Acta Scientiarum. Biological Sciences
ISSN: 1679-9283
eduem@uem.br
Universidade Estadual de Maringá
Brasil

Fernandes Bessa, Gisele; Cardoso Galli Vieira, Ludgero; Bini, Luis Mauricio; Florêncio dos Reis, Deusiano; Benevides de Morais, Paula

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Acta Scientiarum. Biological Sciences, vol. 33, núm. 2, 2011, pp. 179-184
Universidade Estadual de Maringá
.png, Brasil

DOI: 10.4025/actascibiolsci.v33i2.7336

Concordance patterns in zooplankton assemblages in the UHE - Luís Eduardo Magalhães reservoir in the Mid-Tocantins river, Tocantins State, Brazil

Gisele Fernandes Bessa[1*], Ludgero Cardoso Galli Vieira[2], Luis Mauricio Bini[3], Deusiano Florêncio dos Reis[1] and Paula Benevides de Morais[1]

*[1]Laboratório de Microbiologia Ambiental e Biotecnologia, Universidade Federal do Tocantins, Av. NS15, ALCNO14, Bloco II, Sala 06, 77020-120, Palmas, Tocantins, Brazil. [2]Universidade de Brasília, Planaltina, Distrito Federal, Brazil. [3]Departamento de Biologia Geral, Instituto de Ciências Biológicas, Universidade Federal do Goiás, Goiânia, Goiás, Brazil. *Author for correspondence. E-mail: bessagf@yahoo.com.br*

ABSTRACT. The goal of this study was to evaluate the concordance amongst three zooplankton groups (Rotifera, Cladocera, and Copepoda) and between the zooplankton groups and the environmental variables in the Luis Eduardo Magalhães reservoir, in the Mid-Tocantins River, Tocantins State, Brazil. Concordance patterns were found in relation to environmental variables, cladocerans, and rotifers, although values were relatively low. These results indicate that one should be cautious about the use of indicative taxonomic groups to detect environmental changes, where divergent results annul extrapolation possibilities and indicate the existence of distinct environmental factors controlling different groups.

Keywords: concordance, reservoir, rotifera, cladocera, copepoda.

RESUMO. Padrões de concordância entre grupos zooplanctônicos do reservatório da UHE – Luís Eduardo Magalhães no Médio Tocantins – Estado do Tocatins, Brasil. O objetivo deste estudo foi avaliar a concordância entre os três grupos zooplanctônicos (Rotifera, Cladocera e Copepoda) e entre os grupos zooplanctônicos e as variáveis ambientais no reservatório da Usina Hidrelétrica Luis Eduardo Magalhães no Médio Tocantins, Estado de Tocantins. Foram encontrados padrões concordantes em relação às variáveis ambientais e cladóceros e rotíferos, mesmo assim, com valores relativamente baixos de concordância. Estes resultados indicam que se deve ter cuidado no uso de grupos taxonômicos indicadores para detectar mudanças ambientais, em que os resultados divergentes anulam as possibilidades de extrapolação e indicam a existência de fatores ambientais distintos que controlam os diferentes grupos.

Palavras-chave: concordância, reservatório, rotifera, cladocera, copepoda.

Introduction

One of the main objectives of ecological studies and environmental monitoring of aquatic ecosystems is to evaluate the relationship among populations of different species and environmental variables (BINI et al., 2007). Usually the monitoring of aquatic ecosystems uses different biological assemblages (aquatic macrophytes, zooplankton, benthic macroinvertebrates and fishes) and distinct environmental variables (pH, conductivity, dissolved oxygen, nitrogen and phosphorus concentrations) as indicators of environmental quality (BONADA et al., 2006; MARMOREK; KORMAN, 1993; ODEMIS; EVRENDILEK, 2007; SAMECKA-CYMERMAN; KEMPERS, 2002). Nevertheless, few studies verify whether the different taxonomic groups (for example rotifers, cladocerans and copepods) present congruent responses among groups and if these responses correlate to environmental gradients.

The identification of congruency may suggest similar responses to environmental gradients (PAAVOLA et al., 2003), and thus may be used as strong indicators for decision-making related to control, prevention and preservation of water quality as well as the adoption of measures for the management of multiple uses of reservoirs and public health (SANT'ANNA; AZEVEDO, 2000). Nevertheless, the validation of surrogate groups for different practical needs such as the detection of environmental impacts, evaluation of the efficiency of strategies of management and selection of conservation areas must be supported by the existence of concordance between biological groups (PINTO et al., 2008;

SAETERSDAL et al., 2004; UNDERWOOD; FISHER, 2006).

