Zooplankton dormancy forms in two environments of the upper Paraná River floodplain (Brazil)

Formas de dormência do zooplâncton em dois ambientes da planície de inundação do alto Rio Paraná (Brasil)

Palazzo, F., Bonecker, CC. and Nagae, MY.

Programa de Pós Graduação em Ecologia de Ambientes Aquáticos Continentais – PEA,
Núcleo de Pesquisas em Limnologia, Ictiologia e Aqüicultura – Nupélia, Universidade Estadual de Maringá – UEM,
Av. Colombo, 5790, Bloco H-90, CEP 87020-900, Maringá, PR, Brazil
e-mail: biology.fabi@ibest.com.br, claudiabonecker@gmail.com, mynagae@hotmail.com

Abstract: This study evaluated and compared zooplankton dormancy forms in a temporary lagoon (TL) and an open lagoon (OL) of the Upper Paraná River floodplain. We hypothesized that a higher presence of the zooplankton species would be observed in TL as a consequence of a higher number of dormancy forms in sediments due the two effects: i) the community stress during the dry season (dried environment) and ii) absence of the species wash-out from the lagoon to the river (no connectivity). Sediment samplings were performed at two sites in the littoral region of the lagoons during the dry period (August 2001). The sediment samples (5 cm in depth), in triplicates, were placed in polyethylene flasks (1 L) with distilled water, under constant aeration, during 54 days. In the TL experiment, 46 zooplankton taxa were recorded (36 rotifer taxa, 8 cladoceran taxa, and 2 copepod taxa), while 17 taxa were recorded in the OL experiment (13 rotifer taxa and 4 cladoceran taxa). The highest number of exclusive taxa was observed in the TL experiment as well as the changes on the zooplankton groups presence. Rotifers presence was registered in the beginning of the TL experiment and it followed by cladocerans presence in the end. On the other hand, rotifers predominated in the OL experiment, mainly from the middle of the experiment. The hydrodynamic stress of TL environment (dried environment and no connectivity) influenced the zooplankton community structure (higher species richness) in the experiment. Rotifer species contributed to the zooplankton presence in both experiments, mainly in the TL due their opportunistic characteristics which were related to the environmental stress.

Keywords: zooplankton, colonization, sediments, connectivity, floodplain, dormancy.

Resumo: Esse estudo avaliou e comparou a presença do zooplâncton a partir das formas de resistência em uma lagoa temporária (LT) e uma lagoa aberta (LA) da planície de inundação do alto rio Paraná. A hipótese testada foi que ocorresse uma maior presença de indivíduos zooplanctônicos no plâncton na TL, como conseqüência da presença de um maior número de formas dormentes no sedimento, devido: i) o estresse da comunidade no período de seca (ambiente sem água) e a ii) ausência de perda de espécies da lagoa para o rio (sem conectividade). O sedimento foi amostrado em dois locais na margem dos ambientes no período de seca (agosto de 2001). O sedimento de cada amostra (5 cm de profundidade), em tréplica, foi acondicionado em frascos de polietileno, (1L), sendo os frascos preenchidos com água destilada e mantidos com aeração constante, durante 54 dias. No experimento da lagoa temporária, foi registrada a ocorrência de 46 táxons zooplanctônicos (36 rotíferos, 8 cladóceros e 2 copépodes), enquanto que no experimento da lagoa aberta, ocorreram 17 táxons (13 rotíferos e 4 cladóceros). Um grande número de táxons exclusivos foi constatado no experimento da LT, bem como a alteração da estrutura da comunidade. Nesse experimento, os rotíferos estiveram presentes a partir do início do experimento e foram substituídos pelos cladóceros ao final. Por outro lado, no experimento LA os rotíferos estiveram presentes a partir da metade do experimento (32º dia). O estresse hidrodinâmico da LT (ambiente sem água e conectividade) influenciou a estrutura da comunidade zooplanctônica (elevado número de espécies) no experimento. As espécies de rotíferos contribuíram para a presença da comunidade em ambos os experimentos, principalmente na LT, devido as características oportunísticas do grupo, as quais foram relacionadas ao estresse ambiental.

Palavras-chave: zooplâncton, formas de resistência, sedimento, conectividade, planície de inundação.

