Zooplankton abundance and species diversity in two lakes with different trophic states (Corrientes, Argentina)

Abundância e diversidade específica do zooplâncton em dois lagos com estados tróficos diferentes (Corrientes, Argentina)

Frutos, SM.[1,2], Poi de Neiff[1,2], ASG. and Neiff, JJ.[1]

[1] Centro de Ecología Aplicada del Litoral – CONICET, CP 3400, C.C. 291, Corrientes, Argentina
e-mail: margaritafrutos_587@yahoo.com.ar; jj@neiff.com

[2] Departamento de Biología, FACENA, Universidad Nacional del Nordeste
e-mail: guadalupepoi@gmail.com

Abstract: Aim: In this study, we compare the composition and abundance of zooplankton community between a lake affected by the domestic sewage and in an unaffected lake. We also identified the environmental variables associated with the variation in the most abundant populations and the rotifer species that are indicators of trophic state; **Methods:** Seventeen zooplankton samples (50 L per sample) were filtered through a plankton net (53 µm) in the limnetic zone of each site. Non periodic sampling was carried out between April/92 and March/08, during years with different rainfall regime to include the inter-annual variability; **Results:** Peaks of zooplankton abundance in the eutrophic lake were registered in spring and summer during eutrophication episodes in rainy years. This pattern was not found in the mesotrophic lake. A total of 50 species were registered in the eutrophic lake and 45 species in the mesotrophic lake, with a similarity of 0.71. Species richness was significantly greater in the samples from mesotrophic lake than in those from eutrophic lake. There was no significant difference between the specific diversity of the two lakes. Rotifera was the most abundant group in all samplings in both lakes. The Detrended Correspondence Analysis (DCA) scores indicate that the abundance of *Keratella tecta*, *Filinia* spp., *K. Americana, Trichocerca similis* and *Brachionus havanaensis* was related to eutrophication, whereas the abundance of *Polyarthra dolichoptera*, *Keratella cochlearis, Conochilus* spp., *Brachionus* spp. and *Trichocerca* spp. was related to mesotrophic conditions. The changes in the abundance of the dominant taxa were related to pH and water transparency; **Conclusions:** Our results indicate that the species richness and the relative abundance of dominant species are better indicators of eutrophic degree than total abundance and specific diversity. *K. tecta* can be considered a good indicator of eutrophic state of the lakes when its density exceeds 50% of total zooplankton abundance.

Keywords: eutrophication, subtropical lakes, zooplankton structure, indicator species.

Resumo: Objetivo: Neste artigo comparamos a composição e abundância da comunidade zooplanctônica em um lago afetado por esgoto doméstico e em um lago não afetado. Também foram identificadas as variáveis ambientais associadas à variação nas populações mais abundantes e as espécies de rotíferos, que são indicadores do estado trófico; **Métodos:** Dezessete amostras do zooplâncton (50 L por amostra) foram coletadas e filtradas através de uma rede de plâncton (53 µm) na zona limnética de cada local. Amostragens não periódicas foram realizadas entre abril/92 e março/08, durante anos com diferentes regimes de chuvas para incluir a variabilidade inter-anual; **Resultados:** Os picos de abundância do zooplâncton nos episódios eutróficos foram registrados nos meses de primavera e verão durante anos chuvosos no lago eutrófico. Este padrão não foi encontrado no lago mesotrófico. Um total de 50 espécies foi registrado no lago eutrófico e 45 espécies no lago mesotrófico, com uma similaridade de 0,71. A riqueza de espécies foi significativamente maior no lago mesotrófico do que no lago eutrófico. Não foi constatada diferença significativa entre a diversidade específica dos dois lagos. O grupo Rotífera foi o mais abundante em todas as amostragens em ambos os lagos. A análise Detrended Correspondence Analysis (DCA) indica que a presença de *Keratella tecta, Filinia* spp., *K. similis, K. americana, Trichocerca* spp., e *Brachionus havanaensis* foi relacionada à eutrofização, enquanto a presença de *Polyarthra dolichoptera, Keratella cochlearis, Conochilus* spp., *Brachionus* spp. *e Trichocerca* spp. foi relacionada às condições mesotróficas. As mudanças na abundância dos taxa dominantes foram relacionadas ao pH e à transparência da água; **Conclusões:** Nossos resultados indicam que a riqueza das espécies e a abundância relativa das espécies dominantes são melhores indicadores do grau eutrófico do que a abundância total e a diversidade específica. *K. tecta* pode ser considerada um bom indicador do estado eutrófico dos lagos quando a sua densidade excede 50% da abundância total do zooplâncton.

Palavras-chave: eutrofização, lagos subtropicais, estrutura do zooplâncton, espécies indicadoras.

1. Introduction

Edmonson (1993) indicated that eutrophication has been, and will perhaps continue to be, the most widespread type of environmental pollution in freshwater systems. Lakes and dams in tropical regions have similar eutrophication symptoms to those located in temperate regions. However, tropical waters have some particular physical and chemical characteristics (Tundisi and Matsumura-Tundisi, 2008) and more complex food webs (Lazzaro, 1997). The relationship between the composition and abundance of zooplankton and the trophic state of lakes has been studied in both temperate (Sládecek, 1983; Ravera, 1996; Schiewer, 1998; Erbern et al., 2002; Gerasimova and Pogozhev, 2008) and tropical ecosystems (Matsumura-Tundisi et al., 1990; Pecorari et al., 2006; Sendacz et al., 2006; Tundisi et al., 2008). Several studies have analyzed the structural changes of microcrustacean populations in presence of cyanobacteria blooms (Gliwicz, 1977; Lampert, 1982; Gulati, 1990; Matveev et al. 1994; Matsumura-Tundisi et al., 1997). Changes in the biomass of zooplankton in eutrophic tropical reservoirs were analyzed by Pinto-Coelho et al. (2005) and Sendacz et al. (2006). Other studies have focused on the role of microcrustaceans as indicators of eutrophic state (Rocha et al., 2002). Some rotifer species have been reported as bioindicators of eutrophic condition (Hillbritch-Ilkowska, 1983). Manipulation of food-web structure by controlling planktivorous fish that feed upon large-bodied zooplankton, resulting in enhanced zooplanktonic feeding on phytoplankton, has been widely promoted as a powerful eutrophication management tool (Gulati, 1990; Sendacz and Kubo, 1999; Sampaio et al., 2002; Gerasimova and Pogozhev, 2008).

