, 1980). Variables that did not fit to a normal distribution were submitted to normalization by functions such as square or forth root, log, or power, and those that did not fit anyway were discarded. After that, data were standardized by dividing each case in a variable by the sum of all cases. The resultant values were multiplied by 100. To avoid redundant variables input in the PCA, a correlation test was done, and when pairs of

variables with $r > 0.5$ and $p < 0.05$ were found, just one of them were used to compose the principal components, being the others used as complementary variables on plots. A covariance matrix was used to calculate the eigenvalues and eigenvectors of principal components. The PCA was executed using the program Statistica for Windows (StatSoft Inc., 2004).

Forty liters water samples were taken with a bucket and filtered in a $45 \mu\text{m}$ -mesh net to collect zooplanktonic organisms (Crispim et al., 2000). Three replicates were collected from the environment. The animals collected were preserved in a sugar-added 4% formalin solution (Haney and Hall, 1973). One milliliter subsample was taken, from each sample, with a Hensen-Stempel pipette, and analyzed in a Sedgwick-Rafter counting cell, to quantify and qualify zooplankton species. Rotifer and Cladocera species were identified following Ruttner-Kolisko (1974), Koste (1972; 1978), and El Moor-Loureiro (1997).

The diversity of zooplankton community was checked for complementarity among months by a Multidimensional Scaling (MDS) based on a Bray-Curtis matrix of similarities (Clarke and Warwick, 2001). A cluster analysis, with non-weighted par-group average as amalgamation method, was used to define the limits of groups. The software Primer 6.0 beta (PRIMER-E, 2004) was used for these tasks.

3. Results

3.1. Environmental data

Rainfall was concentrated in four months, from the ending of February to the middle of May, and significant but scattered rainfalls occurred in June, a benchmark to the end of the wet season. A clear dry season was observed from July to December when precipitations were almost nonexistent (Figure 2).

The water temperature varied from 22.6 to 29.8 °C, being the highest values found in the wet season, between February and June (Figure 3a). In the early wet season, it was observed a decrease in water transparency from 80 cm in January to 60 cm in March, followed by increasing values along this season, until a maximum of 120 cm, reached in both July and August; the dry season has shown decreasing values of water transparency, with a minimum of 58 cm in December (Figure 3b). Maximum alkalinity (66.7 mg.L⁻¹) was registered in January, but it decreased after the beginning of the wet season and beyond, ranging from 34.0 mg.L⁻¹ in February to 38.3 mg.L⁻¹ in June, and from 23.3 mg.L⁻¹ in July to 28.3 mg.L⁻¹ in November (Figure 3c). The pH values were always above the neutral point, with decreasing values observed from the earlier wet season to September, but higher values were registered in the last three months: 9.1 to 10.0 from October to December (Figure 3d). Decreasing dissolved oxygen values were also a feature of the wet season, which varied from 8.8 mg.L⁻¹ in January to 4.8 mg.L⁻¹ in June, and, contrasting to transparency values, dissolved oxygen increased to 9.8 mg.L⁻¹ in December (Figure 3e). N-nitrite and N-nitrate concentrations increased significantly in the earlier wet season, and

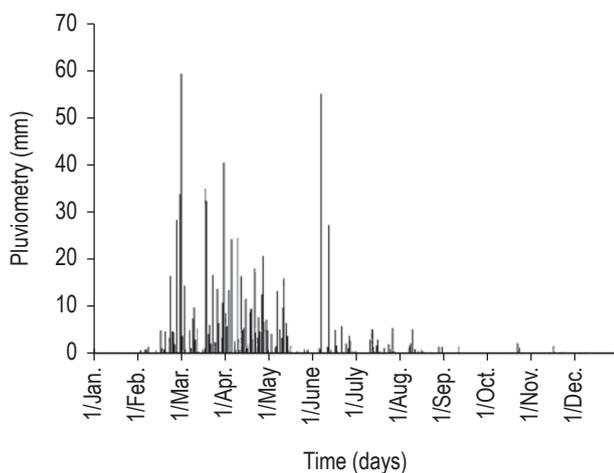


Figure 2. Daily pluviometry registered on the Taperoá City region from January 1st to December 31th. Rainfall concentrated from late February to the beginning May, with considerable precipitation in a couple days in June, at the end of the wet season. After that, came a dry season. Source: Proclima (www.ptec.inpe.br/proclima).

their maximum values were found in June (112.13 and 4.47 µg.L⁻¹, respectively), but after that the values decreased; other peaks of each form were also registered in the dry season: 67.87 µg.L⁻¹ to N-nitrate, and 2.71 µg.L⁻¹ to N-nitrite. On the other hand, N-ammonia peaked with the first rainfalls in later February (71.20 µg.L⁻¹), and after a sharp decrease in March, its concentrations gradually increased, reaching its maximum in September (101.33 µg.L⁻¹), when it decreased back in the later months, stabilizing around 55.00 µg.L⁻¹ (Figure 3f). Total phosphorus showed an elevated peak in March (1.42 µg.L⁻¹), and phosphorus concentrations were higher in February, March, and December (0.04, 0.03 and 0.02 µg.L⁻¹, respectively), while low concentrations of these two forms were registered in other months (Figure 3g, h).