1. Introduction

Growing and reproduction are important features of an organisms' life history and reflect their presence in the environment, including the abiotic and biotic relationships. In their habitat, the organisms should find a way to maximize their fitness and promoted the colonization success of their population and/or their community. In this way, during their life cycle, zooplankton organisms present different strategies to colonize the environment, such as resting eggs and dormancy forms (Margalef, 1983; Rojas, 1995; Hansen and Santer, 2003).

The production of resting forms of zooplankton occurs in periods of unfavorable environmental conditions, such as high population densities, high predation rates, reduced water volume and temperature variation in aquatic environments. These forms are found in sediments of aquatic environments and may remain viable for long time periods (decades to a hundred years) (Ricci, 2001; Fryer, 1996; Maia-Barbosa et al., 2003).

Studies focusing on zooplankton resting eggs and dormancy forms in freshwater environments in Brazil are scarce, and most were conducted in ponds (Crispim and Watanabe, 2000, 2001; Crispim et al., 2003) and reservoirs (Maia-Barbosa et al., 2003).

The present study evaluated and compared zooplankton dormancy forms in a temporary lagoon and an open lagoon in the Upper Paraná River floodplain. We hypothesized that a higher presence of the zooplankton species would be observed in the temporary lagoon as a consequence a higher number of dormancy forms in sediments due the two effects: i) the community stress during the dry season (dried environment) and ii) absence of the species wash-out from the lagoon to the river (no connectivity).

2. Material and Methods

The Leopoldo and Figueira lagoons are located at Porto Rico Island on the Upper Paraná River floodplain (Figure 1). The first lagoon is an open lagoon (OL) and presents a channel (15 m width) which is permanently connected to the Paraná River, and is 966 m in length, 3 m in depth, 2,047 m in perimeter and 2.95 ha in area. Its banks are covered by forest composed of bamboos and *Croton, Cecropia* and *Inga*. *Eichhornia azurea* is the dominant macrophyte species. The water column can be characterized by reduced transparency values (1.3 m mean); slightly a acid to neutral pH (mean 6.85); reduced electrical conductivity (mean 50.7 μS.cm^{-1}); elevated dissolved oxygen values (mean 88%) and high temperatures (mean 26.6 °C) (Thomaz et al., 2001).

The Figueira lagoon is a temporary lagoon (TL), which is shallow (depth 0.4-2.1 m), with high turbidity and, consequently, reduced transparency (mean 0.27 m). This lagoon is is isolated from the river by a high levee.

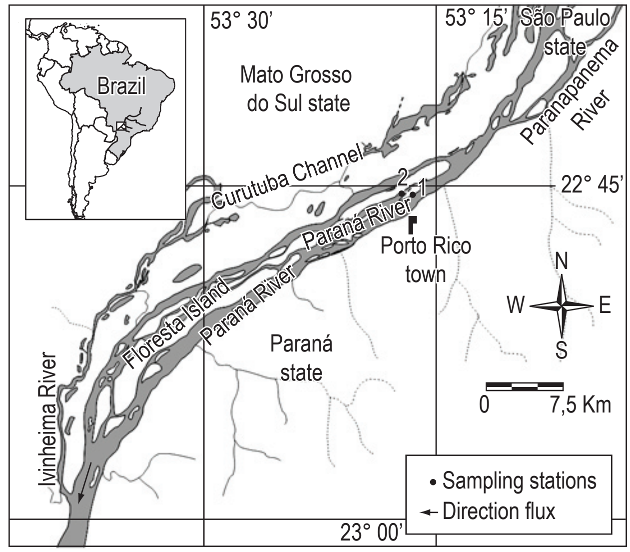

Figure 1. The Upper Paraná River floodplain and the two studied sites (1 = Figueira lagoon and 2 = Leopoldo lagoon) at Porto Rico Island.

The littoral region is occupied by multispecific aquatic macrophytes banks, in which *Nymphaea amazonum* and *Polygonum ferrugineo* are the dominant species. During high water period, this lagoon is approximately 80% larger than in the low water period due to influx from the Paraná River, mainly via groundwater. The water column can be characterized as slightly acid to neutral (mean pH 6.41), with reduced electrical conductivity (mean 60.7 μS.cm^{-1}), high dissolved oxygen saturation (mean 88.4%) and high temperatures (mean of 24 °C) (Veríssimo, 1994).