In Argentina, limnological characteristics of eutrophic waterbodies were reported for reservoirs (Bonetto et al., 1976) and lakes with different salinity conditions (José de Paggi, 1976; José de Paggi and Paggi, 1998; Pecorari et al., 2006; Pedrozo et al., 2007). In northeastern Argentina, eutrophication is frequent in lagoons in urban areas, many of which are used for recreation (Bonetto et al., 1976; Poi de Neiff et al., 1999a; Asselborn et al., 1999; Neiff et al., 2002). Although some of these studies were focused on zooplankton structure, little is known about the changes in the attributes of this community in a long temporal scale comparing lakes with and without human impact.

In this study, we compared the composition and abundance of zooplankton in a lake affected by domestic sewage (eutrophic lake) and an unaffected lake (mesotrophic lake). We also identified the environmental variables associated with the variation in the most abundant populations and the rotifer species that are indicators of the trophic state.

We hypothesized that zooplankton abundance, species richness, rotifer diversity and the relative abundance of the dominant taxa would exhibit different patterns in lakes with different trophic states with respect to changes in the environmental variables.

2. Material and Methods

2.1. Study area

The lakes are adjacent to the urban area of Saladas city (Figure 1), located in Corrientes, Argentina (28° 16′ 14” S and 58° 38′ 21” W). Sanches Lake was categorized as mesotrophic and Soto Lake as eutrophic (Poi de Neiff et al., 1999a) considering the concentration of total nitrogen, total phosphorus, average and maximum concentrations of chlorophyll-*a*, and the water transparency (Ryding and Rast, 1992). The eutrophic lake was affected by different domestic wastewater, although non-point source nutrient load from agricultural areas in the vicinity of the lake may also be contributing to its eutrophication.

Previous investigations have shown that both lakes are mainly supplied with local rainfall, so the relative concentration of the major ions is similar (Poi de Neiff et al., 1999a). During the ENSO (El Niño Southern Oscillation) events that occurred during the study period, the annual rainfall was 1,834 mm (1992) and 1,932 mm (1998), whereas in the year with the least rain, the total rainfall was 1,281 mm (1993). The rainy period occurred during the spring and summer, and the dry period during the winter, according to the mean monthly rainfall for the study period (Figure 2).

Soto Lake had two episodes of eutrophication. The first started in 1992, and it was caused by sewage effluent, coinciding with the construction of a new neighborhood. The second episode occurred in 1998 after the ENSO event, when the entire city was flooded. In both cases, there were distinct chemical changes in the lake, with increases in the concentrations of total phosphorous and nitrogen to 200 and 765 $\mu g.L^{-1}$, respectively, and of chlorophyll-*a* to 220 $\mu g.L^{-1}$. During the second episode there was conspicuous growth of *Microcystis aeruginosa* (Cyanophyta).

In Sanches Lake, maximum total phosphorous, nitrogen and chlorophyll-*a* levels reached to 162, 170 and 35 $\mu g.L^{-1}$, respectively. The spring phytoplankton peak was dominated by Clorophyta and Bacillariophyta. The nitrogen:phosphorous relation indicates a stronger nitrogen limitation in the eutrophic lake than in the mesotrophic lake (Poi de Neiff et al., 1999a).

Thirty four non periodic sampling was carried out from April/92 to March/08, in different seasons (Spring, Summer, Autumn and Winter) during years with different rainfall regime to include the inter-annual variability. Seventeen zooplankton samples in each site (50 L per sample) were filtered through a plankton net (53 μm) in the limnetic zone and preserved in 4% formaldehyde solution.

The Rotifera and larval stages of Copepoda were counted in subsamples in a Sedgwick-Rafter and the adult of