3.2. Zooplankton dynamics

Although the 3 main groups Cladocera, Rotifera, and Copepoda were analyzed, Cyclopoid copepods were identified only to Order. There were found 35 zooplankton species, from which nine were cladocerans and 26 were rotifers (Table 1). Amongst cladocerans, *Moina minuta* Hansen, 1899 and *Ceriodaphnia cornuta* Sars, 1906 (Daphniidae), *Diaphanosoma spinulosum* Herbst, 1967 (Sididae), and *Macrothrix* sp. Baird, 1943 (Macrothricidae) were the most frequent species, each one found respectively in 10, 9, 8 and 7 of 10 sampled months. The most frequent rotifers were *Keratella tropica* Apstein, 1907 (10), *Brachionus falcatus* Zacharias, 1898 (7), *Pompholyx triloba* Pejler, 1957 (7), *Filinia longiseta* (Ehrenberg, 1834) (6) and *Brachionus havanaensis* Rousselet, 1911 (6). The lower number of species was registered in January (5), while February (19) and November (23) showed the greatest ones (Figure 5a).

As shown in Figure 4, microcrustaceans were dominant at first: cladocerans presented highest abundance in January (55.83 ind.L⁻¹), due to *D. spinulosum*'s and *M. minuta*'s density peaks of 45.18 and 8.88 ind.L⁻¹, respectively, while other cladoceran species were registered always at low densities; the calanoid copepod *Notodiaptomus cearensis* Wright, 1935 also had its maximum abundance in January (128.10 ind.L⁻¹), and copepod nauplii were dominant in February and March; cyclopoid copepods showed a slight peak in June. In the wet season, rotifer abundances peaked in February, with highest densities of *Brachionus falcatus* (26.57 ind.L⁻¹) and *Brachionus calyciflorus* Pallas, 1766 (17.17 ind.L⁻¹). Both microcrustaceans and rotifers presented decreasing densities as the wet season gone. The second moment began after August 2006, when rotifers outnumbered cladocerans and copepods until the end of this study; the most abundant and dominating species was *Pompholyx triloba*, whose densities ranged from 43.83 to 92.17 ind.L⁻¹, but *Keratella americana* Carlin, 1943, (28.67 ind.L⁻¹ in August), *Lecane stichaea* Hanning, 1913 (15.33 ind.L⁻¹ in September), *Keratella tropica* (14.33 ind.L⁻¹ in August), and