Sediment sampling was undertaken in two sites in the littoral region of the lagoons during the dry period (August 2001). A volume of 192.4 cm^3 of sediment was sampled with a core sampler and the first 5 cm depth were used as samples for analysis. In the laboratory, samples were refrigerated until the experiment began. The sediment from each sample was divided into three parts and kept in plastic flasks (1 L), and these flasks were filled with distilled water, with constant aeration, and were distributed randomly.

After a week, three water aliquots (5 mL each) were sampled from different depths (surface, middle and bottom of water column) of each flask in the morning, and filtered in a plankton net (68 μm) during a 54 day period. During the first month, sampling was carried out daily, and after this period sampling alternated days. The water temperature (measured with a digital portable thermistor YSI), pH (measured with a digital portable potentiometer Digimed) and dissolved oxygen concentration (measured with a digital portable oxymeter YSI) were recorded at each flask on the same day as the zooplankton samples.

Zooplankton species' richness was analyzed in a Sedgwick-Rafter chamber under an optic microscopic, according to specialized bibliography (Koste, 1978; Elmoor-Loureiro, 1997; Paggi, 1995; Lansac-Tôha et al., 2002; Reid, 1985; Santos Silva, 1989). The entire samples were analyzed and the individual zooplankton presence was evaluated.

3. Results

3.1. Abiotic conditions during the experiments

The results of the abiotic variables in both experiments showed that pH values ranged from to 5.61 to 8.59, and a lower mean variation was observed in the TL experiments, as well as the lower values. In the OL experiment, a higher means variation was observed from the middle (34^{th} day) until the end of the experiment (Figure 2).

Water temperature varied from 19 to 26.5 °C, and the temporal variation was similar in both experiments. The highest mean values were observed at the beginning (from the 1^{st} to the 17^{th} day) and the end (from the 33^{rd} to the 54^{th} day) of both experiments, and lower values were also observed from the beginning to the middle (18^{th}-24^{th} day). A greater variation was also verified in this period (from the 13^{th} to the 32^{nd} day) (Figure 2).

The dissolved oxygen variation showed a similar pattern in both experiments; however the values in the TL experiments showed a greater variation than those observed in the OL samples. The values ranged from 5.05 to 9.03 $mg.L^{-1}$. The highest means values were observed in the TL experiments (5.61-8.7 $mg.L^{-1}$). Lower mean values were observed in the beginning of both experiments, followed by the increased of mean values until the end (46^{th} day) (Figure 2).

3.2. Zooplankton community structure in the experiments

In the whole experiment, 52 taxa were identified (41 rotifers, 9 cladocerans and 2 copepods). In the OL experiments, the community was represented by 17 taxa (13 rotifer and 4 cladocerans) (Table 1). Nevertheless, 4 rotifer taxa (*Brachionus calyciflorus, Epiphanes clavatula, Monommata* sp. and *Polyarthra vulgaris*) and one cladoceran taxa (*Bosminopsis deitersi*) were only registered in this environment (Table 1).

In the TL experiments, 46 zooplankton taxa were identified (36 rotifers taxa, 8 cladocerans taxa and 2 copepods taxa). The families Conochilidae, Dicranophoridae, Euchlanidae, Floscularidae, Gastropodidae, Hexarthridae, Testudinellidae, Trochosphaeridae, Philodinidae (rotifer) and Cyclopidae (copepod) occurred only in this environment, as well as 28 rotifers, 5 cladocerans and 2 copepods species (Table 1).

A clear change in the zooplankton structure was observed in the TL experiments. Rotifers presence was registered in the beginning of this experiment and it followed by cladocerans presence from the 42^{nd} day. On the other hand, rotifers predominated in the OL experiment, mainly from the 32^{nd} day to the end (Figure 3).

4. Discussion

The highest occurrence of the zooplankton observed in the temporary lagoon can be ascribed to the greater production of dormant forms in this environment in comparison to the open lagoon. This production was related to the absence of connectivity with the river, the higher residence time (hydrodynamic instability), and a high abundance of aquatic macrophytes. This vegetation promoted a higher availability of habitats for the colonization by the zooplankton species (Bonecker et al., 1998; Lansac-Tôha et al., 2003). It was also corroborated to the exclusive species occurrence in TL experiment, e.g. Floscularidae, Philodinidae and Cyclopidae which are composed by non-planktonic species.

On the other hand, the hydrodynamic stability of the open lagoon, suggested by the constant water exchange with the river (connectivity), did not favor the production of a great number of dormant forms, as shown by the lowest occurrence of dormant forms observed in the experiment. Studies by Campos (1994) and Lansac-Tôha et al. (2004) showed a higher species richness in a temporary lagoon than in an open lagoon.

