Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v37i3.27759

Rotifer community structure along a stretch under the influence of dams in the Upper Paraná River floodplain

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ABSTRACT. The construction of reservoirs imposes substantial impact on freshwater ecosystems and changes the ecological aspects of the lotic system downstream of dams. We hypothesized an increasing dissimilarity between communities in the sampling sites according to increasing distance from the Porto Primavera Dam. In addition, we expect that the rotifer community in the last sampling site will be influenced more by environmental variables related to trophic status. Samplings were conducted under the water surface of ten sites on the Paraná River in August 2013. Environmental variables were also determined. The highest number of taxa belonged to families Brachionidae, Lecanidae and Trichocercidae. The most abundant species was observed to *Synchaeta oblonga*, *Keratella cochlearis*, *Brachionus calyciflorus*. The species dissimilarity between sampling sites, tested using the Sorensen index, showed high dissimilarity between sampling sites. Redundancy analysis indicated a significant relationship between environmental variables (total phosphorus and ammonia) and abundance of *Brachionus calyciflorus* and *Keratella cochlearis*, in the last sampling site. Our results suggest a greater dissimilarity between the rotifer communities according to increasing distance from the Porto Primavera Dam. In addition, a higher influence of the environmental variables related to trophic conditions was observed in the last sampling site, and influenced indirectly the occurrence and abundance of some rotifer species, due to increased availability of food resources, confirming the predicted hypothesis.

Keywords: rotifer, trophic status, composition, longitudinal distribution.

Estrutura da comunidade de rotíferos ao longo de um trecho sob a influência de barragens na planície de inundação do alto rio Paraná

RESUMO. A construção de reservatórios impõe considerável impacto sobre os ecossistemas de água doce e altera os aspectos ecológicos do sistema lótico a jusante das barragens. A hipótese foi que ocorrerá maior dissimilaridade entre as comunidades nos pontos amostrados à medida que se afastam da barragem de Porto Primavera. Espera-se, ainda, que a comunidade de rotíferos do último ponto de amostragem seja mais influenciada pelas variáveis ambientais relacionadas à trofia. As amostragens foram realizadas à subsuperfície da região pelágica em dez pontos no rio Paraná no mês de agosto de 2013. As espécies mais abundantes foram *Synchaeta oblonga*, *Keratella cochlearis*, *Brachionus calyciflorus.* As variáveis ambientais também foram determinadas. O maior número de táxons registrados pertenceu às famílias Brachionidae, Lecanidae e Trichocercidae. A similaridade da composição de espécies calculada de acordo com o índice de Sorensen registrou elevada dissimilaridade entre os pontos amostrados. A análise de redundância constatou a relação significativa entre as variáveis ambientais (fósforo total e amônia) e a abundância de *Brachionus calyciflorus* e *Keratella cochlearis*, no último ponto de amostragem. Nossos resultados sugerem que ocorreu maior dissimilaridade entre as comunidades de rotíferos à medida que se afastam da barragem de Porto Primavera. Além disso, foi observada maior influência das variáveis ambientais relacionadas às condições tróficas no último ponto de amostragem, e influenciou indiretamente a ocorrência e abundância das espécies de rotíferos, por causa do aumento da disponibilidade de recursos alimentares, corroborando com a hipótese predita.

Palavras-chave: rotífera, trofia, composição, distribuição longitudinal.

Introduction

In Brazil, most of the electric power produced is hydropower because of the large river basins with high slope. This type of energy model was intensified from the twentieth century, and 95% of all energy produced in the country derives from these systems (TUNDISI, 1999). To meet the steadily increasing demand for energy it is frequent the construction of reservoirs, which impose considerable impact on freshwater ecosystems.

These developments alter to some extent, directly or indirectly, all ecological aspects of the lotic system downstream of reservoir (RENAULT; SANTOS, 2002; SILVA et al., 2005; AGOSTINHO et al., 2007).