The concordance between assemblages may be defined as the degree of similarity between the structures of assemblages of different constituent taxonomic groups along different monitoring areas (PASZKOWSKI; TONN, 2000). These responses shared by different taxonomic groups are of great interest because they suggest that these groups are controlled by some few environmental factors (PAAVOLA et al., 2003).

This work aims to evaluate the degree of concordance between (i) the different groups of organisms that make up the zooplankton community (rotifers, cladocerans and copepods) and (ii) between the different zooplankton groups and environmental variables in a tropical reservoir of the Tocantins Hydropower cascade in the State of Tocantins, Brazil. Although cladocerans and copepods have a closest phylogenetic relationship, it would be expected that the higher values for concordance would be found between rotifers and cladocerans that possess a similar reproductive strategy through parthenogenesis. Concordance between the taxonomic groups would reveal similar responses to environmental factors and it would indicate the viability of using one taxonomic group for the detection of impacts on aquatic ecosystems.

Material and methods

Study area

The Luís Eduardo Magalhães Hydroelectrical Power plant is part of the integrated development plan of the Tucuruí-Serra da Mesa electrical system. The reservoir originated by its construction had been completed from September 2001 to February 2002 and has an area of 630 km^2, an extension of 172 km, residence time of 24 days and as main tributaries the rivers Lajeadinho, Santa Luzia, Água Fria, Taquaruçu, São João (Palmas), Mangues, Água Suja, São João (Porto Nacional), do Carmo, Areias and Crixás.

The main channel of the reservoir is recognized to present three main compartments according to the hydrodynamics of the system and four sampling points were set to represent all compartments and the influence of main tributaries (Figure 1). Samples were collected in the dry months of June/2006, April/2007 and July/2007, and rainy season of October/2006 and January/2007.

Biological variables

For the study of the zooplankton community a plankton net 30-inches long with mesh size of 68-μm and mouth opening of 4.5-5 inches was pulled horizontally in the limnetic region for five minutes at an average speed of five 5 km h^{-1} using. Immediately after sampling the material was stored in polyethylene bottles and a chilled solution of formaldehyde added to form a final concentration of 4%.

Identification of the microcrustaceans (young and adult forms) was undertaken using an light microscope Olympus, and quantitative analysis was done with sub-samples added to an acrylic plate under Dimex model MZS–250 light microscope, and 200 individual counted and identified. For enumeration of Cyclopoida and Calanoida homogenous aliquots of 1 mL of sample were counted in Sedgewick-Rafter chamber under low magnification. Density of organisms was expressed as individuals per cubic meter (ind. m^{-3}).

Environmental variables

Physical and chemical parameters were obtained *in loco* at subsurface depth and included: temperature (°C), transparency (m), turbidity (NTU), conductivity (μS cm^{-1}), dissolved oxygen (mg L^{-1}) and pH by using a multi-parameter probe Horiba U22XD. Samples for chlorophyll-*a* (μg L^{-1}) were collected with a Van Dorn bottle at an approximate depth of 50 cm and analyses were done according to American Public Health Association (APHA, 2005).

Data analysis

Sampling units were ordinated using a Detrended Correspondence Analysis (DCA) in relation to biological variables and a Principal Component Analysis (PCA) (BORCARD et al., 2011) in relation to environmental variables. Procrustes analysis (JACKSON, 1995) with 10,000 permutations were run for each group of two variables (for example Copepoda and Cladocerans, or Copepoda and environmental variables), using the scores of the two first axis of each ordination above, resulting in the "*r*" value for concordance between two sets of data that varies from 0 (absence of concordance) and 1 (perfect concordance).

Biological data were expressed as log x+1 and environmental variables were expressed as log values except for pH and standardized using Standard Deviation. All analyses were done using the R program (R DEVELOPMENT CORE TEAM, 2007) and the vegan package (OKSANEN et al., 2009).

