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Distribution of planktonic cladocerans (Crustacea: Branchiopoda) of a shallow eutrophic reservoir (Paraná State, Brazil)

ANDRÉ RICARDO GHIDINI[1]; MOACYR SERAFIM-JÚNIOR[2]; GILMAR PERBICHE-NEVES[3] & LINEU DE BRITO[4]

[1]Programa de Pós-Graduação em Biologia Tropical e Recursos Naturais, Instituto Nacional de Pesquisas da Amazônia/Universidade Federal do Amazonas. André Araújo Avenue, nº 2638, Manaus, Amazonas, Brazil. CEP: 69060-001. Email: arghidini@yahoo.com.br.
[2]Universidade Federal do Recôncavo da Bahia, Centro de Ciências Agrárias, Ambientais e Biológicas – Núcleo de Estudos em Pesca e Aqüicultura (NEPA), CEP 44380-000, Cruz das Almas, BA. Email: moa.cwb@gmail.com
[3]Curso de Pós Graduação em Zoologia, Universidade Estadual Paulista "Júlio de Mesquita Filho" - UNESP, Distrito de Rubião Jr., s/nº, Botucatu, São Paulo, Brazil, CEP: 18618-000. Email: gilmarpneves@yahoo.com.br
[4]Universidade Federal do Paraná, Centro de Estudos do Mar, Beira-Mar Avenue, s/no, Pontal do Sul, Paraná, Brazil. CEP: 83255-000. Email:lineubrito@yahoo.com.br

Abstract. This study focused the spatial and temporal distribution of the composition, abundance, and diversity of planktonic cladocerans from eutrophic, Iraí Reservoir, as well as their relationships with some biotic and abiotic variables. The tested hypothesis was that cladocerans present higher variation in a temporal than in a spatial scale. The samples were taken monthly in 6 stations, from March/02 to July/03. Twenty-four taxa were identified, distributed in 7 families, the richest families being Daphniidae (6 spp.), Chydoridae (6 spp.), and Bosminidae (5 spp.). The most frequent and abundant species were *Bosmina hagmanni*, *Moina minuta,* and *Ceriodaphnia cornuta*. The highest abundances were found in September/2002. Temporally, rainfall influenced organism's distribution, while spatially cladocerans were more affected by reservoir hydrodynamics and wind action. The low species richness could be a reflection of the trophic state of the reservoir, in which a dominance of Cyanobacteria was observed during that study period. Both scales showed high variation, but only the temporal scale showed significant difference to richness and abundance. Nearby the end of this study, higher stable values of species richness were recorded, which could suggest an increase in the water quality due to des-pollutions actions.

Keywords: Cladocera, Iguaçu River basin, Iraí Reservoir, eutrophication, Cyanobacteria.

Resumo. Distribuição de cladóceros planctônicos (Crustacea: Branchiopoda) em um reservatório eutrófico raso (Paraná, Brasil). Esse estudo enfocou a distribuição espacial e temporal da composição, abundância e diversidade de cladóceros planctônicos em um reservatório eutrófico, reservatório do Iraí, bem como suas relações com variáveis bióticas e abióticas. A hipótese testada foi que os cladóceros apresentam maior variação em escala temporal do que espacial. As amostragens foram realizadas mensalmente em seis estações, entre março/02 e julho/03. Vinte e quatro táxons foram identificados, distribuídos em sete famílias, sendo Daphniidae (6 spp.), Chydoridae (6 spp.) e Bosminidae (5 spp.) as que ativeram maior número de espécies registradas. As espécies mais freqüentes e abundantes foram *Bosmina hagmanni*, *Moina minuta* e *Ceriodaphnia cornuta*. A maior abundância foi registrada em setembro/02. Temporalmente a pluviosidade influenciou a distribuição dos organismos, enquanto espacialmente os cladóceros foram mais afetados pela hidrodinâmica do reservatório e pela ação do vento. A baixa riqueza de espécies pode ser um reflexo do estado trófico do reservatório, no qual a dominância de Cyanobacteria foi observada quase que constantemente. Ambas as escalas apresentaram elevadas variações, porém somente a temporal apresentou diferença significativa para a riqueza e abundância. Próximo do final deste estudo, maiores valores estáveis de riqueza de espécies foram verificados, a qual pode sugerir uma melhoria na qualidade de água devido a ações de despoluição.

Palavras-chave: Cladocera, rio Iguaçu, reservatório do Irai, eutrofização, Cyanobacteria.

Introduction

The importance of continental aquatic ecosystems as a source of freshwater to human populations is unquestionable. However, anthropogenic activities have been degrading these environments and the water quality, altering its physical, chemical, and biological properties, a phenomenon called eutrophication (Bollmann & Andreoli 2005).

Changes in the nutrients dynamics of a water body alter the decomposition and production processes that directly affect the consumption. This fact can be evidenced studying planktonic microcrustaceans since its life cycle, development, and reproduction are influenced by biotic and abiotic factors of the environment (Branco & Cavalcanti 1999, Bini *et al*. 2008).