The consequences derived from the construction of reservoirs in a river channel include the disruption of the natural environment that causes a remarkable drop in water turbulence, with consequent sedimentation of suspended matter (VANONI, 1977). These alterations affect the structure of aquatic communities, mainly due to changes in nutrient concentrations. As nutrients are essential to the maintenance of organisms, they become limiting to environment production and directly affect the species (WALL et al., 2001; AGOSTINHO et al., 2004; ARMYNOT DU CHÂTELET et al., 2004; HOEINGHAUS et al., 2008; TUNDISI; MATSUMURA-TUNDISI, 2008).

The Paraná River provides energy for several states, mainly Minas Gerais, São Paulo and Paraná, which amount to almost 60% potential installed in the country (ANEEL, 2014). The section of this river between Porto Primavera and Itaipu reservoirs is the last dam-free in Brazilian territory. Therein, the flood regime is the main structuring force on aquatic communities in these environments, despite of the influence from the twenty-six reservoirs upstream (BORGES; TRAIN, 2009; PAULETO et al., 2009; LUZ-AGOSTINHO et al., 2009). Seasonal disturbances along with high environmental heterogeneity promotes high diversity of species, and this area is considered essential for the maintenance of populations already eliminated by the regulation of reservoirs in other parts of the river (AGOSTINHO et al., 2005).

Although the Paraná River still has a considerable stretch free of dams, it is undergoing oligotrophication. This process consists of increasing water transparency and decreasing concentrations of phosphorus and suspended materials available in the river channel (ROBERTO et al., 2009). Recent studies have observed that environments subjected to such conditions show a reduction of the biomass and the number of planktonic species in the river and environments adjacent to the reservoir (RODRIGUES et al., 2009; BOVO-SCOMPARIN et al., 2013).

Environmental variables related to trophic status have a decisive role in the functioning and dynamics of aquatic communities in floodplains (RIETZLER et al., 2002). The primary productivity of the system, the water transparency and the structural complexity of habitats are affected by environmental variables, influence the interactions between species and cause changes in the structure of aquatic communities (MATSUMURA-TUNDISI et al., 1986, WINEMILLER et al., 2008). Among these aquatic organisms, rotifers can be used as environmental bioindicators and promptly respond to environmental variations due to high turnover rates of rotifer populations (AOYAGUI; BONECKER, 2004; HAVEL et al., 2009; LANSAC-TÔHA et al., 2009; GAOHUA et al., 2013; PERBICHE-NEVES et al., 2013).

The Concept of Serial Discontinuity indicates that the contribution of various tributaries constitutes interference in rivers lateral dimension, contributing to supply of organic and inorganic particulate material, by modifying the natural attributes that have been degraded with the reservoir by regulating the upstream (STANFORD; WARD, 2001). Therefore, it is assumed that the rotifer community structure is also influenced by changes in environmental variables along the dam-free stretch given the input of nutrients from the tributaries that flow into the main channel of the Paraná River. Thus, this study aimed at evaluating the changes in rotifer dissimilarity along the last stretch free of dams in the Paraná River.

In this way, we hypothesized an increasing dissimilarity between rotifer communities in the sampling sites according to increasing distance from the Porto Primavera Dam. Additionally, we expect that the rotifer community in the last sampling site is influenced most by environmental variables related to trophic status, due to the contribution of the different tributaries that flow in the Paraná River channel.

Material and methods

Study area

The study was conducted in the Upper Paraná River floodplain, in the dam-free stretch of 230 kilometers of the Paraná River located downstream of Porto Primavera Dam (São Paulo State, Brazil) (22º37'S; 53º06'W) and the Itaipu Lake (Paraná State, Brazil) (23º55'S; 54º08'W). Ten sampling sites (P1 to P10) were established in the main channel of the Paraná River, located between the areas of influence of the tributaries: Paranapanema, Baía, Ivinhema, Ivaí, Amambaí, Iguatemi and Piquiri (Figure 1).