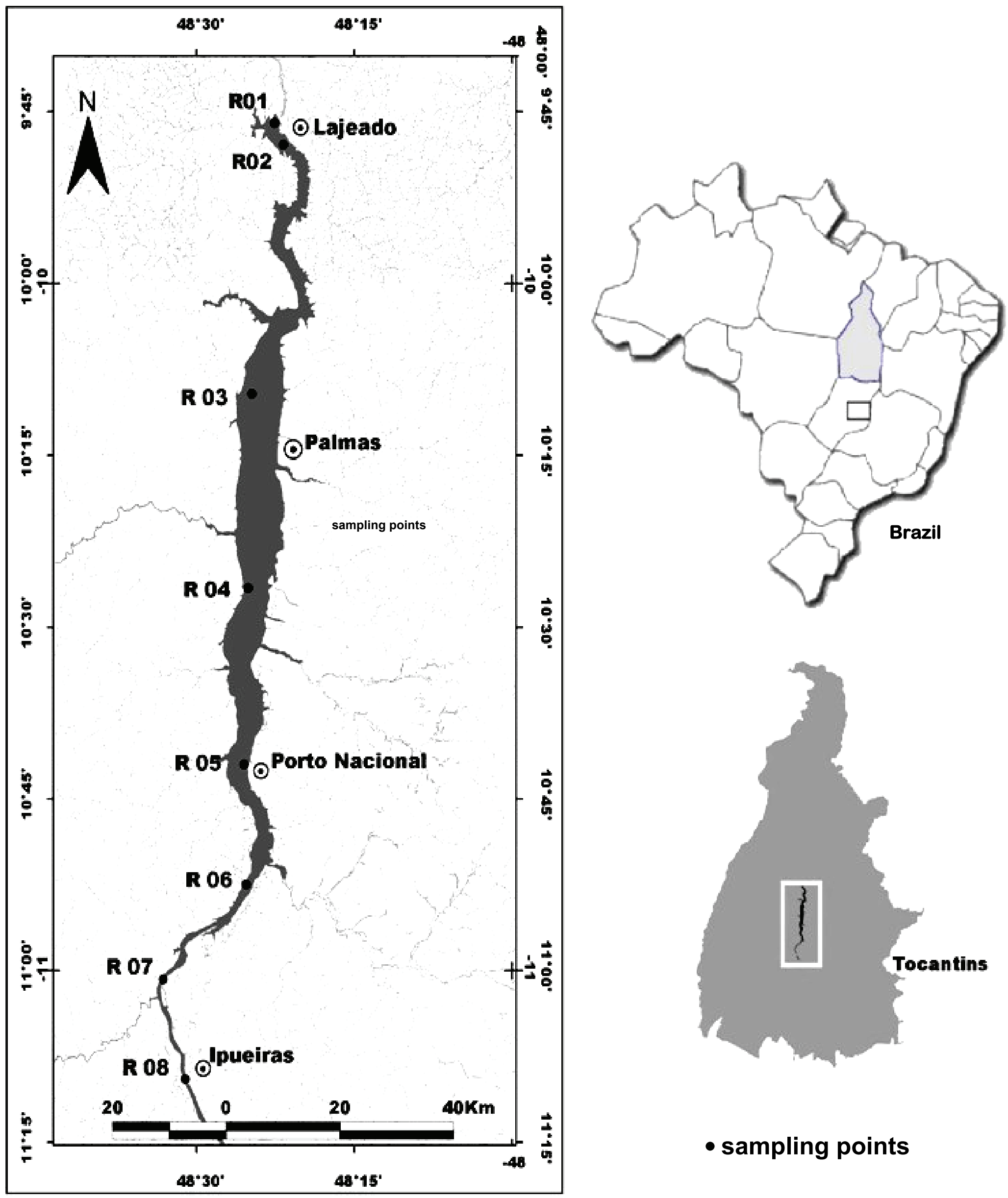

Figure 1. Map of the Reservoir of the Hydropower plant of Luis Eduardo Magalhães and location of the sampling points.

Results and discussion

Among the three zooplanktonic groups, Copepoda, Cladocera and Rotifera, 45 taxa were obtained from 24 samples (Table 1). Rotifera was the most representative along the sampling period and presented 26 species, followed by Cladocera with 14 species and Copepoda with five species. Species richness varied from 26 to 37 (Figure 2). Rotifera was represented by a higher number of species in all sampling points, followed by Cladocera.

Figure 2 shows that Rotifera densities were higher in sampling point 4 (5.352 ind. m^{-3}). Higher densities of Cladocera were found in sampling point 1 (4.342 ind. m^{-3}) whereas Copepoda presented low densities of adults in all sampling points.