Chatterjee and Gopal (1998) attributed the zooplankton colonization success during the low water periods to the production of resting eggs or dormant stages. During the filling phase, these eggs hatch out and colonize the environment, determining, the structure and dynamics of zooplankton communities

Rotifers prevailed in both environments, as would be expected from their opportunistic characteristics (Allan, 1976; Margalef, 1983; Gilbert, 1995), although their presence occurred firstly in the TL experiments. It was also related to the hydrodynamic instability of the environment.

The abiotic variables results did not show a greater variation between the experiments (spatial scale) and days (temporal scale), except pH values which showed greater values in the OL experiments.

According to the results, we agree that the hydrodynamic stress of TL environment (water volume reduction and no connectivity) influenced the zooplankton community structure (higher species richness) in the experiment. Rotifer was important to the zooplankton presence in both experiments, mainly in the TL experiments due their opportunistic characteristics which were related to the environmental stress.

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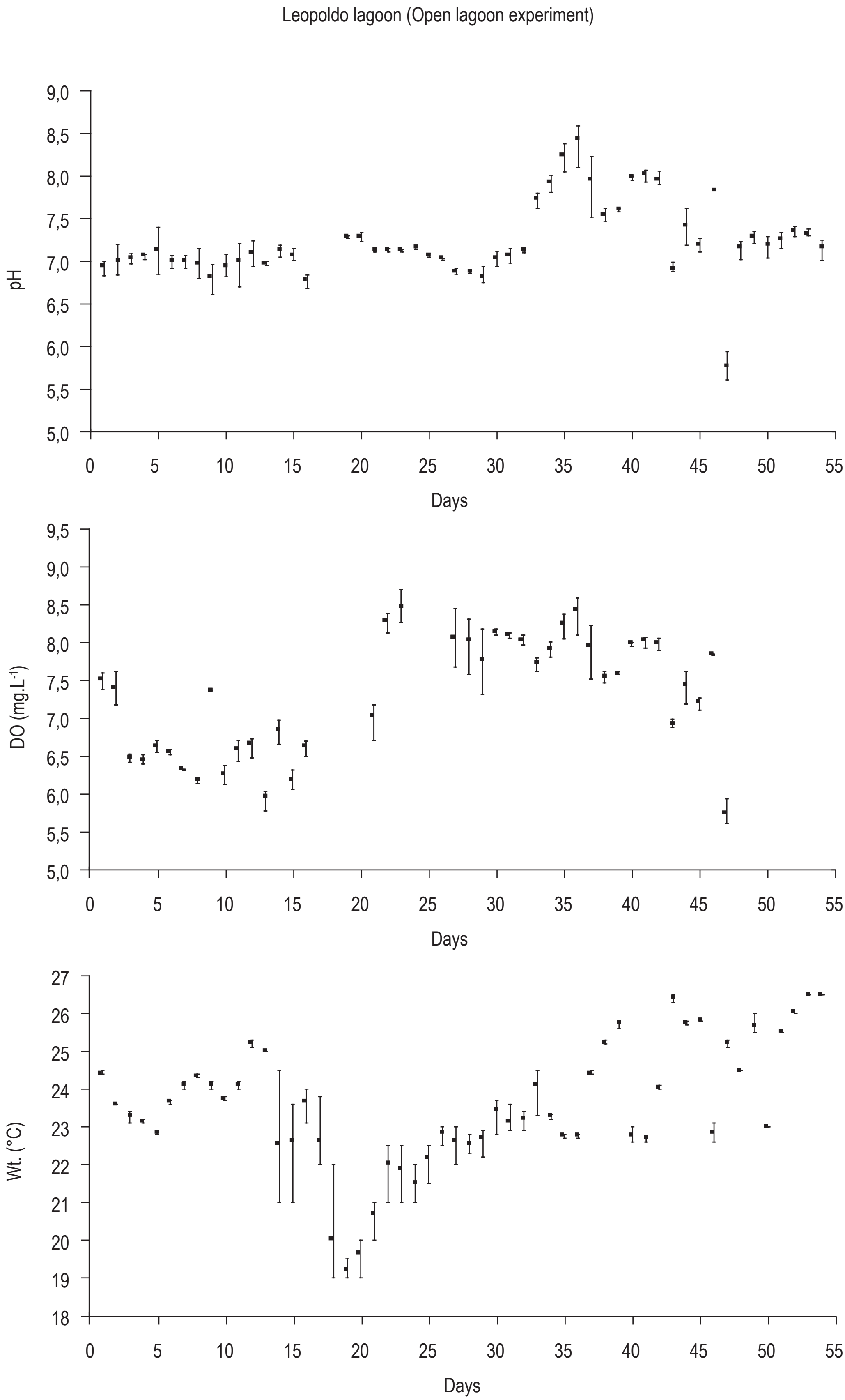