In tropical environments, rain and wind action are the major forces influencing cladocerans population structure, promoting the water column mixing, and stimulating nutrient cycling (Lopes *et al.* 1997, Sampaio *et al*. 2002). Factors as pH, dissolved oxygen, and nutrients (especially P and N) directly affect these organisms, because they strongly influence phytoplankton development (Bonecker *et al*. 2001, Matsumura-Tundisi & Tundisi 2003, 2005). Furthermore, cladocerans populations can oscillate in response to predation by other groups, like insect's larvae and small fishes (Meschiatti & Arcifa 2002).

Most cladocerans are herbivorous and phytoplankton feeders, transferring energy to higher trophic levels (Melão 1999). This is the reason why generalist's cladocerans species are able to develop in a high number of environments, like species of the Bosminidae family. Some large cladocerans (Sididae and Daphniidae families) have preference on the food item ingested, and they became more selective when there is food limitation (DeMott & Kerfoot 1982, Ferrão-Filho *et al*. 2003). Filamentous algae and presence of toxins affect cladocerans growth and filtering rates, besides to increase mortality and polymorphism, which in a spatial-temporal scale influences the composition, distribution and species succession (Ferrão-Filho & Azevedo 2003). This is particularly important in eutrophic reservoirs where food availability from cladocerans changes with time since cyanobacteria blooms, which occur during almost the whole annual cycle, can develop toxicity (Ferrão-Filho *et al.* 2003).

Temporal-spatial variations of microcrustaceans in Brazilian reservoirs have been extensively studied (Bonecker *et al*. 2001, Sampaio *et al.* 2002, Matsumura-Tundisi & Tundisi 2003, 2005, Corgosinho & Pinto-Coelho 2006). However, in small and eutrophic reservoirs, as the case of Iraí Reservoir and which is the aim of this study, the relationships between cladocerans assemblages and limnological factors (biotic and abiotic) are poorly known besides they can affect population structure. Lansac-Tôha *et al*. (2005), Velho *et al.* (2005), Serafim-Júnior *et al*. (2005) and Perbiche-Neves *et al*. (2007) studied this reservoir and attributed the homogeneity of zooplanktonic assemblages to the low depth, long residence time and elevated production, with the dominance of cyanobacteria. Pinto-Coelho *et al*. (1999) made similar observations to Pampulha Reservoir (MG), which is small, eutrophic and located in a region of strong urbanization. In small, shallow and polymictic reservoirs, Henry (1999) highlighted the wind action effects on the water column, where daily or temporary stratifications can occur, but they are subjected to the vertical homogenization in most part of the year.

The comprehension of the relationship between cladocerans assemblages and environmental conditions are important to the development of ecological tools used in management techniques and environmental restoration of eutrophic reservoirs. Also, the knowledge of those relations could be useful to understand Cladocera ecology in sub-tropical reservoirs, nevertheless used to water supply to the city of Curitiba and metropolitan region, composed of *ca*. 3.5 million habitants. The hypothesis tested in this study was that cladocerans variation occurs mainly in a temporal than in a spatial scale, associated to the small size of the reservoir, being a homogeneous assemblage, due the its relation to some limnological variables and specially to phytoplankton community, because their food item selectivity. The aim of this work was to describe: (i) the temporal-spatial distribution of some ecological attributes of cladocerans populations and the major limnological variables influencing them; (ii) the intensity of eutrophication that affect these organisms, and (iii) the relation between cladocerans and the phytoplankton community.

Material and Methods

Study area. The Iraí Reservoir (25º 25'49''S and 49º 06'40''W) is located in the basin of higher Iguaçu River among the cities of Pinhais, Piraquara, and Quatro Barras. It occupies an area of 14 km^2 in the alluvial plain of Iraí River. The mean water volume is $58x10^6$ m^{-3}, the theoretical residence time is 300 to 450 days, and the mean depth is 4 m. (Z_{max}=10 m). The margins are not vegetated, being composed mainly by pastureland (Andreoli & Carneiro 2005).

Iraí Reservoir was built in 2001 and its morphometrical and hydrological features have been causing Cyanobacteria proliferation since its filling, complicating water treatment and reducing water quality (Andreoli & Carneiro 2005).

One of the four main tributaries (Timbú River) is characterized by an elevated nutrient load, especially of phosphorus and nitrogen, due to the disordered urban occupation of the drainage basin. This fact, associated to the high residence time and low dept of the reservoir favored the development of blooms of Cyanobacteria, as *Anabaena* sp., *Cylindrospermopsis* sp., and *Microcystis* sp., promoting significantly changes in the water quality of the reservoir (Bollmann & Andreoli 2005).

Field work, samples and data analyses. The samples were obtained monthly from March/2002 to July/2003 in six stations in the reservoir, totalizing 102 samples. Stations 1, 2 and 3 were located in the dam axis (stations 1 and 3, Z_{max}= 4 m; station 2, Z_{max}= 8 m), and the others were in the main body the reservoir (stations 4, 5, and 6, Z_{max}= 3 m) (Fig. 1).

