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Research Article

Relations among planktonic rotifers, cyclopoid copepods, and water quality in two Brazilian reservoirs

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ABSTRACT. Planktonic rotifers and cyclopoid copepods were studied in two reservoirs of different trophic states (eutrophic and oligo/mesoeutrophic) in the south of Brazil. During a year, monthly samplings were carried out in three stations in each reservoir. Species richness, frequency and abundance were used to find out useful and indicatives trends of water quality based on these organisms, reinforced by literature data. Species that showed higher differences between reservoirs were chosen. For Rotifera, richness, frequency and abundance of *Brachionus* were higher in the eutrophic reservoir, but *Plationus patulus* occurred only in the oligo/mesotrophic reservoir. For copepods, *Tropocyclops prasinus* dominated in the eutrophic reservoir, but *Thermocyclops decipiens, T. minutus, T. inversus* and *Microcyclops anceps* were dominants in the oligo/mesotrophic reservoir. In the canonical correspondence analysis, these species were indicators of the trophic state and were related with chlorophyll-*a*, total phytoplankton and total phosphorus. The use of these species can be efficient in the studied regions (subtropical/temperate), but comparing with other Brazilian reservoirs of tropical climate, the results could be different. Despite the dominance of *T. decipiens* over *T. minutus, T. inversus* has been widely used in Brazil as an indicator of eutrophic waters; in those cases of excessive eutrophication, other species, more rustic, commonly dominate. In the present study, *Thermocyclops* was dominant in the oligo/mesotrophic reservoir. The dominance of *Brachionus* for rotifers and *Tropocyclops prasinus* and *Acanthocyclops robustus* for copepods were indicative of eutrophic conditions.

Keywords: abundance, bioindicators, diversity, evenness, species richness, Brazil.

Relaciones entre los rotíferos, copépodos planctónicos ciclopoides y la calidad del agua en dos embalses brasileños

RESUMEN. Se analizaron los rotíferos y copépodos planctónicos ciclopoides colectados en dos embalses de diferentes estados tróficos (eutróficos y oligo/mesoeutróficos) en el sur de Brasil. Durante un año, se efectuaron muestreos mensuales, en tres estaciones en cada embalse. La riqueza de especies, frecuencia y abundancia, se utilizó para determinar tendencias útiles e indicativas de la calidad del agua sobre la base de estos organismos, complementando con datos de la literatura. Se escogieron aquellas especies que presentaron las mayores diferencias. Para rotíferos, la riqueza, frecuencia y abundancia de *Brachionus* fueron más altas en el embalse eutrófico, *Plationus patulus* se detectó sólo en el embalse oligo/mesotrófico. Para los copépodos, *Tropocyclops prasinus* dominó en el embalse eutrófico, mientras que *Thermocyclops decipiens, T. minutus, T. inversus* y *Microcyclops anceps* dominaron en el embalse oligo/mesotrófico. En el análisis de correspondencia canónica, estas especies fueron indicadoras del estado trófico y se relacionaron con la clorofila-*a*, fitoplancton total y fósforo total. El uso de estas especies puede ser eficaz en las regiones estudiadas (subtropical/templada), pero comparado con otros embalses de clima tropical del Brasil, los resultados podrían ser diferentes. A pesar de la dominancia de *T. decipiens* por sobre *T. minutus*, *T. inversus* ha sido ampliamente utilizado como indicador de agua eutróficas, en aquellos casos de eutroficación excesiva, otras especies, más rústicas, dominan comúnmente. En el presente estudio, *Thermocyclops* fue dominante en el embalse oligo/mesotrófico. La dominancia de *Brachionus* para los rotíferos, y *Tropocyclops prasinus* y *Acanthocyclops robustus* para los copépodos fueron indicativos de condiciones eutróficas.

Palabras clave: abundancia, diversidad, uniformidad, indicadores biológicos, riqueza de especies, Brasil.

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INTRODUCTION

Reservoirs are manmade water bodies and are also considered intermediate ecosystems between rivers and lakes (Thornton, 1990; Tundisi, 1990; Espíndola *et al.*, 2000). Urban reservoirs have several social services and available environments used for fishing, recreation, tourism, and water supply, and are also submitted to many forces due to it is multiple uses, such as discharge of solid residues, shore degradation, punctual and non-punctual sources of phosphorus, sedimentation and intense urban occupation (Tundisi *et al.*, 2008). The building of reservoirs causes changes in the local landscape, in social and economic aspects, and in the aquatic communities and water quality (Straškraba & Tundisi, 1999).