The Paraná River is the main river of the Plata basin and is considered the tenth largest river in the world in discharge and the fourth in drainage area. It encompasses the entire south-central region of South America, from the slopes of the Andes to the Serra do Mar coastal forests, near the Atlantic Coast. This system has a multichannel pattern, average current flow of 1 m s^{-1}, varied width and presence of large islands (SOUZA FILHO et al., 2004).

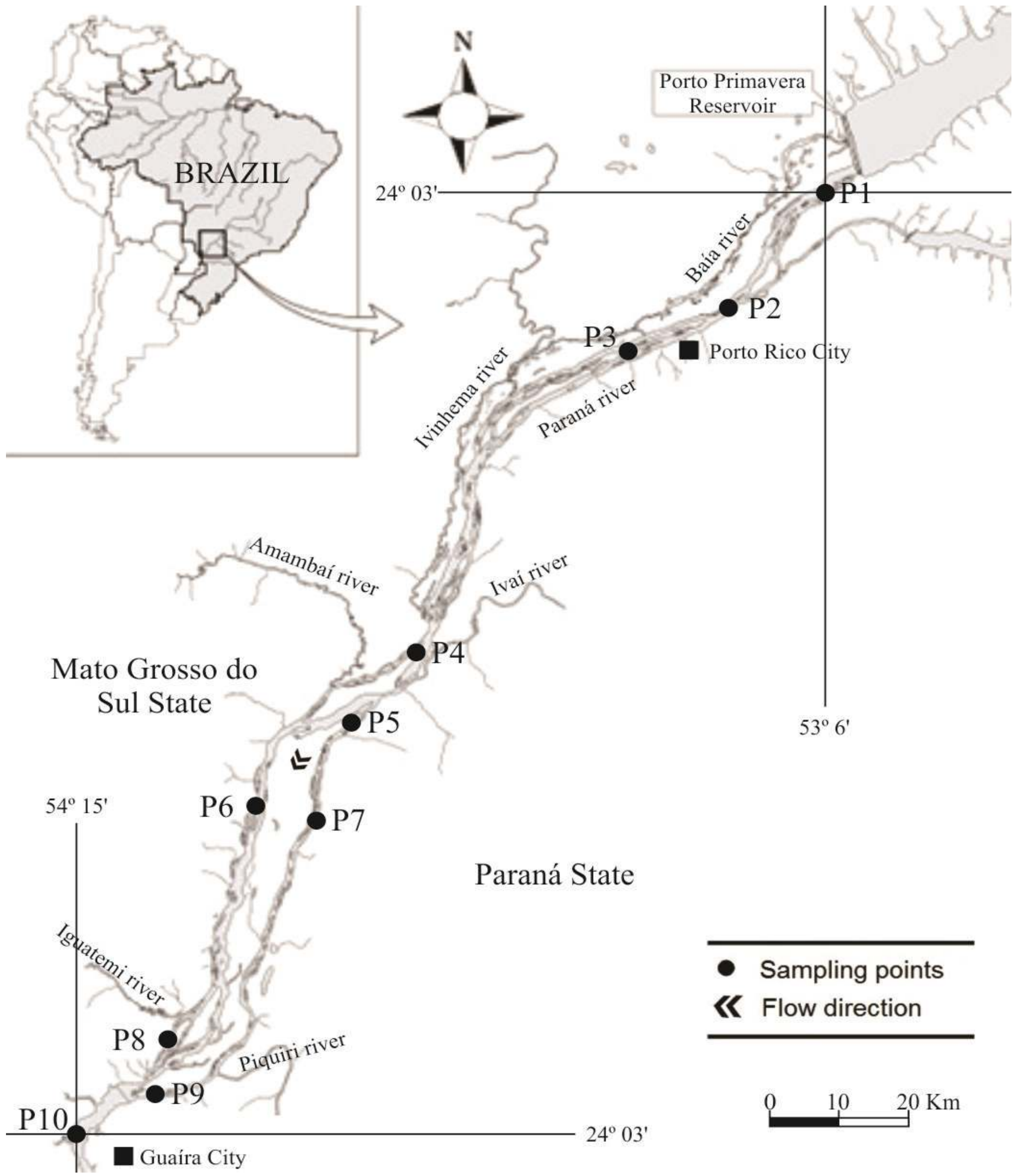

Figure 1. Area of study and location of the sampling points in the Upper Paraná River floodplain, Brazil.