Figure 2. pH, dissolved oxygen (DO), and water temperature (WT) values registered in the experiments, during the 54 day study period (symbol = mean; bar = maximum and minimum values).

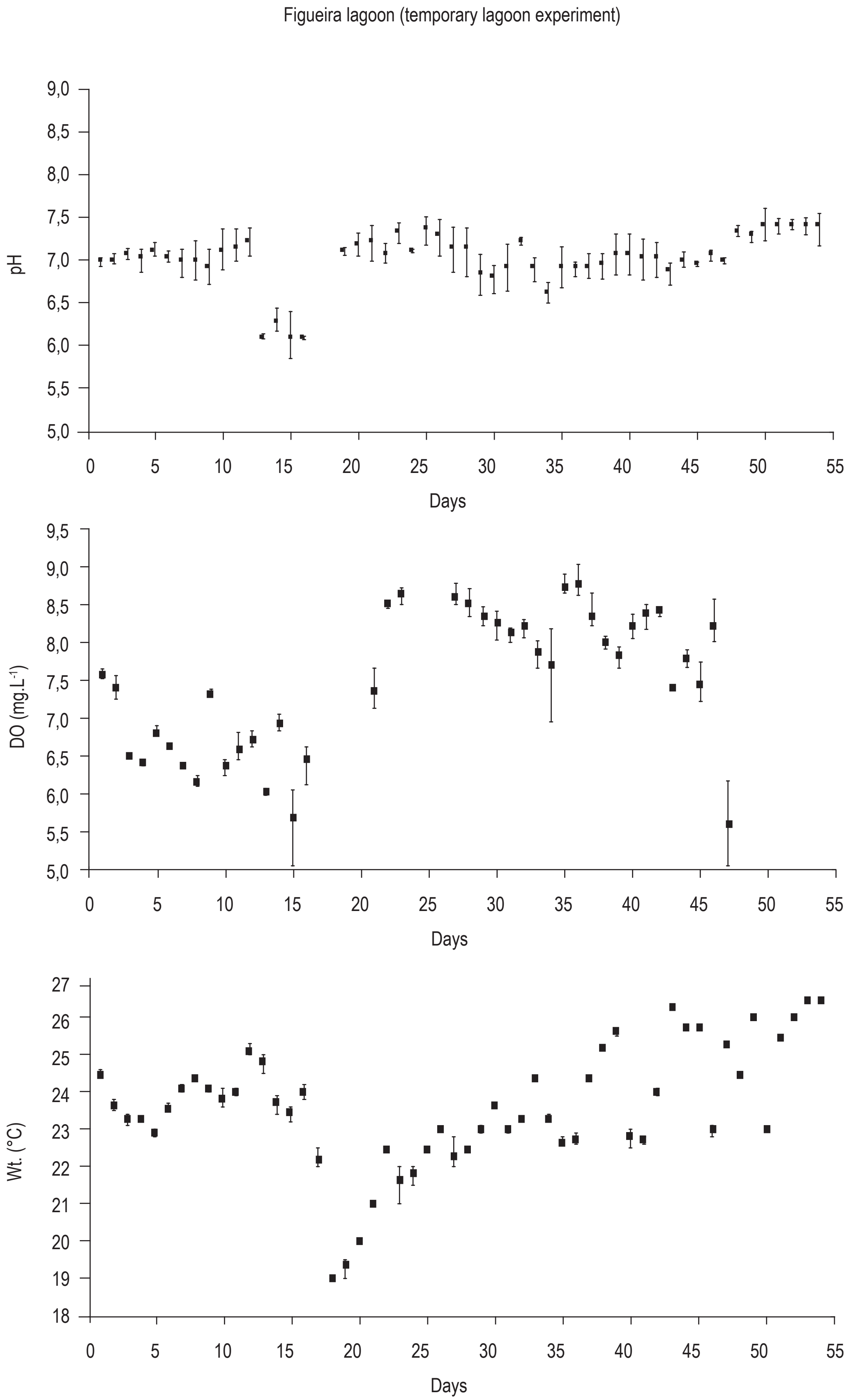

Figure 2. Continued...