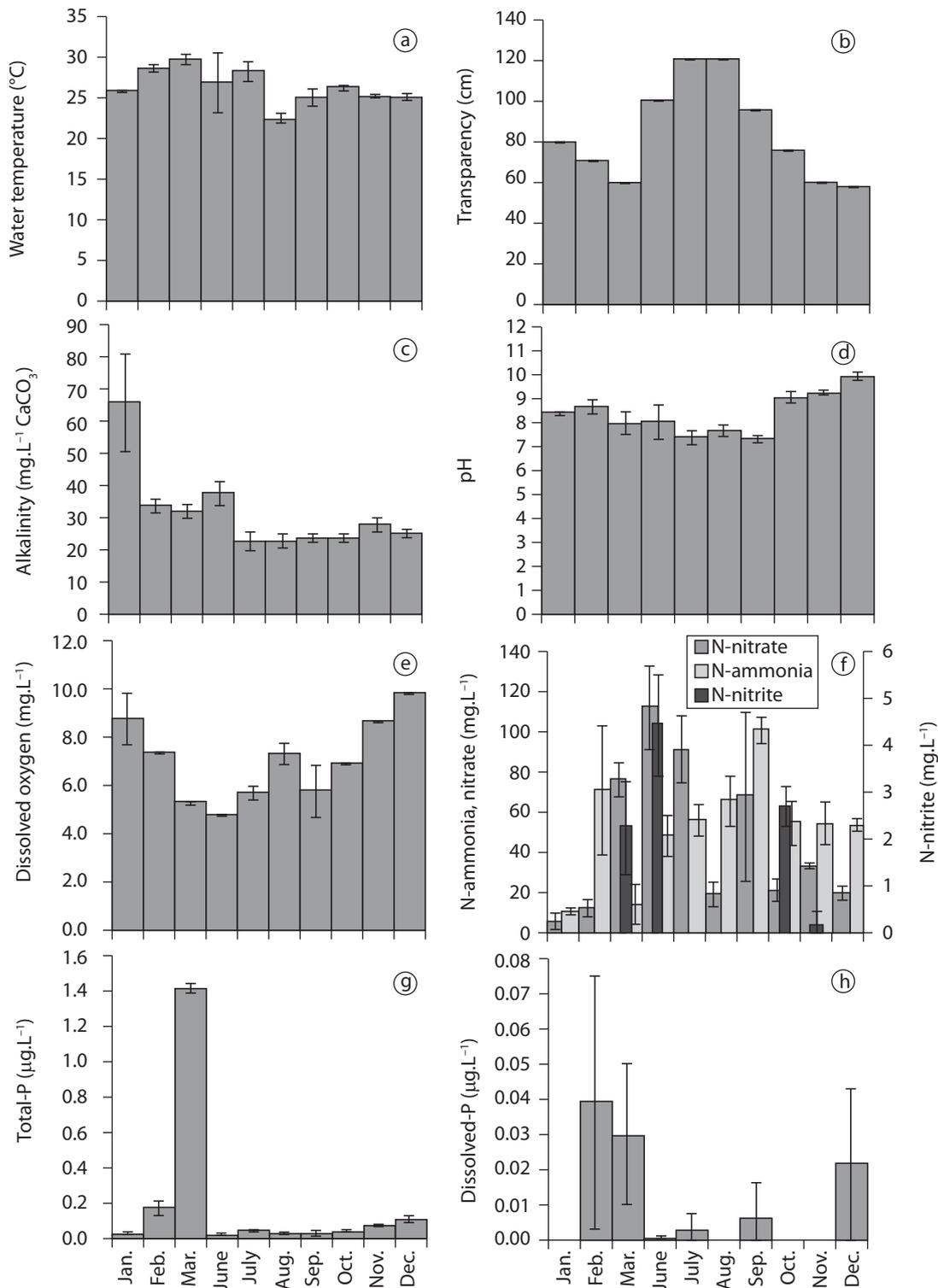


Figure 3. Physical and chemical values of the water from Taperoá II Reservoir: water temperature (a), Secchi disk transparency (b), alkalinity (c), pH (d), dissolved oxygen (e), N-ammonia, N-nitrate and N-nitrite (f), total-P (g), and dissolved-P (h).

Brachionus falcatus (12.83 ind.L⁻¹ in October) also shown isolated peaks in this season.

3.3. Multivariate analysis

Principal components analysis shows that the first component, composed mainly by pluviosity (log Pl),

represented 77.1% of the total variance, and indicates the hydrologic cycle, and the second component (12.89% of the total variance) was composed by the trophic state index (TSI), alkalinity, and ammonia concentrations (Figure 5a). January samples were isolated from the others based both in the hydrologic cycle and trophic degree, and their position

Table 1. Composition, mean abundance and frequency (f) of cladoceran and rotiferan species found in Taperoá II.

Taxa	Mean abundance	SD	Highest abundance	Month at highest abundance	f	Most frequent period
Rotifera						
Brachionidae						
<i>Brachionus angularis</i> Gosse, 1851	0.033	0.070	0.167	Oct./Nov.	0.2	Oct./Nov.
<i>Brachionus calyciflorus</i> Pallas, 1766	1.843	5.388	17.166	Feb.	0.4	Feb. to Mar.
<i>Brachionus caudatus</i> Barrois & Daday, 1894	0.200	0.399	1.167	Oct.	0.3	Sep. to Nov.
<i>Brachionus dolabratus</i> Haring, 1914	0.347	0.567	1.466	Feb.	0.5	Aug. to Nov.
<i>Brachionus falcatus</i> Zacharias, 1898	5.135	8.421	26.566	Feb.	0.9	Feb. to Dec.
<i>Brachionus havanaensis</i> Rousselet 1911	0.546	0.906	2.850	Feb.	0.6	Oct. to Dec.
<i>Brachionus patulus</i> O.F.Müller 1786	1.526	3.547	11.475	Mar.	0.5	Feb. to Sep.
<i>Brachionus quadridentatus</i> Hermann, 1786	0.052	0.163	0.517	June	0.1	June
<i>Brachionus sericus</i> Rousselet, 1907	0.330	1.044	3.300	Feb.	0.1	Feb.
<i>Keratella americana</i> Carlin, 1943	6.767	9.626	28.666	Aug.	0.5	Aug. to Dec.
<i>Keratella lenzi</i> Hauer, 1953	0.162	0.421	1.333	July	0.2	June/July
<i>Keratella tropica</i> Apstein, 1907	5.260	4.738	14.333	Aug.	1.0	Jan. to Dec.
Euchlanidae						
<i>Euhlanis dilatata</i> Ehrenberg, 1832	1.170	3.016	9.533	Aug.	0.2	Feb./Aug.
Filiniidae						
<i>Filinia longiseta</i> (Ehrenberg, 1834)	0.778	1.209	3.666	Feb.	0.6	Feb. to June/Oct. to Dec.
<i>Filinia opoliensis</i> (Zacharias, 1898)	3.908	4.571	11.750	June	0.7	June to Dec.
<i>Filinia terminalis</i> (Ehrenberg, 1834)	0.108	0.193	0.500	Oct.	0.3	Oct./Nov.
Hexarthridae						
<i>Hexarthra mira</i> (Hudson, 1871)	1.348	3.315	10.683	June	0.4	Nov./Dec.
Lecanidae						
<i>Lecane bulla</i> (Gosse, 1851)	0.017	0.053	0.167	Nov.	0.1	Nov.
<i>Lecane hastata</i> (Murray, 1913)	0.017	0.053	0.167	Nov.	0.1	Nov.
<i>Lecane leontina</i> (Turner, 1892)	0.163	0.461	1.467	Aug.	0.2	Feb./Aug.
<i>Lecane luna</i> (Müller, 1776)	0.852	1.659	5.233	Feb.	0.5	June to Aug.
<i>Lecane stichaea</i> Haring, 1913	1.583	4.834	15.333	Aug.	0.2	Aug./Sep.
Mytilinidae						
<i>Mytilina mucronata</i> (Müller, 1773)	0.050	0.158	0.500	Sep.	0.1	Sep.
Synchaetidae						
<i>Polyarthra dolichoptera</i> (Idelson, 1925)	1.300	2.071	5.500	Oct.	0.4	Aug. to Dec.
Testudinellidae						
<i>Pompholyx triloba</i> Pejler, 1957	35.263	39.811	92.166	Nov.	0.7	Aug. to Dec.
<i>Testudinella patina</i>	0.027	0.084	0.267	June	0.1	June
Cladocera						
Daphniidae						
<i>Ceriodaphnia cornuta</i> Sars, 1906	1.284	2.227	7.350	Feb.	0.9	Jan. to Dec. (except Aug.)
<i>Moina minuta</i> Hansen, 1899	2.114	3.342	8.876	Jan.	1.0	Jan. to Dec.
Macrothricidae						
<i>Macrothrix</i> sp. Baird, 1843	0.556	0.982	3.233	Feb.	0.7	Aug. to Dec.
Chidoridae						
<i>Biapertura affinis</i> (Leydig, 1860)	0.256	0.582	1.758	Mar.	0.3	Feb./Mar.
<i>Chydorus eurynotus</i> Sars, 1901	0.055	0.174	0.550	June	0.1	June
<i>Chydorus sphaericus</i>	0.004	0.009	0.025	Dec.	0.2	Nov./Dec.
<i>Ephemeroporus hybridus</i> (Daday, 1905)	0.128	0.403	1.275	Mar.	0.1	Mar.
<i>Euryhalona orientalis</i> (Daday, 1898)	0.003	0.006	0.017	Dec.	0.2	Nov./Dec.
Sididae						
<i>Diaphanosoma spinulosum</i> Herbst, 1967	6.501	14.116	45.175	Jan.	0.8	Jan. to Dec. (Except Aug./Sep.)