The continental zooplankton is composed of rotifers, small crustaceans (cladocerans and copepods) and protozoans. Rotifers have different food habits, being omnivorous, carnivorous (including cannibalism) or even herbivores. Cyclopoid copepods are preferentially carnivorous, and their diet is mainly composed by microcrustaceans. Diptera and Oligochaeta larvae and cladocerans are filter-feeders. Potentiality of zooplankton as bioindicators is very high because their growth and distribution depends on some abiotic (*e.g.*, temperature, salinity, stratification, pollutants) and biotic parameters (*e.g.*, food limitation, predation, competition) (Marzolf, 1990; Ferdous & Muktadir, 2009).

Plankton has been used recently as bioindicator for monitoring aquatic ecosystems and the integrity of water. Zooplankton assemblages may be considered bioindicators of eutrophication, as they are coupled to environmental conditions, responding more rapidly to changes than do fishes, and are easier to identify than phytoplankton. Therefore, they are of considerable potential value as water quality indicators (Gannon & Stemberger, 1978; Sladecek, 1983).

Based on records and comparisons of lakes of different trophy, several workers suggested that rising lake trophy will favor cyclopoid copepods and rotifers over calanoid copepods and cladocerans (Gannon & Stemberger, 1978; Sladecek, 1983; Rognerud & Kjellberg, 1984). Some other authors have also been mentioned the use of rotifers and copepods as bioindicators of water quality in Brazilian reservoirs (Neumann-Leitão & Nogueira-Paranhos, 1989; Güntzel & Rocha, 1998; Nogueira, 2001; Silva, 2011). Examples are the dominance of *Brachionus* genus for Rotifera, and the relations between two species of *Thermocyclops* of Copepoda. In oligotrophic environments, higher frequency of *T. minutus* is noticed, whereas in eutrophic waters the presence of *T. decipiens* is higher. However, in mesotrophic environments, the two species are found sharing the habitat (Rocha *et al.*, 1995; Silva & Matsumura-Tundisi, 2005; Landa *et al.*, 2007; Nogueira *et al.*, 2008).

Some species respond to changes in the water quality, thus differences in the reproduction and development of the zooplankton are predictable (Duggan *et al.*, 2001; Matsumura-Tundisi & Tundisi, 2005; Landa *et al.*, 2007; Silva, 2011). The composition, richness and the diversity of these organisms in eutrophic environments is different when compared to oligotrophic ones. Generally, few species are dominant in high densities in eutrophic reservoirs (Sendacz & Kubo, 1982; Matsumura-Tundisi & Tundisi, 2005), feeding mainly on Cyanobacteria blooms and associated bacteria-according to Maitland's (1978) affirmative. In oligotrophic and also in mesotrophic reservoirs studies indicated higher richness and lower abundances (Nogueira, 2001; Bonecker *et al.*, 2007). However, Matsumura-Tundisi & Tundisi (2005) observed higher species richness in an eutrophic reservoir, as well as Velho *et al.* (2005); Perbiche-Neves *et al.* (2007) and Bini *et al.* (2008) in another eutrophic reservoir.

The scarcity of water in the current decade, mainly during periods of severe droughts in larger cities, as Curitiba (the capital of Parana State, in south Region of Brazil) and its metropolitan region, 4 million habitants emphasizes the importance of this study. The volume of reservoirs destined to water supply is reduced during drought periods and present unfavorable conditions to several organisms, except to

Cyanobacteria algae and some protozoans and invertebrates with different tolerances to drought or pollution, which degrades the remaining water due to its chemical compounds. Thus, it is important to obtain predictive water quality monitoring in urban reservoirs destined to water supply.

We studied rotifers and cyclopoid copepods in two urban reservoirs, but with contrasting trophic states (oligo/mesotrophic and eutrophic), proportions and relations among species, which can be indicative of reservoir's trophic state, supported by relations with environmental variables, were analyzed. In addition, we agree with the hypothesis following Maitland's (1978) statement, which means lower richness and species diversity, and higher abundance of organisms in the eutrophic reservoir. Ecological attributes (richness, abundance and diversity), and environmental variables were analyzed in a complete annual cycle in each reservoir.

MATERIALS AND METHODS

Two small, shallow and polymictic reservoirs near to Curitiba city (Paraná State, Brazil), were studied. The first one, Iraí Reservoir (located in Iraí River - 25°25'24"S, 49°06'46"W), was studied between March 2002 and February 2003, and the other, Verde River Reservoir (located in Verde river- 25°31'40"S; 49°31'38"W), between July 2008 and June 2009, both in the upper Iguaçu basin (Fig. 1). The climate is Cbf, according to Koeppen classification (Maack, 1968). The annual precipitation and the mean temperature are 1,500 mm and 16.5^{o}C respectively (Maack, 1968).