Table 1. The zooplankton community recorded in the Figueira (TL) and Leopold (OL) lagoons experiments, during the 54 days.

Táxon	Figueira lagoon	Leopoldo lagoon
ROTIFERA		
Brachionidae		
Brachionus bidentata Anderson, 1889	x	-
B. budapestinesis Daday, 1885	x	-
B. calyciflorus Pallas, 1886	-	-
B. caudatus Barrois and Daday, 1894	x	-
B. falcatus Zacharias, 1898	x	-
B. quadridentatus Herman,1783	x	-
Keratella americana Carlin, 1943	x	-
K. cochlearis Gosse, 1851	x	-
K. lenzi Hauer, 1953	x	-
K. tropica Apstein, 1907	x	-
Plationus patulus patulus (Müller, 1953)	x	-
Conochilidae		
Conochilus dossuaris (Hudson, 1875)	x	-
Dicranophoridae		
Encentrum sp.	x	-
Epiphanidae		
Epiphanes clavatula (Ehrenberg, 1832)	-	x
E. macrourus (Barrois and Daday, 1894)	x	-
Trochosphaeridae		
Filinia longiseta (Ehrenberg, 1834)	x	-
F. pejleri Hutchinson, 1964	x	-
F. terminalis (Plates, 1886)	x	-
Flosculariidae		
Ptygura sp.	x	-
Gastropodidae		
Ascomorpha ecaudis (Perty, 1850)	x	-
Hexarthridae		
Hexarthra intermedia brasiliensis (Hauer, 1953)	-	-
H. intermedia intermedia Wiszniewski 1929	-	-
Lecanidae		
Lecane cornuta (O. F. Müller., 1786)	x	x
L. curvicornis (Murray, 1913)	x	
L. closterocerca (Schmarda, 1856)	x	x
L. dorissa Harring, 1914	x	x
L. lunaris Ehrenberg, 1832	x	x
L. papuana Murrayi, 1913	x	x
L. pyriformes (Daday, 1905)	-	x
L. proiecta (Hauer, 1956)	x	x
L. roberstsonae Segers, 1993	x	x
Notommatidae		
Cephalodella gibba (Ehrenberg), 1832	x	x
Monommata sp.	-	x
Synchaetidae		
Polyarthra dolichoptera Idelson, 1924	x	-
P. vulgaris Carlin, 1943	-	x
Synchaeta pectinata Ehrenberg, 1832	x	-
Testudinellidae		
Testudinella patina patina (Hermann, 1783)	x	-
T. patina dendradena (De Beauchamp, 1955)	x	-
Philodinidae		
Dissotrocha aculeata (Ehrenberg, 1832)	x	-
CLADOCERA		
Bosminidae		
Bosmina hagmani Stingelin, 1904	x	-
Bosminopsis deitersi Richard, 1834	-	x
Chydoridae		
Allona affinis (Leydig, 1860)	x	-
Chydorus eurynotus Sars, 1901	x	x
C. pubescen Sars, 1901	x	-
Daphniidae		
Ceriodaphnia cornuta Sars, 1886	x	-
Daphnia gessneri Herbst, 1967	x	-
Sididae		
Diaphanosoma brevireme Sars,1901	x	-
D. spinulosum Herbst, 1967	x	-
COPEPODA		
Cyclopidae		
Microcyclops sp.	x	-
Thermocyclops decipiens (Keefer, 1929)	x	-