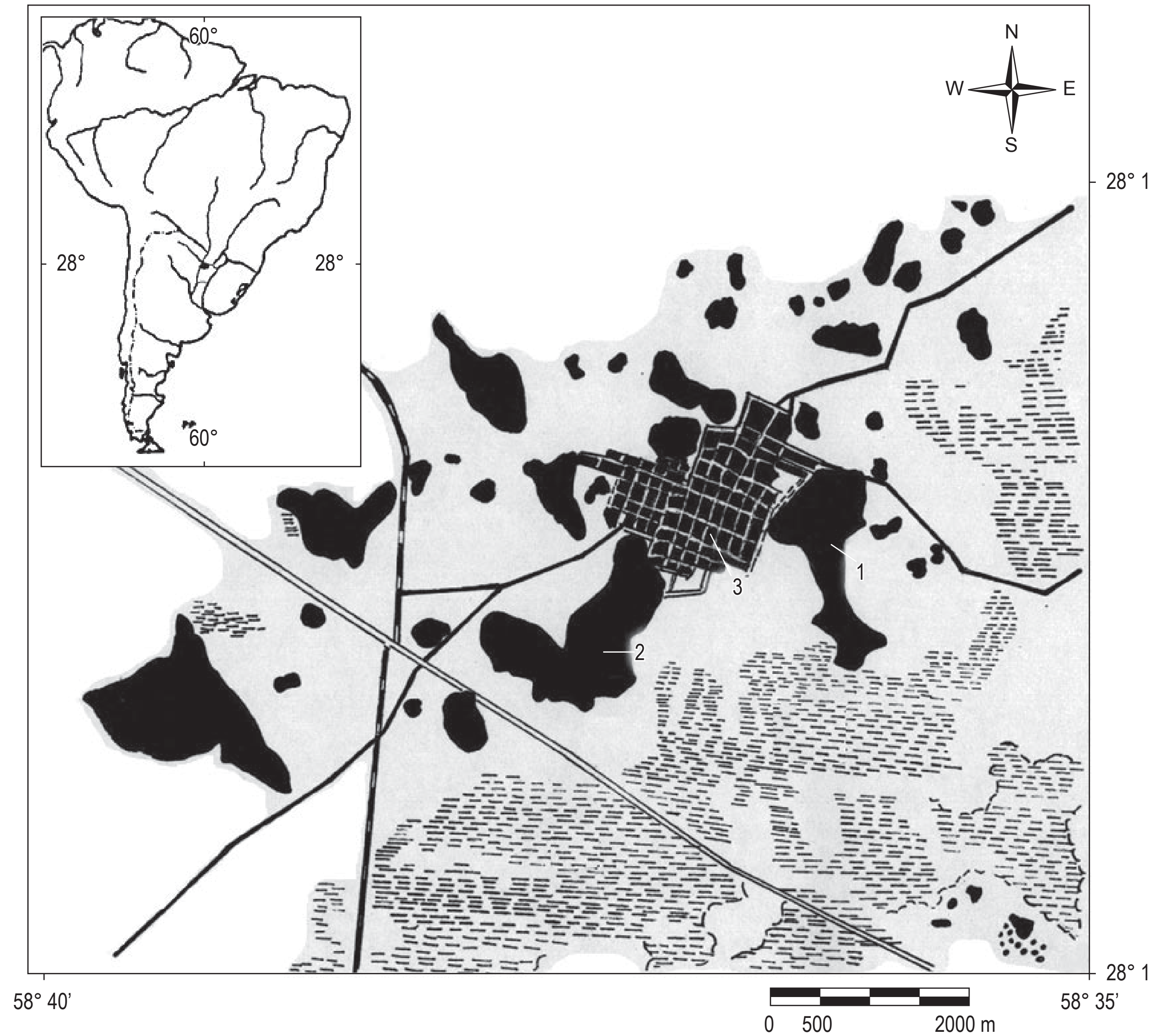

Figure 1. Location of the study sites in Corrientes, Argentina. 1: Soto lake. 2: Sanches lake. 3: Saladas city.

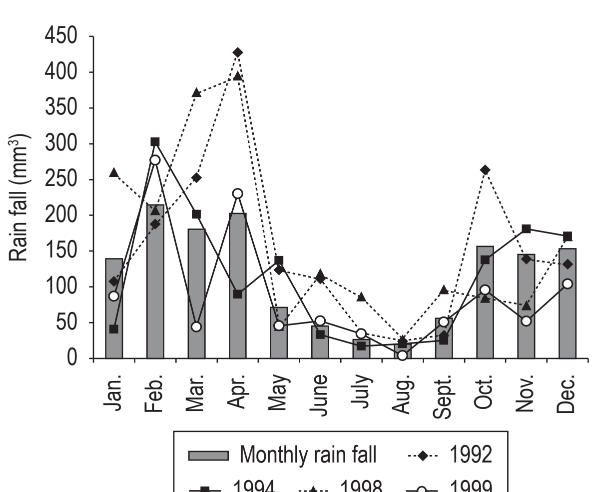

Figure 2. Mean monthly rainfall in the study period and rainfall during the rainy period (1992-1998) and the dry period (1994-1999).

microcrustaceans in a Smirnov chamber counting. Specific diversity of the dominant group (Rotifera, Monogononta) was estimated using the Shannon-Weaver index.

The similarity between the lakes was estimated using the Jaccard index. A non-parametric analysis of variance (Friedman test) was used to test for significant differences in zooplankton abundance, species richness and specific diversity between the lakes. The distribution of the most abundant taxa (Rotifera) of both lakes was analyzed using Detrended Correspondence Analysis (DCA) with PC-ORD multivariate statistical package (version 3.0, 1997, McCune and Mefford). Multiple regression analysis stepwise (Stat Graphic Plus, version 5.1) between axes 1 and 2 of the DCA and water temperature, dissolved oxygen, pH, water transparency and conductivity was used to identify the main abiotic variables that influenced variations in taxa density.

3. Results

3.1. Environmental characteristics

The water in the eutrophic lake was more alkaline, had a higher concentration of dissolved oxygen and was less transparent than in the mesotrophic lake (Table 1). The conductivity measured in the eutrophic lake was double that measured in the mesotrophic lake. Depending on the amount of rainfall, the depth varied between 1.79 and 2.92 m (eutrophic lake) and between 0.73 and 2.5 m (mesotrophic lake). The mean air temperature varied between 11.7 and 26.7 °C.

3.2. Abundance, richness and diversity of zooplankton

During the study period, great variability in zooplankton abundance was recorded in the two lakes (Figure 3). The range varied between 66.78 and 4,465 ind.L^{-1} in the eutrophic lake and between 74.52 and 2,832 ind.L^{-1} in the mesotrophic lake. No significant differences were found between the number of individuals in the two lakes (Friedman test, $p > 0.05$). In the eutrophic lake, we found two spring and-summer peaks of zooplankton after the rainy periods in 1992 and 1998, when chlorophyll-*a* levels reached 75 and 149 µg.L^{-1}, respectively. However, the Friedman test ($p > 0.05$) did not indicate significant differences between zooplankton abundance in the rainy and dry periods.

A total of 50 species were registered in the eutrophic lake and 45 species in the mesotrophic lake, with a similarity of 0.71 (Jaccard index). The number of species recorded per sample in the two lakes ranged from 2 to 24 (Table 2). Species richness was significantly greater in the mesotrophic lake (Friedamn: $p < 0.0475$) than in the eutrophic lake. There was no significant difference between the specific diversity of the two lakes (Table 2, $p > 0.05$).

In both lakes, Rotifera was the most abundant group (Figure 3), except on some sampling date (Figure 3). Among Cladocera, Chydoridae *(Chydorus pubescens*, *Alona* spp.), Sididae (*Diaphanosoma birgei*, *Ceriodaphnia cornuta* and *Daphnia laevis*) and Bosminidae (*Bosmina hagmanni*) presented low density in the eutrophic lake. *D. birgei* occurred only in two dates in the mesotrophic lake. Juvenile stages of Copepoda were recorded in both lakes.