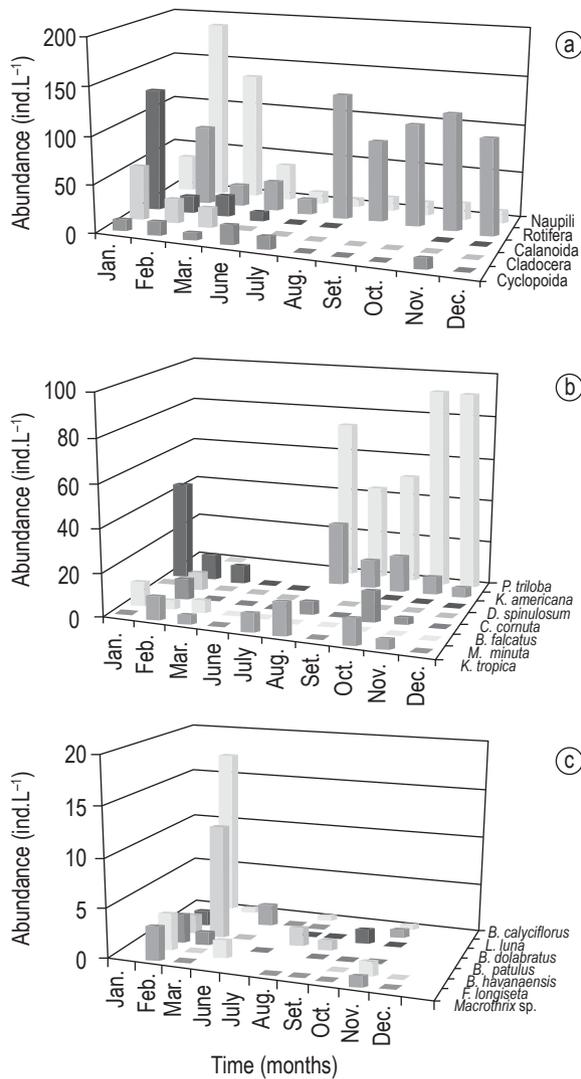


Figure 4. Microcystaceans and rotifers densities by groups (a), and by the most abundant and frequent species (b and c) in Taperoá II Reservoir, from January to December/06. Note that a, b, and c present different y scales.

is related to the high values of the trophic state indexes, as well as in March, where the rainfalls were concentrated. The distance in trophic degree between February and March indicates a rapid eutrophication caused by nutrients runoff. From March to September, it can be observed decreasing trophic state index and pluviosity, and from September to December only an increase in the trophic degree was observed (Figure 5b).

The multidimensional scaling on the similarities among samples showed three distinct groups based on 40% of resemblance (outer lines in Figure 6), which indicates three turn-over events in the community. January samples, joined to February and March, reveals that despite the pressure caused by pluviosity, the community tended to resist the changes, at least in terms of composition. June and July present a period of low species number which persisted in