In average, variability in species richness and densities was low in all zooplankton groups both spatially and temporally (Figure 2). The highest variability was found when comparing density of Copepoda and Cladocera organisms in sampling point 1 and of Rotifera in sampling point 4 (Figure 2).

Table 1. Average and Standard Deviation (SD) and occurrence as presence/absence of the species identified in samples of the reservoir of Luís Eduardo Magalhães Hydropower plant.

Family	Species	Average	SD	Sampling points							
				1	2	3	4	5	6	7	8
Cladocera											
Chydoridae	*Alona* sp.	0.14	0.39				X	X	X	X	
	Alonela sp.	0.03	0.21	X							
Bosminidae	*Bosmina hagmani*	15.01	38.23	X	X	X	X	X	X	X	X
	Bosminopsis deitersi	0.34	0.90	X	X	X	X		X	X	X
Daphnidae	*Ceriodaphnia cornuta cornuta*	11.89	32.81	X	X	X	X	X	X		X
	Ceriodaphnia cornuta rigaudi	7.07	15.91	X	X	X	X	X	X	X	X
	Ceriodaphnia silvestrii	0.02	0.11	X							
	Daphnia gessneri	3.75	16.02	X	X	X	X		X	X	X
Sididae	*Diaphanosoma birgei*	164.83	610.90	X	X	X	X	X	X	X	X
Macrothricidae	*Ilyocryptus* sp.	0.08	0.44				X			X	
	Ilyocryptus spinifer	0.02	0.11					X		X	
	Macrothrix sp.	0.95	2.37				X	X	X	X	X
Daphnidae	*Moina minuta*	5.27	12.68	X	X	X	X	X		X	
	Simocephalus serrulatus	0.83	2.90	X			X	X	X	X	X
Cyclopidae	*Microcyclops anceps*	2.97	7.44	X	X	X	X	X	X	X	X
Copepoda											
Diaptomidae	*Notodiaptomus cearensis*	3.18	15.35	X	X	X	X	X	X	X	X
	Notodiaptomus spinuliferus	4.01	14.44	X	X	X		X		X	X
Cyclopidae	*Thermocyclops decipiens*	0.45	1.35	X	X	X	X	X			X
	Thermocyclops minutus	2.59	6.79	X	X	X		X	X	X	X
Rotifera											
Gastropodidae	*Ascomorpha* sp.	0.91	2.87		X	X	X				
Aplanchnidae	*Asplanchna sieboldi*	3.97	11.91	X	X	X	X	X			
Bdelloidea	Bdelloidea	1.13	2.35	X		X	X	X	X	X	
Brachionidae	*Brachionus caudatus*	0.91	2.75			X	X	X	X	X	
	Brachionus falcatus	10.58	17.43	X	X	X	X	X	X		X
	Brachionus mirus	0.28	1.24	X			X				
	Brachionus zahniseri	0.21	1.34					X			
Collothecidae	*Collotheca* sp1.	4.32	14.03		X	X	X	X			X
	Collotheca sp2.	3.20	8.26			X	X	X	X	X	X
	Collotheca sp3.	40.46	127.50	X	X	X	X	X	X	X	X
Conochilidae	*Conochilus coenobasis*	62.91	129.88	X	X	X	X	X	X	X	X
	Conochilus unicornis	45.49	70.54	X	X	X	X	X	X	X	X
Testudinellidae	*Filinia longiseta*	6.28	11.95	X	X	X	X				
Hexarthridae	*Hexarthra intermedia*	4.03	6.63		X	X	X	X	X	X	X
Brachionidae	*Keratella americana*	134.99	229.17	X	X	X	X	X	X	X	X
	Keratella cochlearis	29.84	70.32	X	X	X	X	X	X	X	X
	Keratella lenzi	4.62	11.87	X	X	X	X			X	X
	Keratella tropica	18.81	31.80	X	X	X	X	X	X	X	X
Lecanidae	*Lecane monostyla*	0.62	1.94		X	X				X	
	Lecane sp.	1.30	3.04		X			X	X	X	
Brachionidae	*Plationus macracanthus*	2.82	9.82	X		X	X			X	X
	Plationus patulus	9.69	21.31	X	X	X	X	X		X	X
Synchatidae	*Polyarthra vulgaris*	53.87	275.50	X	X	X	X	X	X	X	X
Floscularidae	*Sinantherina spinosa*	39.89	135.44	X	X	X	X	X	X		X
Synchatidae	*Synchaeta stylata*	0.14	0.91				X				
Trichocercidae	*Trichocerca cylindrica chattoni*	2.68	4.59	X	X	X	X			X	X

The reservoir maintained a well oxygenated water column; the pH tended to neutrality, and high transparency and low turbidity was observed in sampling points 1 and 2 (Table 2). Sampling points 3, 4, 5 and 6 presented high temperature, low transparency and higher values of turbidity and total dissolved solids.