Two-hundred liters of sub surface water (due to low depth) were filtered in a conical plankton net (55 µm mesh size), using a motorized pump. The samples were narcotized with 4 % buffered formalin. Countings were made through subsamples of 1 mL using Stempel pipette, and a minimum of 200 individuals were counted per sample in a Sedgewick-Rafter chamber under optical microscope. Cladocerans are usually quantified in acrylic gridded Petri dishes using stereomicroscope. However, in this study, countings in Sedgewick-Rafter were possible due to the elevate number of small organisms. Identification of species was based in specialized literature, as Matsumura-Tundisi (1984), Elmoor-Loureiro (1998; 2007), Hollwedel *et al.* (2003) and Elmoor-Loureiro *et al.* (2004). Abundance data were expressed as individuals.m^{-3}.

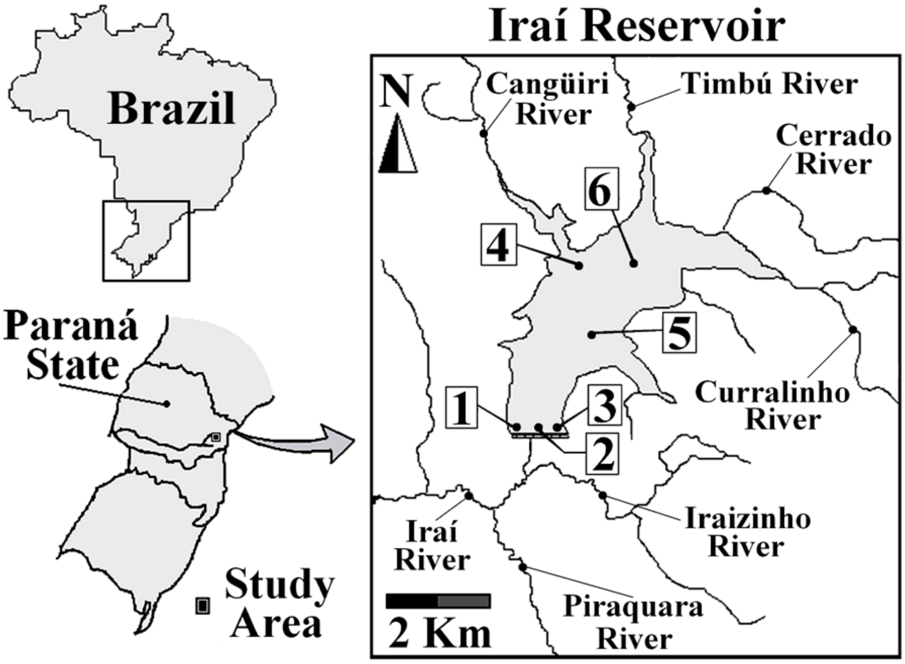

Figure 1. Localization of Iraí Reservoir (Paraná State) and of sampling stations

Non-parametric tests were used after Shapiro-Wilk normality test have indicated a not normal distribution. Organism's richness and abundance were analyzed using H Kruskal-Wallis ANOVA test ($p < 0.05$) to detect significant variations between sampling stations and months. Biotic and abiotic variables for limnological characterization were not different among the stations ($p > 0.05$). It was used data of station 2, in middle dam zone. Biotic and abiotic variables were related to the cladocerans abundance. Phytoplankton species abundance and cladocerans abundance interactions were analyzed using the Spearman correlation ($p < 0.05$). Due to the elevate number of statistical analyses applied, multiple comparisons tests between the means of analyzed categories were used to avoid error type I on null hypothesis. Multiple comparisons analyses of "p" values (Z, $p > 0.05$) were performed on the significance tests of H Kruskal-Wallis ANOVA and Bonferroni correction (β, $p > 0.05$) on Spearman correlations. Despite the corrections, infringements about null hypothesis were not significant. Biotic and abiotic variables were correlated with Cladocera using Factorial Analysis ($p < 0.05$) with extraction by Principal Component Analysis. Mantel test with 1000 permutations for dissimilarity matrices between cladocerans data versus phytoplankton data (also with Bray Curtis distances) versus abiotic data (with Euclidian distances) was performed, but a significant correlation was not obtained. Factorial Analysis was performed using Statistic 6.0 software (Statsoft 2002), and the other analyses were carried out using "R Development Core Team" (2009).

Data of abundance, composition and phytoplankton biomass, and water physical-chemical parameters (chlorophyll-a, pH, temperature, dissolved oxygen, electric conductivity, turbidity, organic nitrogen and total phosphorus) were obtained in same stations and months through the data base of "Projeto multidisciplinar de pesquisa em eutrofização de águas de abastecimento público".

For further details of sampling methodologies and analyses, as well as the responsible authors, see Andreoli & Carneiro (2005). Monthly mean pluviosity was obtained from data base of Technological Institute SIMEPAR.

Results

Species richness (S) values varied significantly during the studied months (H=71.23, $p < 0.00$), with lower mean value in March/2002 (S = 4.2), and higher mean value in December/2002 (S = 12) and November/2002 (S = 11.5). From November/2002 to February/2003 (rainy season), the highest means, maximum values and variation (standard deviation and min/max) in species richness were observed among the stations (Table I). After this, richness tended to stability from July (S: 7.5-10; mean: 8.7). Significant spatial variation of richness was not observed (H = 1.59, p = 0.97, Z = p > 0.05).