Table 1. Physical and chemical variables in the eutrophic and mesotrophic lakes (n.a.: no available).

Date	Depht (m)	Transparency (Secchi) (m)	Temperature (°C)	Dissolved oxygen (mg.L^{-1})	Oxygen saturation (%)	pH	Conductivity (µS.cm^{-1})
Eutrophic lake							
12/05/1992	2.92	0.36	21.50	10.6	123.0	8.60	140
28/12/1992	2.06	0.49	29.00	11.0	144.0	9.30	160
23/03/1993	2.50	0.50	25.00	6.0	74.0	10.20	140
09/06/1993	2.42	0.51	15.00	10.0	154.0	7.55	115
30/08/1993	2.20	0.30	19.00	9.2	102.0	7.60	150
14/03/1994	2.40	0.65	29.00	11.4	149.0	9.98	175
26/05/1994	2.70	0.39	22.00	11.0	129.0	9.70	110
25/09/1997	1.79	0.30	18.00	9.2	100.0	6.45	130
26/03/1998	2.81	0.78	22.00	9.0	106.0	7.33	70
21/04/1999	2.47	0.81	19.00	11.5	128.0	8.41	60
23/08/1999	2.37	0.27	15.00	10.8	111.0	7.00	90
26/04/2000	2.35	0.64	22.00	9.8	n.a.	7.64	180
05/03/2008	1.55	1.55	26.30	n.a.	70.0	7.84	219
Mesotrophic lake							
12/05/1992	2.22	0.45	21.50	7.4	86.0	7.40	60
28/12/1992	2.00	0.32	30.00	7.4	98.0	6.70	60
23/03/1993	2.00	1.00	28.00	7.8	101.0	7.35	60
09/06/1993	2.05	0.55	11.00	10.4	96.0	7.50	45
30/08/1993	n.a.	n.a.	17.00	7.4	79.0	6.50	60
14/03/1994	1.95	0.45	27.00	5.6	71.0	7.10	78
26/05/1994	2.10	0.59	23.00	7.8	93.0	7.40	55
25/09/1997	1.30	0.36	18.70	9.4	104.0	6.55	65
26/03/1998	2.50	0.71	22.00	9.2	108.0	6.89	50
21/04/1999	0.73	0.73	20.00	6.2	70.0	7.19	40
23/08/1999	1.10	1.10	16.00	8.4	88.0	7.16	45
26/04/2000	0.49	0.49	23.00	n.a.	n.a.	7.16	80
05/03/2008	1.06	1.06	29.80	n.a.	153.7	9.52	105

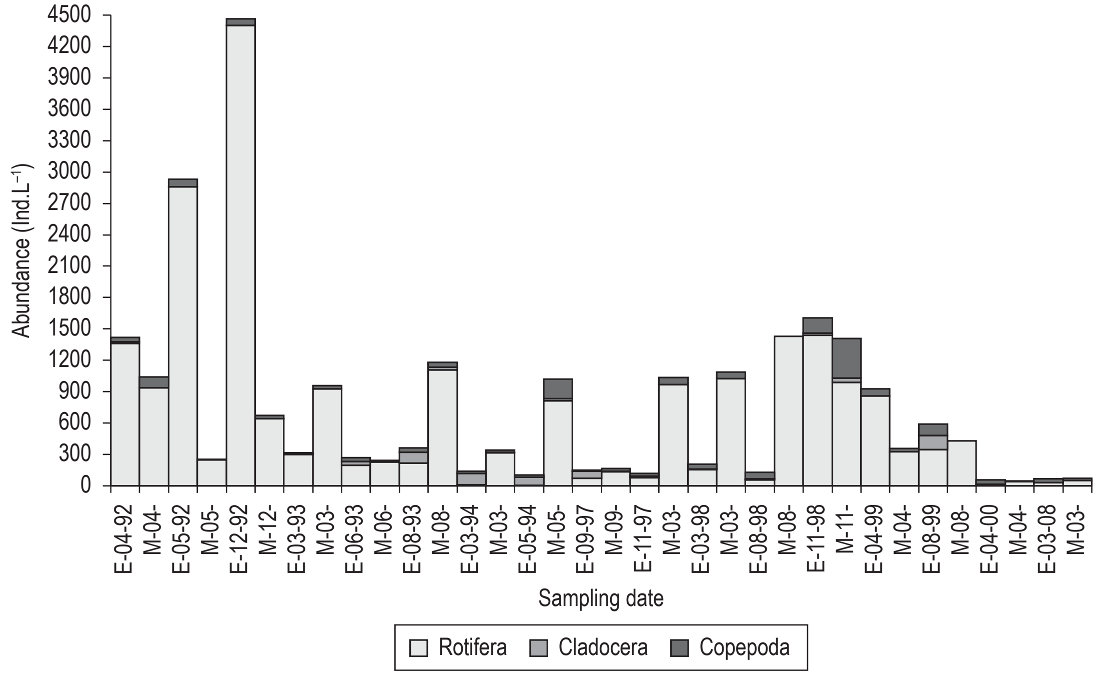

Figure 3. Zooplankton abundance in the eutrophic and mesotrophic lakes. E: eutrophic lake; M: mesotrophic lake.

Table 2. Species richness and diversity of Rotifera (Monogononta) in the two lakes at different trophic condition.

Date	Eutrophic lake		Mesotrophic lake	
	Species richness	Rotifera diversity	Species richness	Rotifera diversity
12/05/1992	11	1.60	15	3.20
28/12/1992	15	1.50	12	2.30
23/03/1993	9	1.60	10	2.40
09/06/1993	12	2.70	13	2.40
30/08/1993	13	2.50	13	2.40
14/03/1994	2	1.80	12	2.60
26/05/1994	2	1.00	12	2.60
25/09/1997	12	3.40	7	1.90
26/03/1998	14	2.43	22	2.80
21/04/1999	8	1.43	11	1.76
23/08/1999	11	2.02	24	2.20
26/04/2000	13	1.44	24	1.92
05/03/2008	11	1.55	6	1.07

Keratella tecta was the most abundant species in the eutrophic lake (Figure 4), especially in the warm rainy season (December/92) when it reached 3,000 ind.L^{-1} (75% of zooplankton). The relative abundance of *K. americana* was less than 30%. In November/98, *Brachionus havanaensis* (Figure 4) reached 40% of the total zooplankton abundance.