Several authors (BINI et al., 2007, 2008; PINTO et al., 2008) evaluated the efficiency of using a surrogate taxa approach for environmental impact assessments. The application of those indicators can improve the efficacy of monitoring programs since it reduces the need to consider a greater number of species or groups. In countries with continental geographical area and scarce resources this is a fundamental aspect of water monitoring. The usefulness of the surrogate taxa depends largely on community concordance or else the evaluations based on few groups may be too weak to provide reliable predictions on the biodiversity patterns and do not appear to be particularly relevant for conservation of freshwater ecosystems (PAAVOLA et al., 2003).

Concordance analysis showed that density and species presence/absence data of zooplankton groups do not provide congruent patterns of ordination of sampling units (Table 3). Similar results were also found by Bini et al. (2007) in Samambaia lake, Goiás State, Brazil. We could not confirm the initial hypothesis that predicted higher values of concordance between Cladocera and Rotifera. We conclude that indicator groups should be used with caution and the use of a single surrogate group for the environmental impact assessment of the reservoir is not recommended.

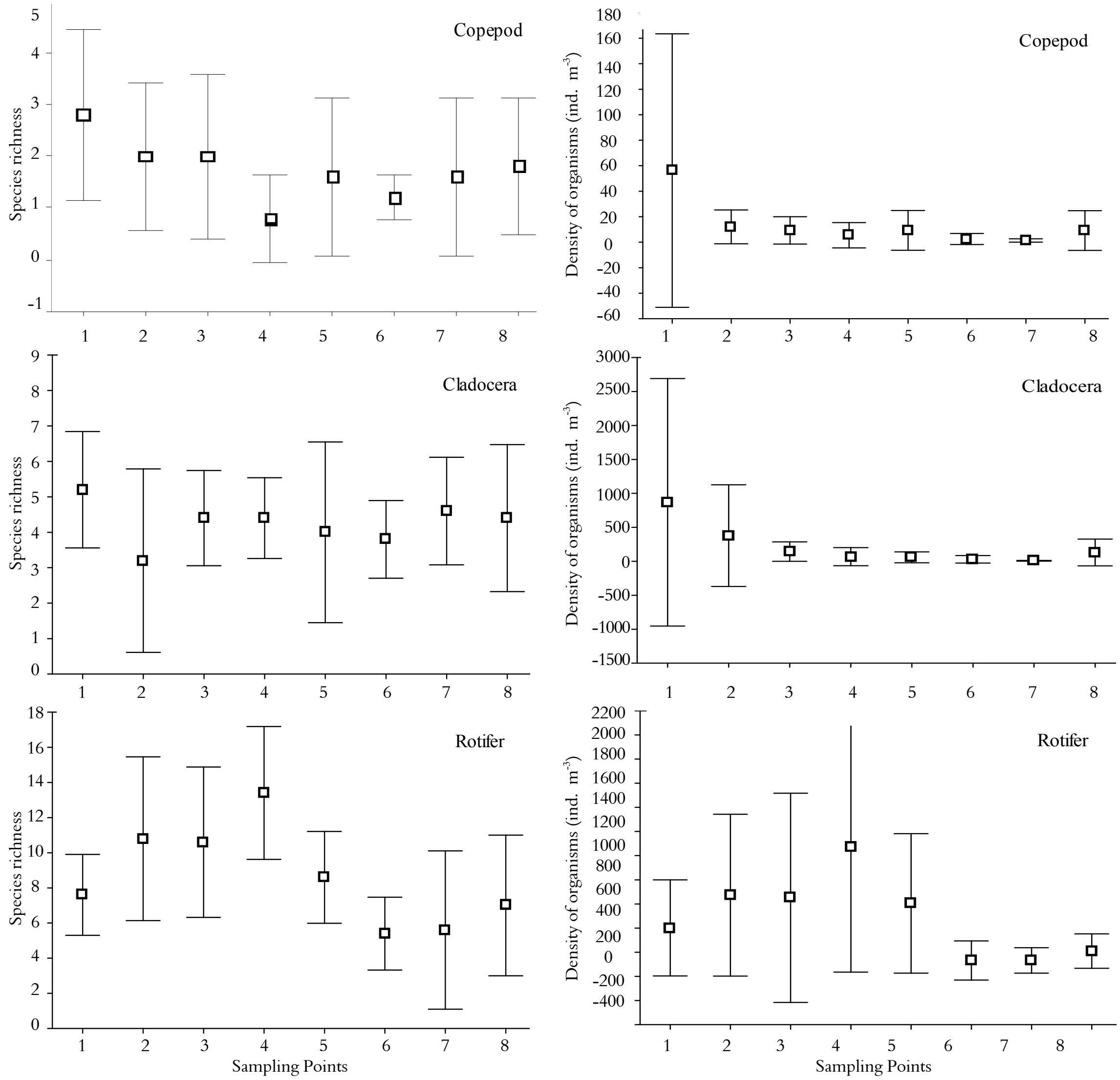

Figure 2. Average and Standard Deviation of the species richness and density of organisms in the eight sampling points.

Table 2. Average and Standard Deviation (SD) of environmental variables measured in eight sampling points of the reservoir of Luís Eduardo Magalhães Hydropower plant.

Variables		Sampling Points							
		1	2	3	4	5	6	7	8
pH	Average	7.09	7.34	7.57	7.45	7.21	7.44	7.62	7.47
	SD	0.56	0.40	0.31	0.19	0.34	0.23	0.15	0.37
Conductivity	Average	68.10	67.90	73.80	77.00	84.50	82.54	83.80	87.22
($\mu S\ cm^{-1}$)	SD	7.18	6.19	10.13	10.44	7.50	8.20	8.35	7.06