Table I. Cladocerans richness species (Mean, Standard deviation - SD and Minimum/Maximum - Min/Max) at Iraí Reservoir from March/2002 and July/2003 (N = 102).

2002	Mean	SD	Min/Max	2003	Mean	SD	Min/Max
Mar	4.2	±1.17	3-6	Jan	10.8	±2.64	8-15
Apr	6.0	±1.26	4-8	Feb	9.5	±1.64	7-12
May	5.5	±1.52	4-8	Mar	7.5	±1.05	6-9
Jun	6.7	±0.82	6-8	Apr	8.3	±2.16	5-11
Jul	6.5	±1.38	6-8	May	9.3	±1.63	9-12
Aug	6.3	±1.63	4-9	Jun	10.0	±0.63	9-11
Sep	7.7	±1.51	6-10	Jul	7.7	±2.07	8-11
Oct	8.8	±1.47	7-11				
Nov	11.5	±1.87	9-14				
Dec	12.0	±1.79	9-13				

A total of 24 species was identified (Table II). The most frequent cladocerans species in the samples were *Bosmina hagmanni* (94%), followed by *Moina minuta* (84%), *Ceriodaphnia cornuta* (70%), *Bosmina longirostris* (67%), and *Ceriodaphnia silvestrii* (64%). *Bosmina hagmanni* was also the most abundant species during the whole study period (relative abundance = 65 %). Chydoridae and Daphniidae families presented higher richness (six species), and the last family was the most abundant. Five Bosminidae species were recorded (Table II).

In a temporal scale, a significant difference in cladoceran abundance was observed along the studied months ($p < 0.00$, H = 70.68), but with no distinguished pattern of variation. Lower abundances were found in March/2002 and 2003, and in June and July/2003. A peak of abundance was observed in September/2002, and to the following months, elevated densities were observed until January/2003. In May/2003 values also increased (Fig. 2).

Most cladocerans species, mainly the more abundant, followed the variation showed in Figure 2. The variation was especially evident to smaller cladocerans, as *B. hagmanni* responsible for the density peak during September/2002, when densities were more than 12 fold higher compared to previous months (≈ 600,000 org.m^{-3}). In October/2002, abundance of that species decreased progressively until its absence in March and April/2003. *Moina minuta* higher densities were found in May/2002 (≈ 55,000 org.m^{-3}), and population declined in August and September/2002. A peak of *Ceriodaphnia cornuta* was observed in October/2002 (≈ 60,000 org.m^{-3}).

Table II. Recorded species at Iraí Reservoir, relative abundances (Ab %), and frequency of occurrence (Fr %) in the samples, from March/2002 to July/2004.

Taxa	Ab%	Fr%	Taxa	Ab%	Fr%
Bosminidae			**Ilyocryptidae**		
Bosmina hagmanni Stingelin, 1904	65.4	94.1	*Ilyocryptus spinifer* Herrick, 1882	<0.1	3.3
Bosmina huaronensis Delachaux, 1918	2.3	40.3	**Macrothricidae**		
Bosmina longirostris Müller, 1785	4.8	58.8	*Macrothrix squamosa* Sars, 1901	<0.1	0.8
Bosmina tubicen Brehm, 1953	<0.1	2.5	**Moinidae**		
Bosminopsis deitersi Richard, 1895	1.5	40.3	*Moina micrura* Kurz, 1874	<0.1	3.3
Chydoridae			*Moina minuta* Hansen, 1899	6.6	84.0
Alona guttata Sars, 1862	<0.1	10.0	*Moinodaphnia macleayi* King, 1853	<0.1	0.8
Alona intermedia Sars, 1862	<0.1	2.5	**Sididae**		
Alona monocantha Sars, 1901	0.1	15.1	*Diaphanossoma birgei* Korineck 1981	0.4	35.2
Alonella dadayi Birge, 1910	<0.1	3.4	*Diaphanossoma brevireme* Sars 1901	0.1	11.7
Chydorus eurynotus Sars, 1901	1.3	37.8	*Diaphanossoma spinulosum* Herbst, 1967	0.1	11.7
Chydorus nitidulus Sars, 1901	0.2	11.7			
Daphniidae					
Ceriodaphnia cornuta Sars, 1886	5.0	73.1			
Ceriodaphnia cf. *laticaudata* Müller, 1867	0.6	24.3			
Ceriodaphnia reticulata Jurine, 1820	2.7	43.7			
Ceriodaphnia silvestrii Daday, 1902	3.7	72.2			
Daphnia gessneri Herbst, 1967	<0.1	8.4			

Considering larger cladocerans (> 1.00 mm), their densities were less representative compared to smaller species. *Diaphanosoma birgei* reached a peak in November/2002 (≈ 2,000 org.m^{-3}) and was always recorded since then. This species was absent in the previous samples (June, August, and September/2002). *Daphnia gessneri* was not found in the first months, appearing in the samples in October/2002, with increasing populations densities in the following months.