Samplings were carried out monthly, along an annual cycle, in three sampling stations in each reservoir, representing mouth zone, intermediate and lentic zones (Marzolf, 1990). The two reservoirs have some similar morphometric characteristics, but contrasting trophic conditions, as shown in Table 1.

The trophic state of the reservoir was obtained by using the Modified Carlson Trophic Index (Mercante & Tucci-Moura, 1999) and is composed by a set of equations: Trophic State Index (TSI) modified from Carlson (1977).

$$\text{TSI (Chl)} = 10\left(6 - \frac{2.04\text{-}0.695\ \text{lnChl}}{\ln 2}\right)$$

$$\text{TSI (TP)} = 10\ \left(6 - \frac{\ln(80.31/\text{TP})}{\ln 2}\right)$$

$$\text{TSI (SD)} = 10\ \left(6 - \frac{0.64 + \text{lsSD}}{\ln 2}\right)$$

where: Chl = Chlorophyll-*a* (µg L^{-1}); TP = Total phosphorus (mg L^{-1}); SD = Secchi disk (m).

The limits defined were: Oligotrophy: TSI < 44; Mesotrophy: 44< TSI > 54; Eutrophy: TSI > 54.

More details of Iraí Reservoir can be found for zooplankton assemblages (Serafim-Júnior *et al.*, 2005; Perbiche-Neves *et al.*, 2007; Ghidini *et al.*, 2009), physical and chemical variables (Andreoli & Carneiro, 2005; Bollmann *et al.*, 2005; Sanepar, 2006). The phytoplankton community estimated biovolume for this reservoir, in the period from August 2002 to 2003, ranged from 0.28 to 14.40 mm^{3} L^{-1}. Also, in this period, 65 species of phytoplankton from nine families were identified. Cyanobacteria dominated quantitatively, with higher abundance of *Aphanocapsa delicatissima*, *Cylindrospermopsis raciborskii*, *Microcystis aeruginosa*, *Microcystis* spp. and *Pseudoanabaena mucicola* (Fernandes *et al.*, 2005). For Rio Verde Reservoir, details of physical and chemical variables are found in Cunha *et al*. (2012).

In both reservoirs, zooplankton samples were collected using conical plankton net (64 µm of mesh size and 30 cm mouth diameter), and the retained material was fixed with formaldehyde 4% buffered with calcium carbonate. Different water volumes were filtered in each reservoir for determining the abundance of zooplankton, because data comes from different projects. In Iraí Reservoir, 300 L of subsurface (30 cm) water were filtered using a motor pump which is widely used to sample zooplankton, and in Rio Verde Reservoir, samples were obtained through vertical hauls (filtering about 400 L of water). Integrated samples are an alternative to evaluate zooplankton vertical distribution (*e.g.*, in relation to abiotic and biotic conditions of water bodies) and differs from samplings at the subsurface where the water column is not sampled. Thus, this could affect the number and density of some collected taxa. Rotifers were counted in sub-samples varying from 0.5 to 1.0 mL, obtained with Hansen-Stempel volumetric pipets and using a Sedgwick-Rafter chamber. A minimum of 200 individuals were counted per sample and density was expressed in individuals m^{-3}. Species identification was based on specialized literature (*e.g.*, Koste, 1978a, 1978b; Segers, 2002). Copepods were identified and quantified under optical microscope, in subsamples varying from 0.5 to 1.0 mL, obtained with Hansen-Stempel pipets and using a Sedgwick-Rafter chamber. A minimum of 200 individuals were counted per sample. Nauplii and copepodits were not included in the analyses, aiming to study only adult organisms that can be identified at the species level. The identification was based in specialized literature: *e.g.*, Reid (1985, 1989), Rocha