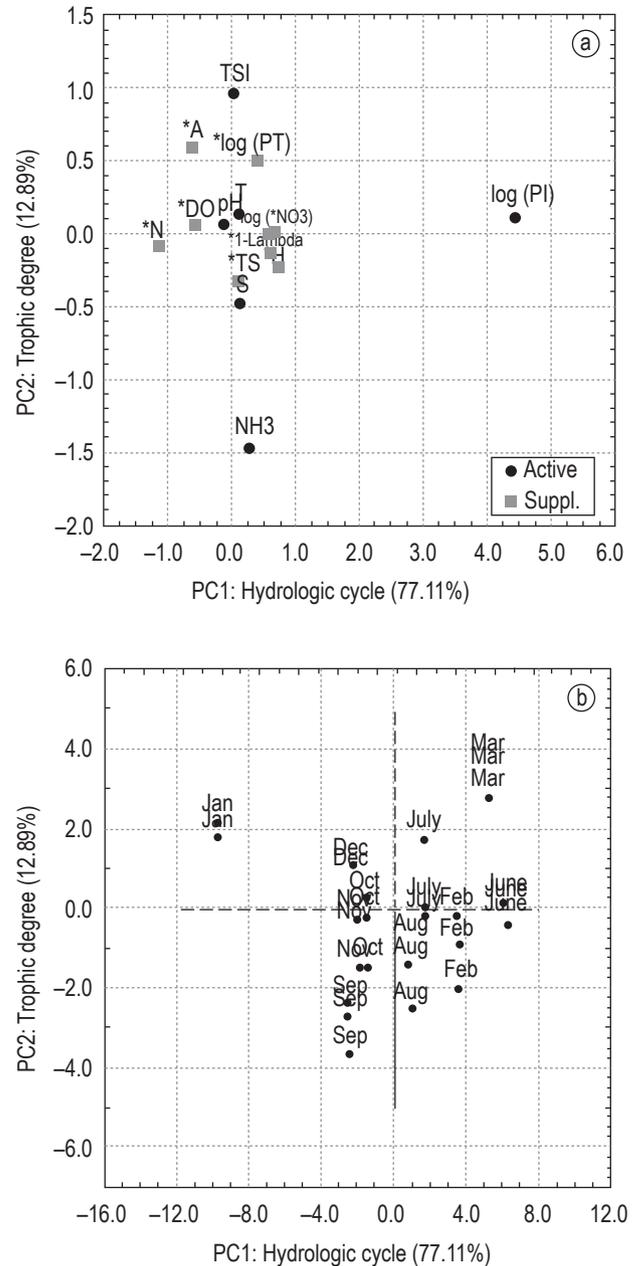


Figure 5. Principal component analysis for the physical, chemical, and community data of the Taperoá II Reservoir from January to December/06. Graphic distribution of variables (a) and samples (b) in a 2-dimension plot based on the first and second principal components.

low densities to this middle-end of the wet period, while August-December group represents a period where the Taperoá II was dominated by high densities of rotifers, which indicates a higher trophic degree.

4. Discussion

In an historical analysis through data collected in previous works in the Taperoá II Reservoir, we can see that the reservoir undergone several changes in water volumes and

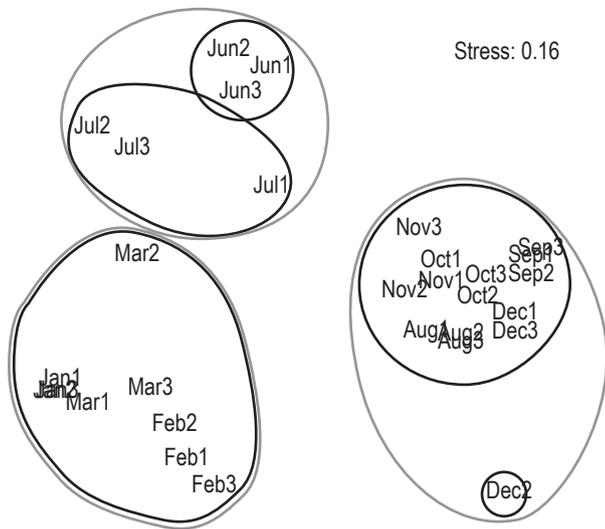


Figure 6. Multidimensional scaling (MDS) based on Bray-Curtis similarities among samples from the zooplankton assemblage of Taperoá II Reservoir. Gray line: resemblance level = 30%; Black line: resemblance = 40%.

in its trophic degree, which lead to changes in plankton assemblages, both in diversity and in biomass. In low-rainfall years, and in consequently reductions in water levels as in 1998-1999 and 2003 (Crispim et al., 2000; Ribeiro, unpubl. data) we can see rotifers as dominant organisms in relation to the other groups, and their numbers tend to rise as the dry season goes on. According to Ceballos (1995) and Costa (2003) the water loss in reservoirs in semi-arid regions by evaporation promotes changes that lead to non-specialist organisms such as most of rotifers and protozoans (Esteves and Sendacz, 1988). Cladocerans and calanoid copepods, that are more selective to food and environmental changes, tend to disappear as dry season becomes harsh (Walz and Welker, 1998), reappearing when proper conditions just returns.

In 2004-05 the rainfalls were above the average and the volume of most reservoirs in the semi-arid of Paraíba recovered its zooplankton diversity: Cladocerans and copepods were more abundant a few months after the earlier rainfalls, and their densities were equivalent to the rotifer ones, as chlorophyceans and diatoms dominated the phytoplankton (Ribeiro, unpubl. data). Amarasinghe et al. (1997), in a study in Sri Lanka about feeding of calanoid copepods and cladocerans, observed that these organisms presented a much better development when raised on chlorophycean cultures, and cyanobacterial cultures caused a decrease in the reproductive rates and a delay in the development.