The Paraná River and Ivinhema River are characterized as oligotrophic rivers and Baía River and Ivaí River are characterized as eutrophic rivers (ROBERTO et al., 2009). The Paranapanema River shows oligo-mesotrophic characteristics (PAGIORO et al., 2005). The other tributaries have eutrophic conditions, due the absence of control by dams and industrial effluents, they are considered to be important contributors to Paraná River (AGOSTINHO; ZALEWSKI, 1996).

Sampling design

Samplings were carried out in August 2013, low water period. Rotifers were sampled in triplicate (center, right bank and left bank) in the main channel of the Paraná River, in the morning, under the water surface of the pelagic and littoral region. Samples were obtained by filtering 600 liters of water per sample through plankton net (68 μm) using a motorized pump. The material retained in the net was stored in labeled polyethylene vials, fixed with 4% formaldehyde solution buffered with calcium carbonate.

At the same time of rotifer sampling, the following environmental variables were measured: water temperature (°C), dissolved oxygen (mg L^{-1}) (portable digital oximeter - YSI 550A), electrical conductivity (μS cm^{-1}) (portable digital conductivity meter - Digimed DM), pH (portable digital pH meter - Digimed DM) and water transparency determined with Secchi disk. Water aliquots were taken for determination of ammonia, chlorophyll-*a*, total phosphorus and nitrogen. These samples were kept in a freezer (-20°C) for later analysis in the laboratory.

In the laboratory, the concentrations of total nitrogen (MACKERETH et al., 1978) and phosphorous (GOLTERMAN et al., 1978) were determined. The concentration of chlorophyll-*a* (μg L^{-1}) was quantified by 90% acetone extraction and read in a spectrophotometer at 663 nm (GOLTERMAN et al., 1978). Values of chlorophyll-*a* were used to estimate the phytoplankton biomass (APHA, 1995).

Laboratory analysis

Rotifer richness was analyzed under light microscope until the stabilization of species accumulation curve, that is, until no new species is registered in the sample. To this end, we used a Sedgwick-Rafter chamber for analysis. Species identification was performed with the aid of common slides and cover slips and optical microscope using the following specialized literature: Koste (1972, 1978), Koste and Robertson (1983), José de Paggi (1989), Nogrady (1993), Nogrady and Pourriot (1995), Segers (1995) and Smet (1996)

For abundance estimation, sub samples were taken with Hensen-Stempell pipette (2.5 mL), and counted at least 50 individuals in Sedgewick-Rafter chambers under optical microscope (BOTTRELL et al., 1976). The abundance was expressed in individuals per m^{-3}.

Data analysis

The species dissimilarity between sampling sites was tested using the Sorensen index (SORENSEN, 1948). This index ranges from zero to one and the higher the value obtained, the greater the difference between environments as for species composition.

To determine which environmental variables influenced the total abundance of rotifers in the different sampling sites, we used a Redundancy Analysis (RDA) (LEGENDRE; LEGENDRE, 1998). The results were based on the values of total inertia and the percentage of explanation of each axis retained ($p < 0.05$). The abundance was log transformed to reduce the effect of the rare species; after this procedure, data were processed according to the Hellinger procedure (LEGENDRE; GALLAGHER, 2001). Furthermore, the multicollinearity between environmental variables was checked by Variance Inflation Factor (VIF).

All the analyses were run in the free software R (R CORE TEAM, 2011).

Results

The rotifer community was composed of 57 taxa belonging to 13 families of the Class Monogononta and one family of the Class Digononta. The highest number of taxa belonged to families Brachionidae (16 taxa), Lecanidae (nine taxa) and Trichocercidae (seven taxa) (Table 1).

Table 1. List of species of the rotifer community recorded in the Paraná River.