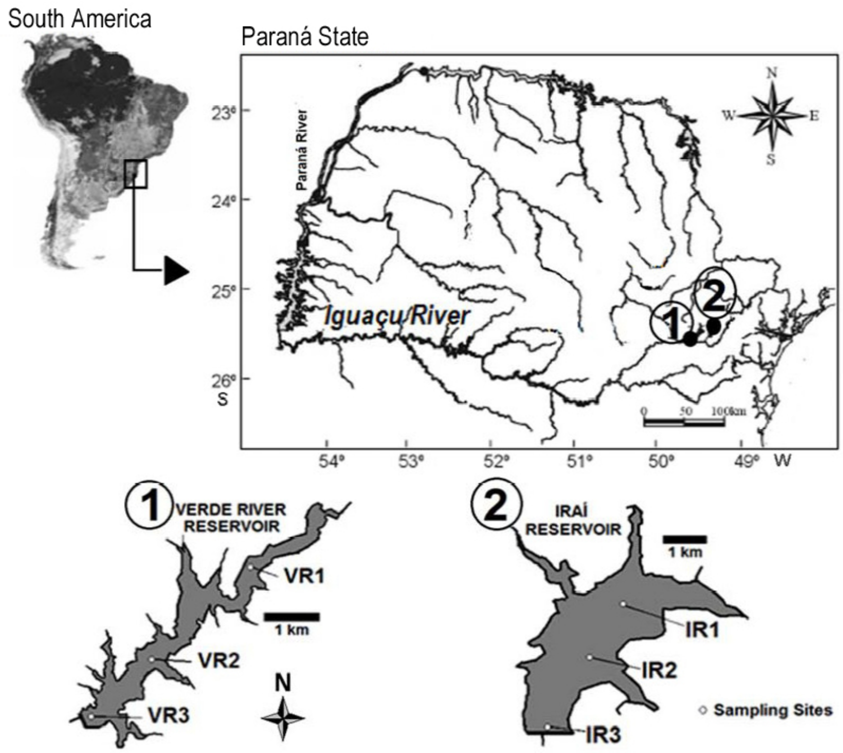

Figure 1. Map of Iraí and Rio Verde reservoirs and location of the sampling stations. IR1, IR2, IR3 and VR1, VR2, VR3: sampling stations in Iraí and Rio Verde reservoirs representing mouth zone, intermediate and lentic zones, respectively.

Table 1. Morphometric characteristics, chlorophyll-*a*, physical and chemical variables* (mean values, n = 118 samples in Rio Verde, n = 90 in Iraí, except transparency: n = 36 in Rio Verde and n = 30 in Iraí) and trophic state (Mercante & Tucci-Moura, 1999) of the studied reservoirs. Data from Andreoli & Carneiro (2005), Sanepar (2006, 2010). Zmax: maximum depth; Zmean: mean depth; WRT: Water retention time.

Characteristics	Iraí	Rio Verde
Coordinates	25°25’24”S, 49°06’46”W	25°31’40”S, 49°31’38”W
Area	14 km²	11 km²
Zmax	10 m	11 m
Zmean	5.1 m	7.2 m
Shape	Pentagonal	Dendritic
Volume	58 x 10^6 m³	25 x 10^6 m³
WRT	375 days	216 days
*Temperature	22.10 ± 3.93°C	20.27 ± 3.26°C
*Conductivity	45.39 ± 2.19 µS cm^{-2}	105.09 ± 10.07 µS cm^{-2}
*Nitrate	0.40 ± 0.26 mg L^{-1}	0.36 ± 0.14 mg L^{-1}
*Total phosphorus	0.10 ± 0.05 mg L^{-1}	0.05 ± 0.02 mg L^{-1}
*Chlorophyll-*a*	29.97 ± 17.57 µg L^{-1}	9.87 ± 5 µg L^{-1}
*Dissolved oxygen	6.84 ± 1.40 mg L^{-1}	6.87 ± 1.41 mg L^{-1}
*pH	7.24 ± 1.18	7.16 ± 0.27
*Transparency (Secchi)	0.70 ± 0.15 m	1.75 ± 0.52 m
Trophic state	Eutrophic	Oligo/mesotrophic
Trophic state index	61.58	52.02

(1998) and Silva & Matsumura-Tundisi (2005). Cladocerans were not included in our studied because they not showed any correlation with water quality.

We evaluated the species composition, richness, mean abundances, Shannon-Weaver diversity (H' = Σpi log (p_i)), and equitability (E = H'/H'max) (Pielou, 1984). The diversity and equitability were calculated using the Past V. 1.48 software (Hammer *et al*., 2001).

Only species that showed differences in ecological attributes between reservoirs were included in the species list and were used as potential indicators of water quality.

Data were log X+1 transformed for a comparative analysis, and a three-way ANOVA was carried out for stations with interaction between reservoirs and months aiming to compare their ecological attributes. The interaction was used to examine if differences among months in each reservoir were absent. All presupposes of these analyses were reached. Homogeneity was tested using Levene's test and normality using Shapiro Wilk test (Zar, 1999). ANOVAs were carried out using Statistic 7.0 (Statsoft, 2002).