The increment of macrophytes in the littoral region of the reservoir was also an important factor after middle 2005 (Ribeiro, unpubl. data), contributing to the increase in microcrustacean diversity. Several studies about the importance of macrophytes to the zooplankton assemblage

were performed over the world (Hambricht et al., 1986; Kuczynska-Kippen and Nagengast, 2006; Rocha et al., 1982; Timms and Moss, 1984; Turner and Mittelbach, 1990). According to Stansfield (1997) macrophytes are excellent shelters to planktonic microcrustaceans acting as safe places to reproduction and avoidance to planktivorous fishes.

In the present study it was observed a great influence of rainfall on zooplankton assemblage, as seen by the lower abundances that were registered when precipitation was higher. Angeler et al. (2005), in their study of the influence of water input on the planktonic biomass in semi-arid regions, in Spain, affirmed that in the beginning of the wet season the elevated input of water in the system lead to a decrease in biomass and diversity caused by the diluting effect, and the hydrologic stress as well, due to the physical and chemical features of the water (Fisher and Grimm, 1991). In the case of Taperoá II Reservoir, these effects were stronger than in later years, as demonstrated by its maximum capacity kept over five months (from April to August).

In the subsequent months, this fact has such an important effect on zooplankton assemblage, and the microcrustaceans densities were very low, meanwhile rotifers dominated at high densities, representing 80% of the total abundance. Porter et al. (1983), noted that organisms with short generation time and that are food generalists, being bacterioplankton their major diet, are favored in environments subjected to huge changes in hydrological dynamics, which is the case of the water bodies in semi-arid environments, over the more exigent microcrustaceans, that need a longer water residence time to establish their populations (Mura and Brecciaroli, 2003; Walz, 1995). The low chlorophyll *a* concentrations also has contributed to the low density of cladocerans because these organisms have higher filtration rates than rotifers, and, thus, need higher food concentrations (Lampert, 1987).

The resemblances between the ordination of environmental data and the scaling of zooplankton assemblage data reveal that the dynamics of the animal community of this reservoir is highly related to the environmental features, and at least three moments can be discriminated as the hydrological cycle goes on: 1) intense rain momentum, related to the maximum precipitation rates; 2) intermediate momentum, where water level maintain some degree of stability; and 3) dry momentum, where the evaporation, instead of water accumulation, is the main force controlling the community.

As we can see, the environmental stress due to the great hydrological variation in the reservoirs of semi-arid regions lead to constant changes in the structure of the zooplankton community. (Angeler et al., 2000; Mura and Brecciaroli, 2003; Walz, 1995; Perez-Martínez et al., 1991). Only species adapted to harsh conditions, like extreme drought and

dehydration, through the formation of resting stages, and hatching when proper conditions are reached can stand in the environment. Diapause, a common resting strategy in invertebrates, was observed in cladocerans species such as *Moina minuta*, *Ceriodaphnia cornuta* and *Diaphanosoma spinulosum*, and rotifer species *Brachionus urceolaris*, *Hexarthra jenkiane*, and *Lecane bulla*, in the semi-arid of Paraíba (Brazil) (Crispim and Watanabe, 2000b; 2001). We observed that the hydrological cycle and the rainfall are key factors to water quality, and zooplankton community as well.

Acknowledgements

To the Programa Ecológico de Longa Duração PELD-Caatinga: Estrutura e Funcionamento and to the Programa de Pós-Graduação em Ciências Biológicas: Zoologia for subsidy and logistical and financial support.