ROTIFERA	
Asplanchnidae	
Asplanchna priodonta (Gosse,1850)	*Asplanchna sieboldi* (Leydig, 1854)
Brachionidae	
Brachionus angularis Gosse, 1851	*Kellicotia bostoniensis* (Rousselet, 1908)
B. budapestinensis Daday, 1885	*Keratella americana* Carlin, 1943
B. calyciflorus Pallas, 1766	*K. cochlearis* Gosse, 1851
B. caudatus Barrois e Daday, 1894	*K. lenzi* Hauer, 1953
B. falcatus Zacharias, 1898	*K. tropica* Apstein, 1907
B. mirus Daday, 1905	*Plationus patulus* (O. F. Müller,1786)
B. quadridentatus quadridentatus Hermann, 1783	*Platyias leloupi* (Gillard, 1957)
B. urceolaris (O.F. Muller, 1773)	*P. quadricornis* Daday, 1905
Epiphanidae	
Epiphanes clavatula (Ehrenberg, 1834)	
Euchlanidae	
Dipleuchlanis propatula propatula (Gosse, 1886)	*E incisa* Carlin, 1939
Euchlanis dilatata Ehrenberg, 1832	
Trochosphaeridae	
Filinia longiseta (Ehrenberg, 1834)	*F. terminalis* (Plate, 1886)
F. opoliensis (Zacharias, 1891)	
Gastropodidae	
Ascomorpha. cf. agilis Zacharias, 1893	*A. ovalis* (Bergendal, 1892)
Lecanidae	
Lecane bulla (Gosse, 1886)	*L. luna* (O. F. Müller, 1776)
L. cornuta (O.F. Muller, 1786)	*L. lunaris* (Ehrenberg, 1832)
L. curvicornis (Murray, 1913)	*L. papuana* Murray, 1913
L. elsa (Hauer, 1931)	*L. proiecta* (Hauer, 1956)
L. ludwigi (Eckstein, 1883)	
Lepadellidae	
Lepadella ovalis (Müller, 1786)	*L. patella* (Müller, 1773)
Mytilinidae	
Mytilina acantophora Hauer, 1938	
Synchaetidae	
Ploesoma truncatum (Levander, 1894)	*Synchaeta oblonga* Ehrenberg, 1831
Polyarthra dolichoptera Idelson, 1925	*S. pectinata* Ehrenberg 1832
P. vulgaris Carlin 1943	*S. stylata* Wierzejski, 1893
Testudinellidae	
Testudinella mucronata (Gosse, 1886)	*T. patina patina* (Hermann, 1783)
Trichocercidae	
Trichocerca bicristata (Gosse,1886)	*T. longiseta* (Schrank, 1802)
T. bidens (Lucks, 1912)	*T. pusilla* (Jennings, 1903)
T. cylindrica (Imhof, 1891)	*T. stylata* (Gosse, 1851)
T. elongata (Gosse, 1886)	
Dicranophoridae	
Dicranophorus caudatus (Ehrenberg, 1834)	*Trichotria tetractis* (Ehrenberg, 1830)
Bdelloidea	

Considering the abundance the rotifer community, was observed that the most abundant species in the study was *Synchaeta oblonga*, *Keratella cochlearis*, *Brachionus calyciflorus* between others (Table 2).

Table 2. List of species most abundant recorded in the Paraná River.

Species	Ind.m^{-3}
Synchaeta oblonga	604.55
Keratella cochlearis	285.49
Brachionus calyciflorus	219.76
Trichocerca bicristata	78.60
Lecane bulla	78.30
Brachionus caudatus	65.92
Ploesoma truncatum	60.67
Kellicottia bostoniensis	41.95
Trichocerca pusilla	31.22
Polyarthra dolicoptera	28.75

The different sampling sites showed alterations as to the dissimilarity. The largest dissimilarity of species was found between P1 and P10, that is, the species composition in the first site, near the Porto Primavera Dam (P1), differed from that verified in the last site (P10). The lowest values of dissimilarity were observed in the sites closest to the Porto Primavera Dam (P1 and P2) (Table 3).