In the mesotrophic lake, *Polyarthra dolichoptera* was dominant in 1992 and 1999, and *K. cochlearis* was dominant in March/94 (Figure 4). *Trichocerca* spp. were more abundant taxa in August/93 (>500 ind.L^{-1}), becoming scarce in another sampling dates.

The ordination of the taxa in a reduced space (DCA; Figure 5) shows the relationship between the most frequent and abundant taxa and the trophic degree and environmental characteristics of both lakes. The two axes 1 and 2, with 0.25 and 0.13 of inertia, respectively, with a gradient of 3.68 and 3.39 (S.D.), adsorbed 38% of the total zooplankton variance. Species of the mesotrophic lake was positioned on the right end of axis 1, in opposite to the species of the eutrophic lake. *Keratella tecta*, *Filinia* spp., *K. americana* and *Brachionus havanaensis* were related to eutrophic conditions, in opposite to *Polyarthra dolichoptera, Conochilus* spp., *Brachionus* spp., *K. cochlearis* and *Trichocerca* spp., which were associated with lower trophic degree. Multiple regression analysis (stepwise) between the abundance of dominant taxa and the environmental variables (Table 3) indicates that 41% of the main variations in zooplankton were related to variability in pH and water transparency. The same abiotic variables were not significantly related to the species in axis 2.

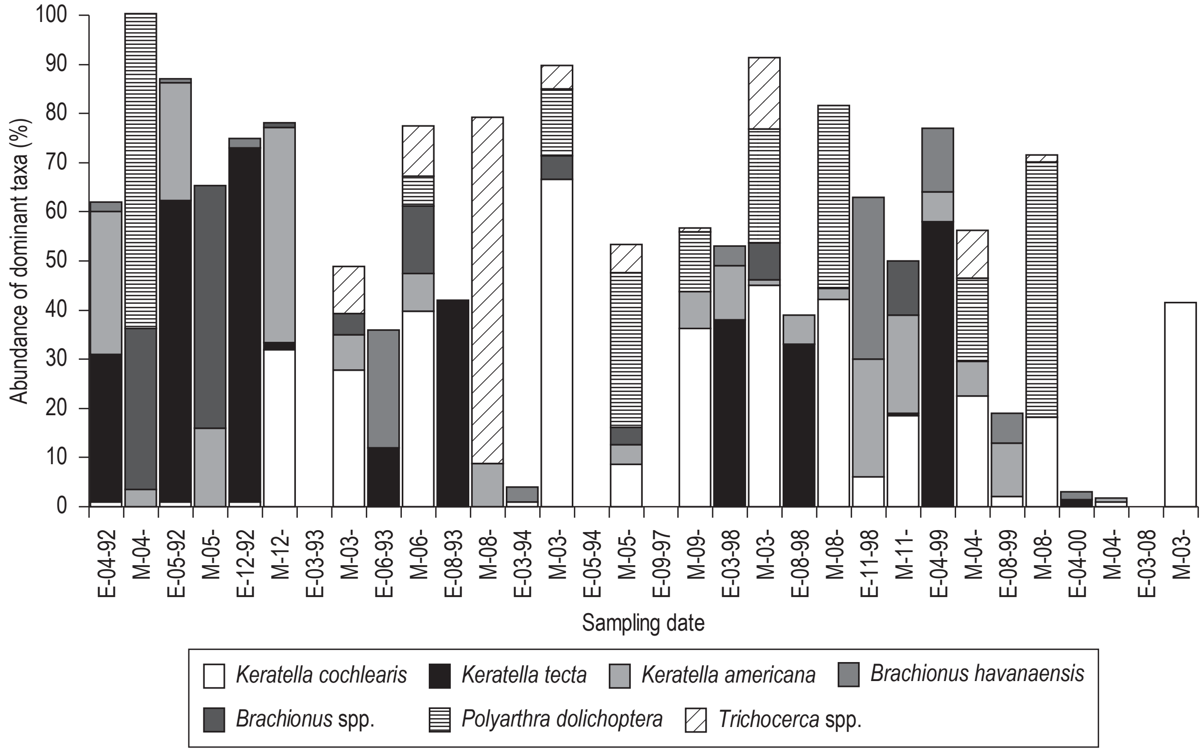

Figure 4. Dominant taxa in the eutrophic and mesotrophic lakes. E: eutrophic lake; M: mesotrohic lake.