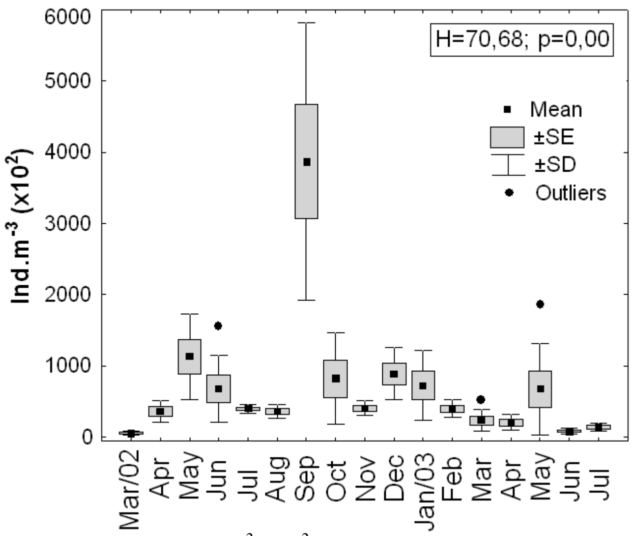

Figure 2. Cladocerans mean densities (individuals.m^{-3} x10^3) from March/2002 to July/2003, at Iraí Reservoir (N=102).

Inside Iraí Reservoir, *B. hagmanni* population densities were, generally, slightly higher in stations 1 and 3, located in the left and right margins of the dam, while *C. cornuta* was more abundant at station 5, followed by stations 1 and 3. Some larger species, like *D. birgei,* presented elevated maximum abundances in stations 4 and 5, and *D. gessneri* in station 6 (Fig. 3). It was not detected any significant difference between total and species abundance among sampling stations (H = 4.54, p = 0.60, Z = p > 0.05).

Significative Spearman correlation (R) between dominant cladocerans abundance and phytoplankton densities showed positive correlation with two *Ceriodaphnia* and two Chydoridae species with densities of *Microcystis aeruginosa*, one of the most abundant Cyanobacteria present in the reservoir in this study. There were no positive correlations between cladocerans and the other algae genera (β = p > 0.05) (Table III).

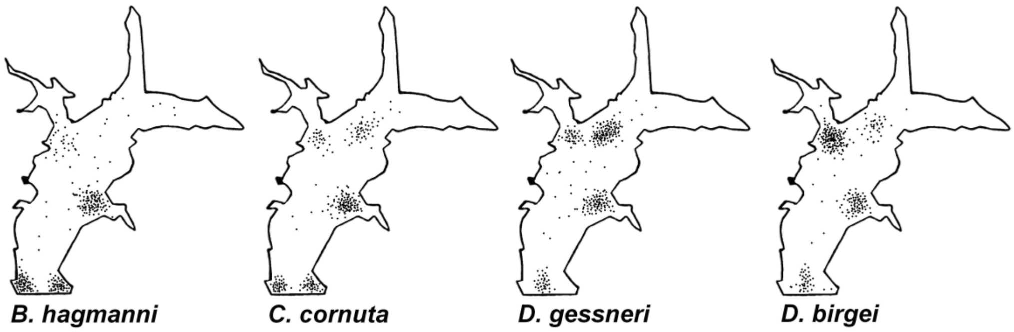

Figure 3. Spatial distribution of some cladocerans species inside Iraí Reservoir. Dark paths represent higher mean abundances from March/2002 to July/2003. For localization of stations sampling, see Figure 1.

Table III. Significative Spearman correlations between cladocerans and phytoplankton considering the mean population density during the studied period (p<0.05). Aual- *Aulacoseira alpigena,* Miae- *Microcystis aeruginosa,* Momi- *Monoraphidium minutum*, Peum- *Peridinium umbonatum*, Scen- *Scenedesmus sp.*, Tetr- *Tetraedon sp*, Uros- *Urosolenia sp*.

	Aual	Miae	Momi	Peum	Scen	Tetr	Uros
C. cornuta		0.72		-0.63	-0.72		
C. reticulata	-0.63				-0.69		
C. silvestrii		0.73			-0.76	-0.64	
C. eurynotus		0.73			-0.79	-0.67	
C. nitidilus		0.79		-0.69	-0.71	-0.72	
D. gessneri	-0.79		-0.77			-0.66	
D. birgei							-0.79
D. brevireme							-0.75

Spearman correlations were not significant (p < 0.05) among environmental variables (dissolved oxygen, pH, electric conductivity, total phosphorus, organic nitrogen, water transparency, and chlorophyll-a) and cladocerans population densities (β = p > 0.05). Results from Factor Analysis (Factor 1: 31.59%, Factor 2: 22.10%) indicated a close relation between cladoceran abundance and mean pluviosity (Fig. 4). Slightly correlation among Cladocera with phytoplankton and turbidity in the second factor were observed.