Canonical correspondence analysis (CCA) ($P < 0.1$ with 1,000 permutations) was used to correlate rotifer and copepod abundance with environmental variables, grouping data from both reservoirs (Kindt & Coe, 2005). The following variables were used: water temperature, nitrate, total phosphorus, transparency, pH, conductivity, dissolved oxygen, chlorophyll-*a* and total phytoplankton. Some of these variables were measured in profiles of the water column such as temperature, pH, turbidity, dissolved oxygen and conductivity using a multi-probe (Horiba model U-22). Transparency was obtained with the immersion of the Secchi disk until its visual disappearance (m). Water samples were taken to the laboratory for determination of nitrogen (Mackereth *et al.*, 1978) total phosphorus (Strickland & Parsons, 1960) and chlorophyll-*a* (Talling & Driver, 1963). CCA was carried out using the R Cran Project software (R Development Core Team 2009).

RESULTS

The species that showed significant differences between reservoirs are shown in Table 2. Species of *Brachionus* genus, with *Filinia longiseta, Keratella cochlearis, K. lenzi,* and *Tropocyclops prasinus* were dominant in eutrophic reservoir, in contrast of *Kellicotia bostoniensis, Keratella americana, Plationus patulus, Thermocyclops decipiens, T. inversus, T. minutus* and *Microcyclops anceps,* dominant in oligo/ mesotrophic reservoir.

Keratella cochlearis (11,331 ± 6,581 ind m^{-3}) and *K. lenzi* (11,307 ± 17,967 ind m^{-3}) showed the highest mean abundance in the eutrophic reservoir, followed by *Filinia longiseta* (5,609 ± 9,119 ind m^{-3}). In oligo/mesotrophic reservoir, *Kellicotia bostoniensis* (18,375 ± 18,709 ind m^{-3}), *Keratella americana* (11,946 ± 7,457 ind m^{-3}) and *K. lenzi* (2,651 ± 2,727 ind m^{-3}) showed the highest abundance. Among copepods, *Microcyclops anceps* were more abundant in the eutrophic reservoir (2,385 ± 764 ind m^{-3}) and *T. decipiens* (1,249 ± 815 ind m^{-3}) in the oligo/ mesotrophic reservoir.

Only copepods showed significant differences among stations, reservoirs, and in the interaction between reservoir and months (Table 3). In both reservoirs, diversity and richness were higher at station 2, and abundance at station 1. Diversity and richness were higher in oligo/mesotrophic reservoir, in contrast with abundance, which was higher in the eutrophic reservoir. Significant differences among sampling months were not observed, but months interacting in each reservoir showed significant differences to diversity and richness, and were higher in oligo/mesotrophic reservoir.

Canonical Correspondence Analysis explained 64% of relationships between rotifers and environmental variables, and 57% between copepods and environmental variables (Table 4, Fig. 2). For both taxa, the two reservoirs were clearly separated.

For Rotifera, 13 species showed significant correlations ($P < 0.1$), and amongst the nine environmental variables, only nitrate and dissolved oxygen did not show significant correlations (Table 4). In the eutrophic reservoir, in the first canonical variable, mainly *Polyarthra remata*, *P. vulgaris* and *P. truncatum* were positively correlated with total phytoplankton; chlorophyll-*a*, and inversely correlated with *C. coenobasis*, *K. bostoniensis*, *C. unicornis* and *Hexarthra* sp., with water transparency (Secchi) and conductivity. In the second canonical variable, *Ptygura* sp., *Brachionus reductus, F. longiseta, K. lenzi, K. cochlearis* and *Ascomorpha saltans*, were positively correlated with total phosphorus, water temperature, pH, chlorophyll-*a* and total phytoplankton. Inversely, *C. unicornis*, *Hexarthra* sp., *B. falcatus*, *K. americana* and *Polyarthra dolychoptera* were positively correlated with conductivity and transparency.

Among copepods, only *M. anceps* did not show significant correlation. In first variable, *Acanthocyclops robustus* and *Tropocyclops prasinus* were correlated with total phosphorus, water temperature, chlorophyll-*a*, and total phytoplankton in the eutrophic reservoir. Three species of *Thermocyclops* genus were correlated with conductivity and transparency in

Table 2. List of species of Rotifera and Copepoda Cyclopoida in our study, with frequency among samples (Fr.%).