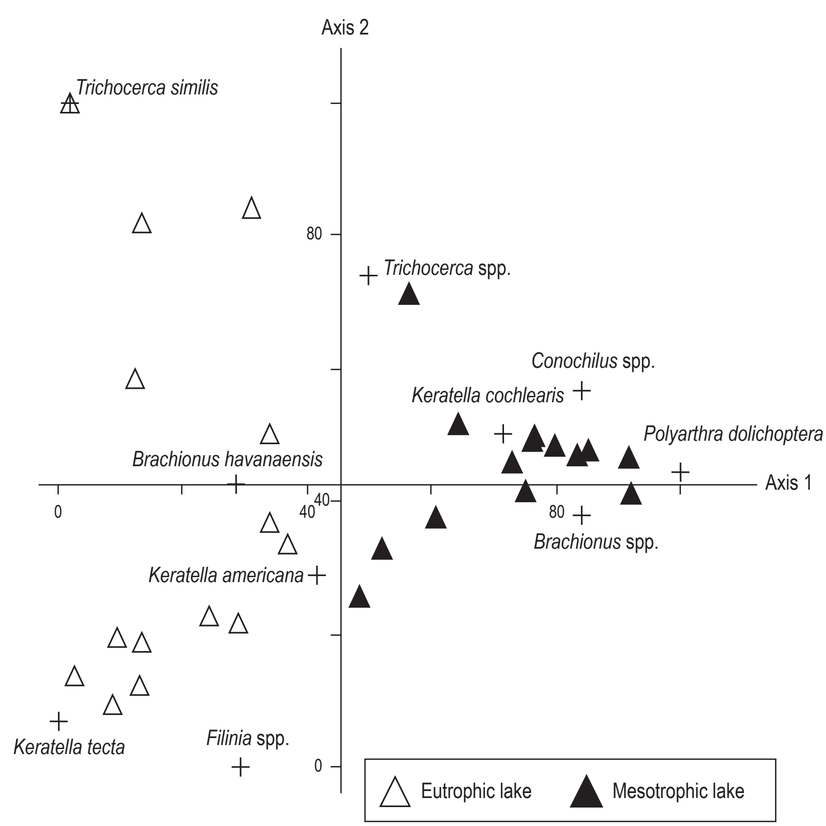

Figure 5. Detrended Correspondence Analysis ordination plot of site scores on the 1 and 2 axes at two lakes of eutrophic and mesotrophic state.

Table 3. Multiple regression analysis (stepwise) between axis 1 of DCA and environmental variables of the two lakes at different eutrophic state; r^2: 46.92; Estimate error: 95.98; Mean Error: 77.06. The environmental variables were not significantly related to the same species in axis 2.

Axis 1				
Variables	Estimate	Standard error	T value	R^2 adjusted (%)
Constant	787.817	371.901	2.11835	0.00
pH	–1244.81	363.11	–3.4282	21.61
Transparency	285.508	123.777	2.30663	41.02

4. Discussion

Peaks of zooplankton abundance in the eutrophic lake were registered in spring-summer during eutrophication episodes in rainy years. This pattern was not found in the mesotrophic lake. Comparing zooplankton community structure between the two lakes, the species richness was the only community attribute that have significant differences.

The range of zooplankton abundance in the mesotrophic lake was consistent with that observed in lakes with low concentrations of nutrients in the Riachuelo River basin and the Iberá system (Bonetto et al., 1978; Frutos, 2003).

The higher zooplankton abundance in the eutrophic lake was influenced by the higher Rotifera population that increased in high water temperature and presence of cyanobacteria blooms, which is also observed in other studies in temperate and warm eutrophic lakes (Hillbritch-Ilkowska, 1983; Gulati, 1990; Erben et al., 2002; Yildiz et al., 2007). Is probable that the high eutrophic condition promote a high concentration of detritus that enhances bacterial production, which may be an important source of food for rotifers (Hillbritch-Ilkowska, 1983; Gulati, 1990). In contrast, lower abundance of zooplankton in the eutrophic lake than the mesotrophic lake was found in Brazil by Rocha et al. (1997). According to these authors, the low density was caused by the low levels of energetic transfer from *Microcystis aeruginosa* blooms.

The dominant rotifers population (*K. tecta*, *B. havanaensis* and *K. americana*) of eutrophic lake were also found in temperate and warm eutrophic lakes (Hillbritch-Ilkowska, 1983; Gulati, 1990; Yildiz et al., 2007). Comparatively, the former specie was founded abundant in dry season of eutrophic reservoir from Brazil (Sendacz et al., 2006).

In the studied eutrophic lake, the low density of cladocerans of large body size, with presence of Bosminidae and immature stages of *Daphnia* was attributed to active predation of fish (*Aphyocharax*, *Cheirodon*, *Cynolebias*, *Acestrorhynchus* and *Aequidens*) by Poi de Neiff et al. (1999b; 2007). The absence of *Daphnia* adults in our study is consistent with observations by Matveev et al. (1992) in another lake (northeastern of Argentina) where fish included cladocerans of large body size like *Daphnia laevis* in their diets.

The DCA scores indicate that the presence of *Keratella tecta*, *Filinia* spp., *K. americana* and *Brachionus havanaensis* was related to eutrophication state, whereas the presence of *Polyarthra dolichoptera*, *Conochilus* spp., *Brachionus* spp., *Keratella cochlearis* and *Trichocerca* spp. was related to mesotrophic conditions. Environmental variables such as pH and water transparency were related to changes in the abundance of dominant taxa. In our study, the correlation of pH with population density could be due to the high production of cyanobacteria blooms. Changes in pH and percentage of oxygen saturation in the water surface have been used as indicators of periods of rapid photosynthesis in eutrophic temperate lakes (Edmonson, 1993).

Among the dominant populations in the eutrophic lake, *Keratella tecta* surpassed the abundance found by Erben et al. (2002). This species is frequent in tropical and subtropical eutrophic waters (Olivier, 1965; Rüttner-Kolisko, 1974).

K. tecta has high plasticity to survive in eutrophic conditions due to its capacity to ingest particles of variable size, including bacteria, detritus and colonies of cyanobacteria. In our study, *K. tecta* reached 75% of total abundance in the eutrophic lake, in contrast with the mesotrophic lake where it represented less than 1% of total abundance. According to Hillbritch-Ilkowska (1983), *K. tecta* surpasses 50% of zooplankton density in hyper-eutrophication conditions, and is present at low densities in mesotrophic conditions. In eutrophic lakes with a high saline concentration, the abundance of *K. tecta* and *Brachionus havanaensis* is low (Schiewer, 1998; José de Paggi and Paggi, 1998). *K. tecta* was associated with *Polyarthra vulgaris* and *Filinia opoliensis* in a eutrophic reservoir (Sendacz et al., 2006) and it was associated with *Brachionus quadridentatus*, *K. cruciformes* and *Filinia longiseta* in hypertrophic temperate estuaries (Schiewer, 1998).

The frequent association of *Keratella* spp. and *Polyarthra* spp. observed in the mesotrophic lake in this study has also been observed in rivers with mesotrophic and eutrophic conditions (Matsumura-Tundisi et al., 1990). The easy adaptation of both species to different degrees of eutrophication has brought their status as "indicator species of eutrophic state" into question (Matsumura–Tundisi et al., 1990). In the northeast of Argentina, both taxa and *Brachionus* are frequent in lakes, rivers and streams non eutrophicated (Bonetto et al., 1978; Martinez and Frutos, 1986; Frutos, 1993; 1996). The *Brachionus-Trichocerca* relation observed by Sladecek (1983) in eutrophic temperate lakes was not found by us in the studied lakes.