Table 3. Mean values of dissimilarity between sampling sites.

	P1	P2	P3	P4	P5	P6	P7	P8	P9
P2	0.44								
P3	0.71	0.64							
P4	0.75	0.72	0.76						
P5	0.66	0.68	0.56	0.80					
P6	0.60	0.62	0.62	0.67	0.67				
P7	0.65	0.79	0.76	0.76	0.71	0.71			
P8	0.69	0.76	0.78	0.78	0.77	0.78	0.65		
P9	0.57	0.60	0.65	0.72	0.57	0.64	0.64	0.58	
P10	0.89	0.78	0.72	0.76	0.68	0.63	0.57	0.51	0.61

The RDA indicated that the rotifer abundance was associated with environmental variables between the sampling sites ($p < 0.05$) and the ordination model explained 37.6% of the variance in the data matrix.

The species gradient in the axis 1 distributed most species on the positive side of the axis. They were not positively associated with environmental variables related to trophic status. Although most sampling sites were not associated with environmental variables related to the trophic condition, we observed a positive influence of these variables in the site farthest from the Porto Primavera Dam (P10). *Brachionus calyciflorus* and *Keratella cochlearis* were correlated with P10 and to trophic environmental variables (ammonia and total phosphorus). In contrast, these same species were negatively correlated with pH (Figure 2).

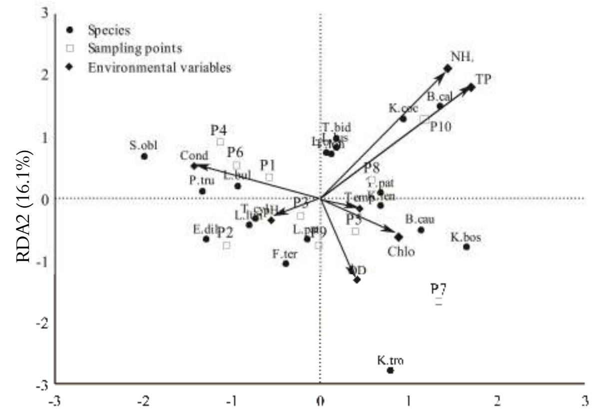

Figure 2. Ordination diagram of RDA. Environmental variables: temp= water temperature; OD= dissolved oxygen; Cond= electrical conductivity; TP= total phosphorus; Chlo= chlorophyll *a*; NH_4= ammonia; pH. Species: B.cal= *Brachionus calyciflorus;* B.cau= *Brachionus caudatus;* E.dil= *Euchlanis dilatata*; F.ter= *Filinia terminalis;* K.bos= *Kellicottia bostoniensis;* K.coc= *Keratella cochlearis;* K.len= *Keratella lenzi;* K.tro= *Keratella tropica;* L.bul= *Lecane bulla;* L.lun= *Lecane luna;* L.lus= *Lecane lunares;* L.ova= *Lepadella ovalis;* L.pat= *Lepadella patela;* P.tru= *Ploessoma truncatum;* S.obl= *Synchaeta oblonga;* T.pat= *Testudinella patina;* T.bid= *Trichocerca bidens;* T.cyl= *Trichocerca cylindrica;* T.lon= *Trichocerca longiseta*. Only species most associated with each axis were used to easily identification of the relations between species and environmental variables. VIF analysis excluded water transparency, total nitrogen and phosphate.

Discussion

Families Brachionidae, Lecanidae and Trichocercidae showed the highest number of taxa. Numerous studies have shown that these families are frequently recorded in freshwater environments, considered typical of Neotropical regions, such as South America (DABÉS, 1995; ASTLZ; ALVAREZ, 1998; AOYAGUI; BONECKER, 2004). In addition, these families may represent to 50% of total taxa recorded in the Upper Paraná River floodplain (BONECKER et al., 1998; SERAFIM-JÚNIOR et al., 2003; LANSAC-TÔHA et al., 2004, 2009).