Species	Eutrophic Iraí Reservoir Fr. %	Oligo/mesotrophic Verde River Reservoir Fr. %
Rotifera		
Brachionus calyciflorus (Pallas, 1766)	14	-
Brachionus caudatus personatus (Ahlstrm, 1940)	20	-
Brachionus dolabratus dolabratus (Harring, 1915)	26	-
Brachionus falcatus falcatus (Zacharias, 1898)	29	-
Brachionus mirus var. *reductus* (Koste, 1972)	54	-
Filinia longiseta (Ehrenberg, 1834)	50	3
Kellicotia bostoniensis (Rousselet, 1908)	75	100
Keratella americana (Carlin, 1943)	64	94
Keratella cochlearis (Gosse, 1851)	96	100
Keratella lenzi (Hauer, 1953)	76	75
Plationus patulus (Müller, 1786)	-	31
Copepoda		
Acanthocyclops robustus (Sars, 1863)	21	33
Microcycplops anceps (Richard, 1897)	39	78
Thermocyclops minutus (Lowndes, 1934)	-	81
Thermocyclops decipiens (Kiefer, 1929)	17	81
Thermocyclops inversus Kiefer, 1936	-	67
Tropocyclops prasinus (Fischer, 1860)	59	3

Table 3. ANOVA's results ("*F*"/"*P*" values) of ecological attributes of cyclopoid copepods in two reservoirs. Significant values are in bold.

Attributes/Factors	Stations	Reservoirs	Reservoirs* Months
Diversity	**5.37/0.00**	**34.01/0.00**	**2.98/0.01**
Equitability	0.64/0.67	0.73/0.40	0.96/0.48
Richness	**5.65/0.00**	**34.89/0.00**	**3.72/0.00**
Cyclopoida abundance	**9.35/0.00**	**47.48/0.00**	1.83/0.09
Freedom degrees	5	1	9

oligo/mesotrophic reservoir. In the second canonical variable, *T. minutus*, *T. decipiens* and *A. robustus* were positively associated with water temperature, chlorophyll-*a* and water transparency, for both reservoirs.

DISCUSSION

The results indicated that some species can be related with the water quality in the studied reservoirs, and can be useful for the region with temperature climate and probably for most of south of Brazil. Rotifers and cyclopoids species can be selected due its contrasting abundances between reservoirs. Our results corroborate most of the literature used, for example Sendacz & Kubo (1982), Matsumura-Tundisi & Tundisi (2003); Silva & Matsumura-Tundisi (2005), and Silva (2011).

The composition of rotifer communities responds to environmental factors and therefore can be used as

Table 4. Correlation coefficients (r^2) and *P* value (*P*) of the environmental variables and Rotifera and Copepoda species through the Canonical Correspondence Analysis, using 1,000 permutations. Abbreviations of species ( ) to look Figure 2. Significant values are in bold.

Environmental variables	r^2	*P*	Environmental variables	r^2	*P*
Total phosphorus	0,28	**0,03**	Total phosphorus	0,3	**0,05**
Nitrate	0,19	0,12	Nitrate	0,1	0,47
pH	0,29	**0,02**	pH	0,1	0,46
Dissolved oxygen	0,01	0,89	Dissolved oxygen	0,1	0,22
Water temperature	0,49	**0**	Water Temperature	0,5	**0**
Conductivity	0,73	**0**	Conductivity	0,9	**0**
Transparency (Secchi)	0,52	**0**	Transparency (Secchi)	0,7	**0**
Chlorophyll-*a*	0,39	**0,02**	Chlorophyll-*a*	0,4	**0,02**
Total Phytoplankton	0,60	**0**	Total phytoplankton	0,8	**0**
Rotifera species			Copepoda species		
Ascomorpha saltans (Asal)	0,53	**0,01**	*Acanthocyclops robustus* (Arob)	0,1	**0,1**
Brachionus falcatus falcatus (Bfal)	0,07	0,42	*Microcycplops anceps* (Manc)	0,2	0,12
Brachionus reductus (Bred)	0,30	**0,04**	*Thermocyclops decipiens* (Tdec)	0,7	**0**
Collotheca sp. (Cosp.)	0,07	0,48	*Thermocyclops inversus* (Tinv)	0,5	**0**
Conochilus coenobasis (Ccoe)	0,15	0,13	*Thermocyclops minutus* (Tmin)	0,4	**0,01**
Conochilus unicornis (Cuni)	0,52	**0**	*Tropocyclops prasinus* (Tpra)	0,4	**0,01**
Filinia longiseta (Flon)	0,51	**0,01**			
Hexarthra sp. (Hesp)	0,08	0,33			
Keratella americana (Kame)	0,51	**0**			
Kellicottia bostoniensis (Kbos)	0,26	**0,06**			
Keratella cochlearis (Kcoc)	0,47	**0**			
Keratella lenzi (Klen)	0,51	**0,01**			
Ploesoma truncatum (Ptrun)	0,73	**0**			
Polyarthra dolychoptera (Pdol)	0,23	**0,1**			
Polyarthra remata (Prem)	0,76	**0**			
Polyarthra vulgaris (Pvul)	0,77	**0**			
Ptygura sp. (Ptysp.)	0,46	**0,04**			

biological indicator of trophic conditions status of aquatic systems (Sladecek, 1983; Pontin & Langley, 1993). In the eutrophic reservoir, the higher richness was found for the Brachionidae family and *Brachionus* species, and are suggested as indicators of high trophic state (Sládecek, 1983).