References

- AB'SÁBER, AN. *Os domínios de natureza no Brasil: potencialidades paisagísticas*. São Paulo: Ateliê Editorial, 2003. 159 p.
- AMARASINGHE, PB., BOERSMA, M. and VIJVERBERG, J. The effect of temperature, and food quantity and quality on the growth and development rates in laboratory-cultured copepods and cladocerans from a Sri Lankan reservoir. *Hydrobiologia*, 1997, vol. 350, p. 131-144.
- ANGELER, D., ALVAREZ-COBELAS, M., ROJOS, C. and SÁNCHEZ-CARRILLOS, S. The significance of water inputs to plankton biomass and trophic relationships in semi-arid freshwater (central Spain). *J. Plankton Res.*, 2000, vol. 22, no. 11, p. 2075-2093.
- ANGELER, DG., MARTIN, S. and MORENO, JM. *Daphnia* emergence: a sensitive indicator of fire-retardant stress in temporary wetlands. *Environment International*, 2005, vol. 31, no. 4, p. 615-620.
- BARBOSA, JEL., BORDINI, JÁ. and WATANABE, T. *Interferência de alterações climáticas globais no funcionamento de um açude do trópico semi-árido paraibano*. São Carlos: UFSCar, 2002. 46 p.
- CEBALLOS, BSO. *Utilização de indicadores microbiológicos na tipologia de ecossistemas aquáticos do trópico semi-árido*. São Paulo: USP, 1995. [PhD Thesis].
- CLARKE, KR and WARWICK, RM. *Change in marine communities: an approach to statistical analysis and interpretation*. 2 ed. Plymouth: PRIMER-E, 2001.
- CLESCERI, LS., GREENBERG, AE. and EATON, AD. *Standard methods for the examination of water and wastewater*. 20 ed. Baltimore: American Public Health Association / American Works Association / Water Environment Federation, 1998. 1325 p.
- COSTA, IAS. *Dinâmica de populações de cianobactérias em um reservatório eutrofizado do semi-árido nordestino brasileiro*. São Carlos: UFSCar, 2003. [PhD Thesis].
- CRISPIM, MC. and WATANABE, T. Heterogeneidade no ecossistema lacustre, baseado na comunidade zooplânctônica de açudes. In: *Anais do V Simpósio de Ecossistemas Brasileiros: Conservação*. Vitória: UFES, 2000a, vol. 3, p. 431-441.
- CRISPIM, MC. and WATANABE, T. Ovos de resistência de rotíferos presentes em sedimentos secos de um açude no semi-árido paraibano. *Acta Limnol. Bras.*, 2000b, vol. 12, p. 89-94.
- CRISPIM, MC. and WATANABE, T. What can dry reservoir sediments in a semi-arid region in Brazil tell us about cladocera? *Hydrobiologia*, 2001, vol. 442, p. 101-105.
- CRISPIM, MC. and FREITAS, GTP. Seasonal effects on zooplankton community in a temporary lagoon of northeast Brazil. *Acta Limnol. Bras.*, 2005, vol. 17, no. 4, p. 385-393.
- CRISPIM, MC., PAZ, RJD. and WATANABE, T. Comparison of different *Moina minuta* populations dynamics eclosed from resting eggs in a semi-arid region in Brazil. *Braz. J. Ecol.*, 2003, vol. 1/2, p. 33-38.
- EL MOOR-LOUREIRO, LMA. *Manual de identificação dos cladóceros límnicos do Brasil*. Brasília: UCB, 1997. 100 p.
- ESKINAZI-SANT'ANNA, EM., MENEZES, R., COSTA, IS., PANOSSO, RF, ARAÚJO, MF. and ATTAYDE, JL. Composição da comunidade zooplânctônica em reservatórios eutróficos do semi-árido do Rio Grande do Norte. *Oecol. Bras.*, 2007, vol. 11, no. 3, p. 410-421.
- ESTEVES, FA. *Fundamentos de Limnologia*. 2 ed. Rio de Janeiro: Interciência-FINEP, 1998. 602 p.
- ESTEVES, FA. and SENDACZ, S. Relações entre a biomassa do zooplâncton e o estado trófico de reservatórios do estado de São Paulo. *Acta Limnol. Bras.*, 1988, vol. 2, p. 587-604.
- FELICIANO, MLM. and MELO, RB. *Atlas do estado da Paraíba: informação para gestão do patrimônio natural*. João Pessoa: SEPLAN/IDEME, 2003. 58 p.
- FISHER, SG. and GRIMM, NB. Streams and disturbance: are cross-ecosystems comparisons useful? In: COLE, JC., LOVETT, GM. and FINDLAY, SEG. (eds). *Comparative analysis of ecosystems: patterns, mechanisms and theories*. New York: Springer-Verlag, 1991. p. 196-221.
- FREITAS, GTP, CRISPIM, MC. and HERNÁNDEZ, MIM. Changes in life-history parameters of cladoceran *Ceriodaphnia cornuta* (Sars, 1886) in the presence of *Chaoborus* larvae. *Acta Limnol. Bras.*, 2007, vol. 19, no. 3, p. 295-303.
- GANNON, JE. and STEMBERGER, RS. Zooplankton (especially Crustaceans and Rotifers) as indicators of water quality. *Trans. Amer. Micros. Soc.*, 1978, vol. 97, no. 1, p. 16-35.
- GOLTERMAN, HL., CLYMO, RS. and OHNSTAD, MAM. *Methods for physical and chemical analysis of freshwaters*. 2 ed. Oxford: Blackwell, 1978. 213 p.
- HAMBRIGHT, KD., TREBATOSKI, RJ. and DRENNER, RW. Experimental study of the impacts of Bluegill (*Lepomis macrochirus*) and Largemouth Bass (*Micropterus salmoides*) on pond community structure. *Canadian Journal of Fisheries and Aquatic Sciences*, 1986, vol. 43, p. 1171-1177.
- HANEY, JS. and HALL, DJ. Sugar-coated *Daphnia*: a preservation technique for Cladocera. *Limnol. Oceanogr.*, 1973, vol. 18, no. 2, p. 331-333.