The pluviometric means at Iraí Reservoir region showed an increase in rainfall episodes in September/2002, indicating the beginning of rainy period (Fig. 5). In the same month, the peak of *B. hagmanni* density was observed in station 2, calling attention a peak in phytoplankton abundance one month before (August/2002). In dry period of 2002 (May from August) were recorded a decrease in the pluviometric indexes, as to April to June of 2003, when cladocerans abundances were also low, except in May/2003.

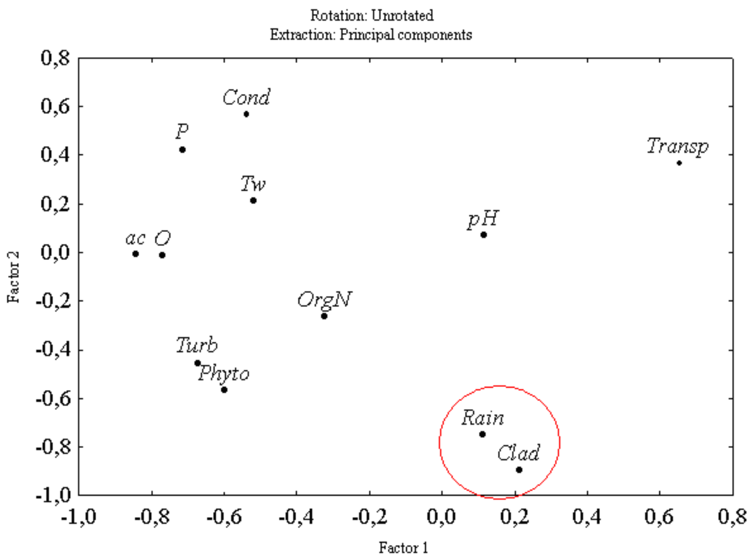

Figure 4. 2D loadings for factors 1 and 2 of the Factor Analysis of station 2. ac: a-chlorophyll; Clad: cladocerans total density; Cond: electrical conductivity; O: dissolved oxygen; OrgN: organic nitrogen; Phyto: phytoplankton's species richness; TotP: total phosphorus; Rain: mean rainfall for each month; Transp: Secchi's transparency; Turb: turbidity; Tw: water temperature.

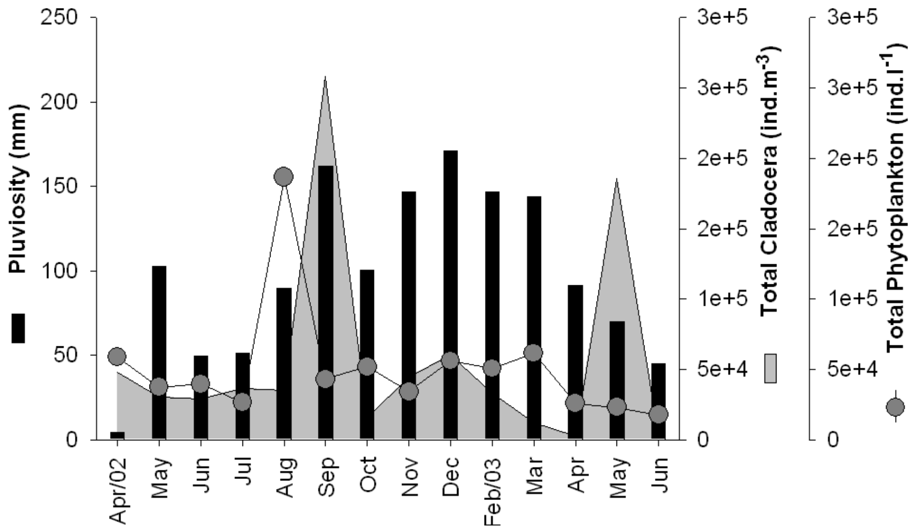

Figure 5. Mean pluviosity, total Cladocera and phytoplankton abundance in station 2 between April/2002 and June/2003.

Discussion

Most species recorded in this study are commonly found in the basin of Paraná River, especially the dominant planktonic, as *B. hagmanni*, *M. minuta,* and *C. cornuta* (Nogueira *et al.*, 2008). These species were also found in other aquatic Brazilian environments (Robertson & Hardy 1984, Santos-Wisniewski *et al.* 2000). In general, Bosminidae, Moinidae, and Daphniidae families are dominant in lenthic aquatic ecosystems like reservoirs as verified by Sampaio *et al*. (2002). Lansac-Tôha *et al*. (2005) also found the dominance of these families at Iraí Reservoir.

Representants of Macrothricidae and Ilyocryptidae families were less common in this study. They living in the littoral zone or nearby (Serafim-Júnior *et al.* 2003), and their presence in limnetic zone is accidental. The same consideration can be done to the Chydoridae family, but *C. eurynotus* and *C. nitidilus* were found in relatively high abundances compared to the other species of this family. Records of Chydoridae in the limnetic zone were found by Paggi & José de Paggi (1990) that considered some *Alona* species as pseudoplanktonic since its abundance was higher in the limnetic zone compared to the littoral zone of river channel and floodplain lakes.