The communities showed a high dissimilarity of species between the sampling sites P1 and P10. This result is probably related to changes caused by reservoirs upstream of the first sampling site. Dams strongly affect the environments near the reservoirs and are a major anthropogenic disturbance to these ecosystems (STANFORD; WARD, 2001; SOUZA FILHO et al., 2004; OLIVER; MERRICK, 2006; THOMAZ et al., 2007). These systems inevitably imply the ecological transformation of an environment, interfering with the local hydrological, climatological and biological components (RENAULT; SANTOS, 2002; SILVA et al., 2005).

Furthermore, lower values of dissimilarity in the two sites closest to the Porto Primavera Dam are directly influenced by the reservoir. These results are also in agreement with Bonecker et al. (2009), who showed a significant change in the rotifer composition in environments downstream of the Porto Primavera Reservoir.

Differences in dissimilarity found in the different sampling sites can be ascribed to variations in environmental variables. The results may be related to the contribution of several secondary rivers (Paranapanema, Baía, Ivinhema, Ivaí, Amambaí, Iguatemi and Piquiri). These tributaries flow into the main channel of the Paraná River, near the sampling sites, and alter the environmental conditions in the region of confluence with the Paraná River (MORETTO; NOGUEIRA, 2003; FEITOSA et al., 2006). According to the serial discontinuity concept (STANFORD; WARD, 2001), small rivers constitute a lateral interference with longitudinal processes, thereby providing, changes in environmental variables in the receiving water body.

The RDA results evidenced that the associations of environmental variables related to trophic status positively influenced the occurrence of rotifers in the last sampling site (P10). Several studies have demonstrated that the dominance of certain rotifer species is associated with the trophic condition of the environment (FARIA et al., 2000; BRANCO et al., 2002, 2008). Our results pointed out that the positive relationship of *Keratella cochlearis* and *Brachionus calyciflorus* with P10 may indicate more productive environments, attributed to total phosphorus and ammonia. These two species were also registered by other authors to represent the environments with higher concentrations of environmental variables related to trophic status (BËRZINŠ; PEJLER, 1989; PIVA-BERTOLETTI, 2001). According to Matsumura-Tundisi (1999), *Brachionus calyciflorus* is an indicator organism to higher concentrations of nutrients. In England, rotifers were also employed to classify some aquatic environments, and *Keratella cochlearis* indicator environments with higher yields (PONTIN; LANGLEY, 1993).

Rotifers species do not depend directly from nutrients for their survival, since they are affected by the quality and quantity of bacteria, protozoans, and debris. Thus, the environmental variables related to trophic affected indirectly the community structure (HARPER, 1992; LATHROP; CARPENTER, 1992), indicated by the higher abundance observed in the last point, due the contributions from the tributaries. These organisms have a high able to take these food particles, and before it is benefit from environments considered more productive (ALLAN, 1976; FARIA et al., 2000). Thus, the rotifer community at the site farthest from the Porto Primavera Dam was influenced by the increased availability of food resources, due the contribution of the tributaries.

Conclusion

Our results suggest a greater dissimilarity between the rotifer communities according to increasing distance from the Porto Primavera Dam, with higher influence from trophic variables. In addition, a higher influence of the environmental variables related to trophic conditions was observed in the last sampling site, due this last sampling site received a greater contribution from the tributaries that flow in the Paraná River channel. Thus, the environmental variables influenced indirectly the occurrence of some rotifer species, due to increased availability of food resources, confirming the predicted hypothesis.

Acknowledgements

We thank Dr. Ciro Yoshio Joko for suggestions, criticisms and contributions. The authors also acknowledge the Programa de Pesquisa Ecológica de Longa Duração/Conselho Nacional de Desenvolvimento Científico e Tecnológico (PELD-CNPQ), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Fundação Araucária and Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura - Universidade Estadual de Maringá (Nupélia/UEM) for the logistic and financial support.

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Received on May 5, 2015.
Accepted on July 24, 2015.