Our results indicate that in the studied lakes species richness and the relative abundance of dominant species are better indicators of eutrophic degree than total abundance and specific diversity. *K. tecta* can be considered a good indicator of eutrophication when its density exceeds 50% of total zooplankton abundance.

Acknowledgements

The authors are thankful at the anonymous referees by theirs valuable suggestions.

References

ASSELBORN,VM., Zalocar de DOMITROVIC, Y. and CASCO, SL. Estructura y variaciones del fitoplancton de la laguna Soto (Corrientes, Argentina). *Bol. Soc. Argent. Bot.* 1999, vol. 33, no. 3-4, p. 17-27.

BONETTO, AA., NEIFF, JJ., POI DE NEIFF, A., VARELA, ME., CORRALES, MA., and ZALAKAR, Y. Estudios limnológicos en la cuenca del Riachuelo (Corrientes, Argentina) III. Laguna La Brava. *Ecosur*. 1978, vol. 5, no. 9, p. 57-84.

BONETTO, A., DI PERSIA, D., MAGLIANESI, R. and CORIGLIANO, MC. Caracteres limnológicos de algunos lagos eutróficos de embalse de la región central argentina. *Ecosur*. 1976, vol. 3, no. 5, p. 47-120.

EDMONSON, WT. Eutrophication effects on the food chains of lakes. *Mem. Inst. Ital. Idrobiol*. 1993, vol. 52, p.113-132.

ERBERN, R., LAJTNER J., KLOBUEAR, G., MAGUIRE, I., LUCIA, A. and STAMBUK, A. Zooplankton reflecting the trophic state of the dam reservoir Modrac (Bosnia and Herzegovina). *International conference on limnology of shallow lakes 2002.* Balantonfured, Hungary: [s.n.], 2002. p. 51.

FRUTOS, SM. Zooplancton en cuerpos de agua isleños del Bajo Paraná. *Ambiente Subtropical* 1993, vol. 3, p. 87-121.

FRUTOS, SM. Zooplancton de la laguna Turbia (Isla del Cerrito) en la confluencia de los ríos Paraná y Paraguay (Argentina). *Rev. Bras. Biol.* 1996, vol. 56, no. 3, p. 569-580.

FRUTOS, SM. Zooplancton en lagunas y cursos de agua del Sistema Iberá. In: Poi de Neiff, ASG. (ed.). *Limnología del Iberá. Aspectos físicos, químicos y biológicos de las aguas*. Corrientes: EUDENE editora, 2003. p. 143-161.

GERASIMOVA, TN. and POGOZHEV, PI. Studying the potential of food chain filterers in the processes of de-eutrophication of water bodies. *Water Resour.* 2008, vol. 35, no. 3, p. 3543-3562.

GULATI, RD. Zooplankton structure in the Loosdrecht lakes in relation to trophic status and recent restoration measures. *Hydrobiol.* 1990, vol. 191, p. 173-188.

GLIWICZ, ZM. Food size selection and seasonal succession of filter feeding zooplankton in an eutrophic lake. *Ekol. Pol.* 1977, vol. 25, no. 2, p. 179-225.

HILLBRITCH-ILKOWSKA, A. Response of planktonic rotifers to the eutrophication process and to the autumnal shift of blooms in Lake Biwa, Japan. I. Changes in abundance and composition of rotifers. *Jap. J. Limnol*. 1983, vol. 44, no. 2, p. 93-106.

JOSÉ DE PAGGI, S. Distribución espacial y temporal de un cuerpo de agua eutrófico (Lago Del Parque Gral. Belgrano, Santa Fe). *Physis* 1976, vol. 35, no. 91, p. 171-183.

JOSÉ DE PAGGI, S. and PAGGI, JC. Zooplancton de ambientes acuáticos con diferente estado trófico y salinidad. *Neotrópica* 1998, vol. 44, no. 111-112, p. 95-106.

LAZZARO, X. Do the trophic cascade hypothesis and classical biomanipulation approaches apply to tropical lakes and reservoirs?. *Verh. Internat. Verein. Limnol*. 1997, vol. 26, p. 719-730.

LAMPERT, W. Further studies on the inhibitory effect of the toxic blue-green *Microcystis aeruginosa* on the filtering rate of zooplankton. *Arch. Hydrobiol*. 1982, vol. 95, no. 1/4, p. 207-220.

MARTINEZ, CC. and FRUTOS, SM. Fluctuación temporal del zooplancton en arroyos y esteros del Chaco Oriental, (Argentina). *Ambiente Subtropical* 1986*,* vol. 1, p. 112-133.

MATSUMURA-TUNDISI, T., LEITÃO, SN., AGHENA, LS. and MIYAHARA, J0. Eutrofização da represa de Barra Bonita: estrutura e organização da comunidade de Rotifera. *Rev. Bras. Biol.* 1990, vol. 50, no. 4, p. 923-935.

MATUSUMURA-TUNDISI, T., ROCHA, O. and TUNDISI, JG. Carbon uptake by *Scolodiaptomus corderoi* and *Thermocyclops minutus* feeding on different size fractions of phytoplankton from Lake Dom Helvécio. In: Tundisi, JG. and Saijo, Y. (eds.). *Limnological studies on the Rio Doce Valley Lakes.* São Paulo: Brazilian Academy of Sciences, 1997. p. 275-284.

MATVEEV, V., MARTINEZ, CC., FRUTOS, SM. and ZALOCAR de DOMITROVIC, Y. Population control in planktonic crustaceans of a subtropical lake during seasonal succession. *Arch. Hydrobiol*. 1992, vol. 124, no. 1, p. 1-18.

MATVEEV, V., MATVEEVA, L. and JONES, GJ. Study of *Daphnia carinata* King to control phytoplankton and resist cyanobacterial toxicity: Implications for biomanipulation in Australia. *Aust. J. Mar. Freshwater Res*. 1994, vol. 45, p. 889-904.