Dissolved	Average	7.61	7.52	7.52	7.37	6.48	6.89	6.62	7.50
Oxygen (mg L^{-1})	SD	1.25	2.22	2.51	2.49	2.27	2.13	3.51	2.58
Temperature	Average	29.74	29.26	29.24	29.31	29.10	28.42	26.35	27.91
(°C)	SD	1.43	1.23	1.61	2.31	1.31	2.29	4.07	2.75
Turbidity	Average	2.16	1.74	2.44	3.04	6.37	6.45	4.45	3.98
(NTU)	SD	1.97	1.60	1.93	1.38	5.02	0.84	1.14	2.36
Chlorophyll-*a*	Average	5.48	7.54	8.68	6.86	5.92	6.68	7.90	5.80
($\mu g\ L^{-1}$)	SD	1.04	5.30	5.62	4.93	2.45	4.87	4.41	2.95
Transparency (m)	Average	3.35	2.84	2.20	1.65	1.39	1.56	2.08	1.88
	SD	0.58	0.85	0.68	0.61	0.15	0.24	0.71	0.38

Table 3. Procrustes analysis (r) and significance (P). Bold figures represent those with significant concordance.

	Abundance		Presence/Absence	
	r	P	r	P
Cladocera x Copepoda	0.22	0.414	0.12	0.890
Cladocera x Rotifera	0.15	0.690	0.23	0.234
Copepoda x Rotifera	0.33	0.083	0.22	0.441
Cladocera x Env. variables	0.36	0.009	0.30	0.064
Copepoda x Env. variables	0.19	0.586	0.14	0.827
Rotifera x Env. variables	0.36	0.010	0.42	0.002

Concordance patterns between environmental variables and zooplankton groups showed that Rotifera and Cladocera showed some degree of concordance to spatial variation of physical and chemical parameters although it was low (Table 3). This could be explained probably because (i) the different groups produce different responses to the environmental variables, (ii) lack of data on an important environmental variable such as predation and flow speed, or (iii) the prevailing action of neutral parameters such as dispersion.

Conclusion

In conclusion, the absence of congruent patterns in general, and the low values of significant concordance between zooplanktonic groups, and also to environmental variables, are strongly indicating that these groups should not be used to monitor environmental changes in the UHE-Luis Eduardo Magalhães reservoir.

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Received on June 15, 2009.
Accepted on November 3, 2009.