Cladocerans are affected by several factors at Iraí Reservoir, mainly due to its shallowness, presenting a large superficial area as shown in Figure 1. In the beginning of the rainy season, increased nutrients availability to the water column allowed their incorporation by the aquatic communities (Nogueira *et al.* 2008, Serafim-Júnior *et al*. 2005). The low depth and the geomorphology of the reservoir induce organic matter and nutrients accumulation, and consequently, phytoplankton presence in areas next to the margins, favoring the development of small cladocerans. Larger species, however, are distributed in areas far from the dam.

The great amplitude variation of species richness in the rainy season can be related to two factors. First, the spatial heterogeneity of cladocerans, which explore the environment in different ways (Pinel-Alloul 1995), searching for adequate conditions for their development, for example, when an increase in altimetric quote and volume of the reservoir raises food availability and alter the phytoplankton community. Second, rain effect is noticeable because it causes the transport of autochthonous (from littoral zone) and allochtonous materials (from tributaries and other smaller lakes in the same basins). Lansac-Tôha *et al*. (2005) found slightly higher cladocerans richness at Iraí Reservoir during the rainy period.

Generally, there was an increase in cladocerans species richness during this study, possibly reflecting the processes of colonization and stabilization of the water column, a fact also observed in other reservoirs (Esteves & Camargo 1983). A trend of cladoceran temporal variation was observed after November/2002, when a richness peak was observed, followed by stable values, with a mean of 8.7 species. In contrast, in the same period, considering other plankton communities, Fernandes *et al*. (2005) did not find a pattern of species richness variation and abundance of the phytoplankton in Iraí Reservoir, as well as Perbiche-Neves *et al*. (2007) studying copepods. Also despollution actions were made in Iraí drainage basin and it can reflect in better quality water conditions. Elmoor-Loureiro *et al.* (2004) verified similar conditions in Paranoá Reservoir (Brazil), with new cladoceran records after a long period of water quality treatment of this reservoir.

Spatial variation of the most limnological features of the reservoir was very similar and homogeneous (Andreoli & Carneiro 2005), except by the concentration of nitrogenates and phosphates forms due to the tributaries rivers. Except the nutrients, homogeneous conditions can be associated to the constant cladocerans species numbers among sampling stations, probably related to the carrying capacity of the reservoir. Begon (2007) comments about this for ecological communities in general. Generally, in small and shallow reservoirs, two important parameters that promote water column mixing in reservoirs are the tributaries water velocity and wind dynamics. At Iraí Reservoir, wind effect is very important because its action on water surface causes accumulation of nutrients and algae in areas next to the dam (Gobbi *et al.* 2005), also influencing, as an example, the phytoplankton community (Fernandes *et al*. 2005) and the spatial distribution of copepods (Perbiche-Neves *et al*. 2007). Wind can also affect cladocerans spatial distribution, but a significant difference was not detected in the total abundance of cladocerans assemblages, as well as of species richness in this study.

Considering cladoceran temporal abundance peaks, was noticed the dominance of small organisms, especially *B. hagmanni*. In contrast, Elmoor-Loureiro (1988) states that to *B. longirostris*, *B. hagmanni* have never been associated to eutrophic environments and that elevated densities of these species were found in lakes with low nutrients. Thus, *B. hagmanni* dominance can be related with other variables not favorable to the dominance of *B. longirostris*, but detailed studies, as laboratory bioassays must be carried out to evaluate this relations. Dominance of small cladocerans like bosminids in eutrophic reservoirs was also found in other Brazilian studies (Branco & Cavalcanti 1999, Pinto-Coelho *et al.,* 1999, Sendacz *et al.,* 2006). It can be suggested that the dominance of *B. hagmanni* was favored by the eutrophication of Irai Reservoir, because this species corresponded to more than half of the total relative abundance. On the other hand, other species of the Daphniidae, Sididae, and Moinidae families were dominant in oligo/mesotrophic environments like some reservoirs of high Paranapanema River (Nogueira *et al.,* 2008).

Although not so abundant as *B. hagmanni*, *M. minuta* and *C. cornuta* elevated abundances can be explained by the adaptation of these species to food resources. They fed not only on phytoplankton, but also on detritus and bacteria (DeMott & Kerfoot 1982, Dole-Olivier *et al.* 2000). Furthermore, they have a fast development, associated to the high water temperature in the rainy season and to the great offer of food during the whole year at Iraí Reservoir, represented by Cyanobacteria. According to Monakov (2003), predation of cladocerans on bacterioplankton is one of the reasons of the development success of these organisms in adverse conditions. Success of this species was verified in many reservoirs in Paranapanema River (Brazil) (Nogueira *et al*., 2008).