NEIFF, J.J., PATIÑO, CA., POI DE NEIFF, AS., ZALOCAR DE DOMITROVIC, Y. and FRUTOS, SM. Response of a natural to chemical and biological inputs of eutrofic waters (Saladas, Corrientes, Argentina). *Rev. Asoc. Bras. Rec. Hidr*. (ABRH) 2002, vol. 7, no. 3, p. 53-62.

OLIVIER, RO. Rotíferos planctónicos de Argentina. *Rev. Mus. de la Plata.* 1965, vol. 8, no. 63, p. 77-260.

PECORARI, S., JOSÉ DE PAGGI, S. and PAGGI, JC. Assesment of the urbanization effect on a lake by zooplankton. *Water Resour.* 2006, vol. 33, no. 6, p. 677-685.

PEDROZO, F., DÍAZ, M., REYNOLDS, C. and TEMPORETTI, P. Estado trófico de lagos patagónicos de Argentina. In: Feyen, J., Aguirre L. and Moraes M. (eds.). *Congreso Internacional sobre Desarrollo, Medio Ambiente y Recursos Naturales:*

sostenibilidad a múltiples niveles y escalas. Cochabamba: [s.n.], 2007, vol. 2, p. 1203-1211.

PINTO-COELHO, RM., BEZERRA-NETO, JF. and MORAIS-JR, CA. Effects of eutrophication on size and biomass of crustacean zooplankton in a tropical reservoir. *Rev. Bras. Biol.* 2005, vol. 6, no. 2, p. 325-338.

POI DE NEIFF, AS., NEIFF, JJ., PATIÑO, C., RAMOS, A., CACERES, J., FUTOS, SM. and CANON VERÓN, MB. Estado trófico de dos lagunas en planicies anegables con áreas urbanas de la provincia de Corrientes. *FACENA*. 1999a, vol. 15, p. 93-110.

POI DE NEIFF, AS., CANON VERÓN, MB. and FRUTOS, SM. Relaciones tróficas entre peces, macroinvertebrados y zooplancton en una laguna eutrófica (Corrientes, Argentina). *Comunicaciones científicas y tecnológicas* (UNNE). 1999b, p. 6-11.

POI DE NEIFF, A., NEIFF, JJ., ZALOCAR DE DOMITROVIC, Y., FRUTOS, SM. and CANON VERÓN, MB. Estructura de las comunidades en un lago eutrófico y perspectivas de manejo (Corrientes, Argentina). In: Feyen, J., Aguirre, L. and Moraes, M. (eds.). *Congreso Internacional sobre Desarrollo, Medio Ambiente y Recursos Naturales: sostenibilidad a múltiples niveles y escalas.* Cochabamba; [s.n.], 2007. vol. 2, p. 1197-1202.

RAVERA, O. Zooplankton and trophic state relationships in temperate lakes. *Mem. Inst. Ital. Idrobiol*. 1996, vol. 54, p. 195-212.

ROCHA, MIA., BRANCO, CWC., SAMPAIO, GF. GÔMARA, GA. and DE FILIPPO, R. Spatial and temporal variation of limnological features, *Microcystis aeruginosa* and zooplankton in an eutrophic reservoir (Funil Reservoir, Rio De Janeiro). *Acta Limnol. Bras*. 2002, vol. 14, p. 73-86.

ROCHA, O., MATSUMURA-TUNDISI, T. and SAMPAIO, EV. Phytoplankton and zooplankton community structure and production as related to trophic state in some Brazilian lakes and reservoirs. *Verh. Internat. Verein. Limnol.* 1997, vol. 26, p. 599-604.

RUTTNER-KOLISKO, A. Plankton Rotifers. Biology and Taxonomy. In: ELSTER, H. and OHLE, W. (eds.). *Die Binnengewässer.* Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung, 1974. p. 1-146 p.

RYDING, S. and RAST, W. *El control de la eutrofización en lagos y pantanos*. Madrid: Pirámide, 1992. 375 p.

SAMPAIO, EV., ROCHA, O., MATSUMURA-TUNDISI, T. and TUNDISI, JG. Composition and abundance of zooplankton in the limnetic zone of seven reservoir of the Paranapanema River, Brazil. *Bras. J. Biol.* 2002, vol. 62, no. 3, p. 525-545.

SENDACZ, S. and KUBO, E. Zooplâncton de reservatórios do Alto Tietê, In: HENRY, R. (ed.). *Ecologia de reservatórios*: *estrutura função e aspectos sociais*. Botocatu: FAPEST/FUNDIBIO, 1999. p. 509-530.

SENDACZ, S., CALEFFI, S. and SANTOS SOARES, J. Zooplankton biomass of reservoirs in different trophic condition in the state of São Paulo, Brazil. *Rev. Brasil. Biol.* 2006, vol. 66, no. 1, p. 337-350.

SLADECECK, V. Rotifers as indicators of water quality. *Hydrobiol.* 1983, vol. 100, p. 169-201.

SCHIEWER, U. Hypertrophy of a Baltic estuary-changes in structure and function of the planktonic community. *Verh. Internat. Verein. Limnol*. 1998, vol. 26, p.1503-1507.

TUNDISI, JG. and MATSUMURA TUNDISI, T. *Limnologia*. San Paulo: Oficina de texto, 2008. 631 p.

TUNDISI, JG., MATSUMURA-TUNDISI, T. and Abe, DS. The ecological dynamics of Barra Bonita (Tietê River, SP, Brazil) reservoir: Implications for its biodiversity. *Braz. J. Biol*. 2008, vol. 68, no. 4, p. 1079-1098.

YILDIZ, S., ALTINDAG, A. and ERGÖNÜL, MB. Seasonal fluctuations in the zooplankton composition of a eutrophic lake: Lake Marmara (Manisa, Turkey). *Turk J. Zool.* 2007, vol. 31, p. 121-126.

Received: 20 May 2009
Accepted: 09 October 2009