However, even with the trend observed in the present study, the use of rotifers as bioindicators must be careful due to the contrasting results that can be found in the literature. For example, Nogueira (2001) and Sampaio *et al.* (2002) have found high frequency of *Collotheca* sp., *Conochilus coenobasis, C. unicornis, Keratella americana, K. cochlearis* and *Polyarthra vulgaris* in oligotrophic reservoirs of Paranapanema River, in contrast with Matsumura-Tundisi & Tundisi (2005), who observed abundance peaks of *C. coenobasis* and *K. americana* in an eutrophic reservoir. Another example is the study of Bonecker *et al.* (2007), that studied 30 reservoirs in Paraná State (Brazil), and concluded that *Hexartra intermedia*, *Synchaeta pectinata* and *Trichocerca insignis* indicated eutrophic conditions and *Trichocerca pusilla* and *T. similis* mesotrophic conditions.

Thus, only the high richness of Brachionidae can be pointed out as indicator of eutrophic conditions, even considering the other relationships commonly

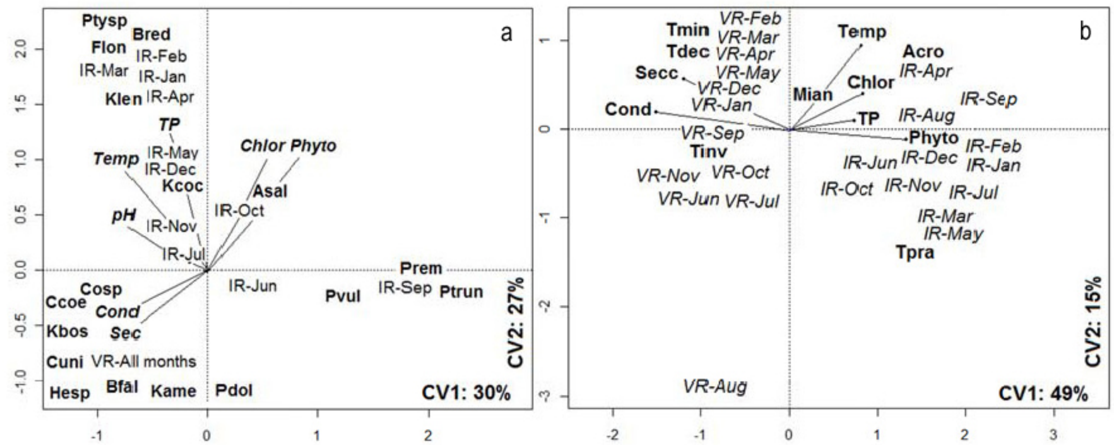

Figure 2. Correspondence Canonical Analysis for abundance of a) rotifers, and b) copepods species and environmental variables of the two reservoirs.

found in the literature. These findings are in agreement with the results of Paggi & Paggi (1998), and more recently with Claps *et al.* (2011), in shallow Argentinean lakes, which show relationships of high richness of Brachionidae and eutrophic conditions. Several studies provided lists of rotifer species that are indicative of different trophic states, among them good indicators of eutrophic conditions are *Brachionus* sp., *Trichocerca pussila*, *Filina longiseta*, *Keratella cochlearis* (Radwan, 1976; Sladecek, 1983; Duggan *et al*., 2001).

For copepods, *Thermocyclops decipiens* has been employed in other studies as indicators of eutrophic waters (Landa *et al.*, 2007; Nogueira *et al.*, 2008), because this species is able to maintain a high population density even in the presence of a Cyanobacteria bloom (Rocha *et al*., 2002). The species was dominant only in the oligo/mesotrophic reservoir, whereas in the eutrophic reservoir, *Tropocyclops prasinus* and *Acanthocyclops robustus* were dominants. This result suggest that in reservoirs with hypereutrophic conditions, more rustic species, as *T. prasinus* can become dominant over *T. decipiens*. *Tropocyclops prasinus* has already been registered in ephemeral environments (Menu-Marque, 2001), and was recently suggested by Silva (2011) as indicator of eutrophic waters in São Paulo State. Other species of cyclopoid copepods can become dominant in hypereutrophic environments, such as *Metacyclops mendocinus*, found in high abundance in Barra Bonita Reservoir, in Tiete River (Zaganini *et al.*, 2011).