Generally, large cladocerans abundance is low when compared to small cladocerans, however, their biomass is high, balancing the contribution of these organisms to the community (Sendacz *et al*., 2006; Corgosinho & Pinto-Coelho, 2006). Studies indicate that large cladocerans fed on algae, few species are detritivorous, and most species are selective to food quality (DeMott & Kerfoot 1982, de Bernardi *et al.* 1987). Other studies show that herbivory on large phytoplankton, as large colonies of Cyanobacteria by zooplanktonic filter feeders is difficult and energetically poor, especially if it involves algae toxicity (Ferrão-Filho & Azevedo 2003). Considering *Ceriodaphnia cornuta*, a dominant cladoceran in this study, the explanation of the high correlation with *M. aeruginosa* could be the great niche variety that this species could occupy, feeding, in this case, on Cyanobacteria early associated with cyanotoxins in Iraí Reservoir (Fernandes *et al.* 2005).

Ferrão-Filho & Azevedo (2003) found that feeding on colonial (*Microcystis*) and filamentous algae is difficult to small cladocerans and that they feed mainly on individual or in decomposition cells. Apparently, only large cladocerans, as *Daphnia*, are able to feed on individual cells or colonies of *Microcystis* (Rohrlack *et al.* 1999, Nandini 2000). Kobayashi *et al.* (1998) also state that large cladocerans are able to feed efficiently on large *Microcystis* colonies and that this can be influenced not only by alga toxicity, but also by colony disaggregation. The same was observed in Trabeau *et al.* (2004) experiments, that rising alga biovolume and microcystin production observed a decline of *Daphnia* populations, associated to an increase in energetic costs of feeding. Conversely, Alva-Martinez *et al.* (2001) detected an increase of population growth of one species of *Daphnia* and one of *Ceriodaphnia* when fed with increasing concentrations of *Microcystis aeruginosa.* Similar results could be expected in Iraí Reservoir, but laboratory bioassays are needed to test the influence of food on cladocerans populations.

Other phytoplankton species demonstrated negative correlation with cladocerans, as *D. gessneri*, that showed a negative correlation with *A. alpigena*, *M. minutum,* and *Tetraedon* sp. Lampert (1987) states that *Daphnia* feeding apparatus is specialized to feed on nanoplankton (5-60µm, according to Hutchinson 1967), and that ingested algae species can vary with the animal body size. Considering the three cited algae species, they are too large to be consumed by *D. gessneri*, explaining the negative correlation found in this study.

Diaphanosoma birgei and *D. brevireme* showed a negative correlation with the diatomacean *Urosolenia* sp. Despite baccilariophyceans are considered an indispensable food item to cladocerans that feed on periphyton, they are not commonly ingested by planktonic cladocerans (Nogueira *et al.* 2003). In the other hand, for copepods, Perbiche-Neves *et al.* (2007) found a high positive correlation with the diatomaceans during the same period of the present study at Iraí Reservoir.

After *B. hagmanni* peak in September/2002 there was a subsequent decline of *Bosmina* population's densities, when *Microcystis aeruginosa* cells densities was higher within chlorophyll-levels until January/2003. This decline could be related to the difficult of cladocerans in feeding on Cyanobacteria colonies, or due to the toxicity of the alga. The fact that *M. aeruginosa* and cladocerans densities decreased in October/2002 and that cladoceran species richness raised after October can indicate an increase in the food offered to cladocerans. *M. aeruginosa* blooms can also be associated with the population increase or appearance of the larger cladocerans *Daphnia* and *Diaphanosoma* in the lake that could be favored by the development of this alga.

Pinel-Alloul *et al.* (1988), studying the spatial distribution of zooplankton suggests that developmental stage, body size, and periodicity are factors that can influence data obtainment of population density horizontal variation and zooplankton species richness. However, tropical lakes are generally small, shallow, and it is difficult to establish a large scale of spatial heterogeneity (Rocha *et al.* 1995, Sarma *et al.* 2005). In these cases, density and species richness spatial variation can only be determined when adjacent regions of lenthic zones are included in the sampling program. Areas next to the margins, where detritus and cyanobacterians accumulate due the low water flux and wind direction, favor the development of small cladocerans, while larger species find better habitat conditions and greater food diversity in areas far from the dam.

Through the studied months, elevated rain episodes promoted water column mixing, occasioning slightly relation with turbidity in factor analysis, returning nutrients and organic matter to the water column, causing the abundance peak of *B. hagmanni* in September/2002. The water column mixing increased the nutrients availability to the primary producers, and, in this case, high abundance of cyanobacterians favored the appearance and development of larger cladocerans. This can also be associated to an increase of the food quantity and quality available, promoting the development of more species, explaining the elevated cladoceran species richness during the summer of 2002 and 2003 years. But in the absence of higher pluviosity, it was also verified a peak of phytoplankton abundance, like in August/02, represented by strategic cyanobacterians that can development in such conditions.

Both spatial and temporal variations were relevant but the first was not significant, rejecting in part the hypothesis that the temporal variation was more probable. Spatial variation was influenced mainly by morphometrical characteristics of the reservoir, and temporal variation by climatic changes in the sampling period, especially pluviosity and water temperature, very contrasting events in sub-tropical regions. Seasonal and temporal variation of species richness and population densities described in this study probably is due to alterations in the hydrological and biological characteristics of the reservoir. The modifications can be considered responses to natural processes of colonization and to environmental natural changes, or also a result of the management performed by the responsible sanitation company in the reservoir, in consequence of the degradation of water quality.

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