- KOSTE, W. *Rotatoria*: Die Rädertiere Mitteleuropas ein Bestimmungswerk begründet von Max Voigt: Monogononta. Berlin: Gerbruder Borntrëgger, 1978. 1147 p.
- KOSTE, W. Rotatorien aus Gewässern Amazoniens. *Amazoniana*, 1972, vol. 3, no. 3/4, p. 258-505.
- KUCZYNSKA-KIPPEN, N. and NAGENGAST, B. The influence of the spatial structure of hydromacrophytes and differentiating habitat on the structure of rotifer and cladoceran communities. *Hydrobiologia*, 2006, vol. 559, p.203-212.
- LAMPERT, W. Feeding and nutrition in *Daphnia*. *Mem. Ist. Ital. Idrobiol.*, 1987, vol. 45, p. 143-192.
- LEITÃO, AC., FREIRE, RHE, ROCHA, O. and SANTAELLA, ST. Zooplankton community composition and abundance of two Brazilian semiarid reservoirs. *Acta Limnol. Bras.* 2006, vol. 18, no. 4, p. 451-468.
- MAEMETS, A. Indirect effect of planktivorous fish on the growth and reproduction of *Daphnia galeata*. *Hydrobiologia*, 1983, vol. 225, p. 193-197.
- MALTCHIK, L. Biodiversidade e estabilidade em lagos do semi-árido. *Ciência Hoje*, 1999, vol. 25, no. 148, p. 64-67.
- MOREDJO, A. *Avaliação dos efeitos das atividades humanas sobre o estado trófico dos açudes paraibanos, com ênfase na utilização da comunidade zooplactônica como bioindicador*. Paraíba: João Pessoa-PRODEMA/UFPB, 1998. 137 p. [Master Thesis].
- MURA, G. and BRECCIAROLI, B. The zooplankton crustacean of the temporary waterbodies of the Oasis of Palo (Rome, central Italy). *Hydrobiologia*, 2003, vol. 495, p. 93-102.
- NORDI, N. and WATANABE, T. Nota preliminar sobre os rotíferos (zooplâncton) do açude Epitácio Pessoa, Boqueirão, Paraíba. *Revista Nordestina de Biologia*, 1978, vol. 1, no. 1, p. 31-39.
- PARAÍBA, Secretaria de Planejamento. *Avaliação da infra-estrutura hídrica e do suporte para o sistema de gerenciamento de recursos hídricos do Estado da Paraíba*. João Pessoa: SEPLAN, 1997. 144 p.
- PEJLER, B. Zooplankton indicators of trophy and their food. *Hydrobiologia*, 1983, vol. 101, p. 111-114.
- PÉREZ-MARTÍNEZ, C., MORLES-BAQUERO, R. and SANCHEZ-CASTILLO, P. The effect of the volume decreasing on the trophic status in four reservoirs in Southern Spain. *Verh. Internat. Verein. Limnol.*, 1991, vol. 24, no. 3, p. 1382-1385.
- PORTER, KG., ORKUTT, JD. and GERRITSEN, J. Functional response and fitness in a generalist filter feeder, *Daphnia magna* (Cladocera: Crustacea). *Ecology*, 1983, vol. 64, p. 735-742.
- PRIMER-E. *Primer - Plymouth Routines in Multivariate Ecological Research*. (Beta R3). [S.l.]: PRIMER-E Ltd, 2004. [Computer Program].
- REIS, ACS. Clima da Caatinga. *Anais Acad. Bras. Ciências*, 1976, vol. 48, no. 2, p. 325-335.
- ROCHA, O., MATSUMURA-TUNDISI, T. and TUNDISI, JG. Seasonal Fluctuation of *Argyrodiaptomus furcatus* populations in Lobo reservoir (São Carlos, SP-Brazil). *Tropical Ecology*, 1982, vol. 23, no. 1, p. 134-150.
- RUTTNER-KOLISKO, A. Plankton Rotifers: Biology and Taxonomy. *Die Binnengewässer*, 1974, vol. 26, no. 1, p. 1-146.
- SILVA AMA., MEDEIROS, PR., SILVA, MCBC. and BARBOSA, JEL. Diel vertical migration and distribution of zooplankton in a tropical Brazilian reservoir. *Biotemas*, 2009, vol. 22, no. 1, p. 49-57.
- SOKAL, RR. and ROHLF, FJ. *Biometry: The principles and practice in biological research*. 2 ed. New York: WH. Freeman, 1980. 859 p.
- STANSFIELD, JH. Submerged macrophytes as refuges for grazing Cladocera against fish predation: observations on seasonal changes in relation to macrophyte cover and predation pressure. *Hydrobiologia*, 1997, vol. 342/343, p. 229-240.
- STATSOFT Inc. *Statistica for Windows*. Tulsa: Statsoft Inc. [Computer Program]
- TIMMS, RM. and MOSS, B. Prevention of growth of potentially dense phytoplankton populations by zooplankton grazing, in the presence of zooplanktivorous fish, in a shallow wetland system. *Limnol. Oceanogr.*, 1984, vol. 29, p. 472-486.
- TOLEDO Jr., AP., TALARICO, M., CHINEZ, SJ. and AGUDO, EG. Aplicação de modelos simplificados para a avaliação de processos de eutroficação em lagos e reservatórios tropicais. In: *Anais do 12º Congresso Brasileiro de Engenharia Sanitária*. Camboriú, SC: Associação Brasileira de Engenharia Sanitária, 1983. p. 34.
- VIEIRA, DM., CRISPIM, MC. and WATANABE, T. Impacto da cheia e da seca sobre a comunidade zooplactônica do açude São José dos Cordeiros no semi-árido paraibano. In: *Anais do V Simpósio de Ecossistemas Brasileiros*. Vitória, ES: ACIESP, 2000. (pub. no. 109), p. 401-407.
- WALZ, N. Rotifers populations in plankton communities. Energetics and life history strategies. *Experientia*, 1995, vol. 51, p. 437-453.
- WALZ, N. and WELKER, M. Plankton development in rapidly flushed lake in the River Spree system (Neundorfer See, Northeast German). *Journal of Plankton Research*, 1998, vol. 20, p. 2071-2087.
- WILLIAMS, WD. Biotic adaptations in temporary lentic waters, with special reference to those in semi-arid and arid regions. *Hydrobiologia*, 1987, vol. 125, p. 85-110.

Received: 02 October 2008
Accepted: 01 September 2009