Although more abundant in the eutrophic reservoir due to abundance peaks, *Microcycplops anceps* was more frequent in the oligo/mesotrophic reservoir. This result corroborates those observed by Silva (2011), suggesting this as an indicator of oligo/mesotrophic reservoirs. Again, as well as for rotifers, this copepod species has been found in environments of several trophic states. For example, if in the present study only two samplings were carried out in the eutrophic reservoir, in dry and wet periods, and the abundance peak of *Microcycplops anceps* was registered, we conclude that this species is successful in the eutrophic and not in the oligo/mesotrophic environments. Nevertheless, with more available data opposite trends of variation can be noticed.

Even though occasionally some of these species are found in different trophic conditions, this study confirms that *T. prasinus* dominates in eutrophic reservoirs, in subtropical and temperate climates. It is worth to emphasize that this species easily develops and dominate in ephemeral environments as water pools. The same is observed for some species of *Metacyclops* genera.

Species diversity index for aquatic systems offers distinct possibilities for quantitatively evaluate the response of a community to pollution. For example, according to Paturej (2008) the Shannon-Weaver index of species diversity, for the whole zooplankton community, tends to decrease as a water body becomes more eutrophic. In central Brazil, one comparative study of the zooplankton composition of six lacustrine ecosystems, observed a tendency of decreasing diversity with increasing trophic level (Starling, 2000). In China, Xiong *et al.* (2003), in their study with plankton community, conducted in four Chinese lakes of different trophic states, concluded that species number was negatively correlated with degree of water eutrophication.

A close relationship among richness, diversity and total abundance of copepods was observed in the interaction between months and reservoirs, suggesting that reservoirs show distinct temporal variations according to the trophic state. In the oligo/mesotrophic reservoir, seasonal cycles are generally more regular with increases in summer, but in the eutrophic reservoir, the cycles are irregular and show abrupt oscillations due to peaks of abundance of opportunistic species, as *T. prasinus*. Other authors found similar results in eutrophic reservoirs. For example, according to Matsumura-Tundisi & Tundisi (2003), some chemical changes in water are probably responsible for the growth of different species of phytoplankton, and thus changes in zooplanktonic community can be noticed. These authors stated that some modifications in diversity are responses to the environmental stress caused by eutrophication.

The canonical correspondence analysis showed more satisfactory results for copepods than for rotifers, associating *T. prasinus* and *A. robustus* with chlorophyll-*a*, total phytoplankton and total phosphorus, in the eutrophic reservoir. On the other hand, transparency and conductivity were positively correlated with *Thermocyclops decipiens* and *T. minutus* in the oligo/mesotrophic reservoir, in contrast to the expected of finding higher abundance of *T. decipiens* in the eutrophic reservoir, as commonly found in reservoirs of the southeast of Brazil, in the tropical zone (Nogueira 2001; Landa *et al.*, 2007; Nogueira *et al.*, 2008). Probably due the excessive eutrophication with intense algal blooms and other variables such reservoir morphometry, climate and altitude, *Thermocyclops* was present but was never dominant during the studied period. In our study, the rotifer population density is positively related with total phosphorus and conductivity, this result corroborates that observed by Arora & Mehra (2003), in the backwater of the Delhi segment of the Yamuna River.

Primary productivity in lakes and reservoirs is controlled by a set of physical, chemical and biological variables (Thornton, 1990). Generally, zooplankton groups have different responses to changes in water residence time: rotifers dominate when the residence time of water is low or intermediate. On the other hand, when the residence time is higher the community tends to be dominated by microcrustaceans (Barany *et al.*, 2002). However, in our study, the rotifer population density was higher than the copepod population in the eutrophic reservoir, which has higher water residence time (Table 1). Similar result was found in two lakes in Argentina, where rotifer was not affected by decreased water residence time (Rennella & Quirós, 2006). Iraí Reservoir has a residence time of 375 days. Although phytoplankton biomass increases with water residence time, other factors are important in determining biomass accumulation. This reservoir is located next to urban, agriculture, pasture and mining areas, and the susceptibility to eutrophication is also favored by characteristics such as low average depth and high retention time (Andreoli & Carneiro, 2005).

It is concluded that the results are in agreement with the Maitland’s (1978) assertion, since higher diversity and richness were found in the oligo/mesotrophic compared to the eutrophic reservoir, where organisms abundance was higher. The dominance of some species of *Brachionus* for rotifers and *T. prasinus* and *A. robustus* for copepods indicates eutrophic conditions, but in the cases of excessive eutrophication, other species, more rustic, commonly dominate. Although the dominance of *T. decipiens* over *T. minutus* and *T. inversus* was widely used in Brazil as indicator of eutrophic waters, *Thermocyclops* was dominant in the oligo/mesotrophic reservoir.

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