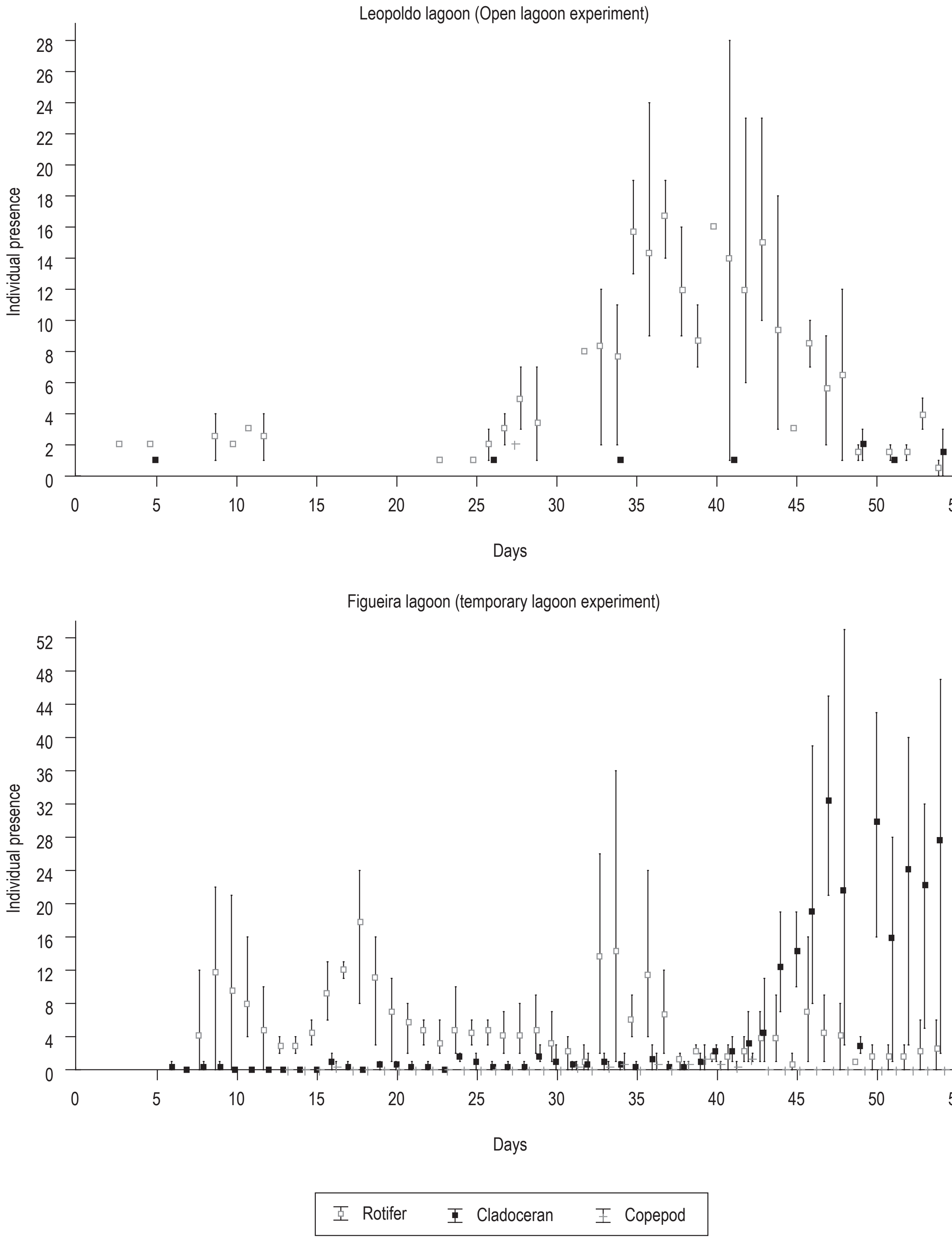

Figure 3. Presence of the zooplankton individuals in the experiments, during the 54 day study period (symbol = mean; bar = maximum and minimum values).

References

ALLAN, JD. Life history patterns in zooplankton. *Am. Nat.*, 1976, vol. 110, no. 971, p. 165-180.

CAMPOS, JRC. *Análise qualitativa e quantitativa do zooplâncton de três lagoas da Ilha Porto Rico, na planície de inundação do alto Rio Paraná. Maringá*. Universidade Estadual de Maringá, 1994. 43 p. [Monografia - Curso de Ciências Biológicas].

CRISPIM, MC. and WATANABE, T. Ovos de resistência de rotíferos presentes em sedimentos secos de um açude no semi-árido paraibano. *Acta Limnol. Bras.,* 2000, vol. 12, no. 1, p. 89-94.

CRISPIM, MC. and WATANABE, T. What can dry reservoir sediments in a semi-arid region in Brazil tell us about cladocera? *Hydrobiologia,* 2001, vol. 442, no. 1-3, p. 101-105.

CRISPIM, MC., PAZ, RJ and WATANABE, T. Comparison of different *Moina minuta* populations dynamics ecloded from resting eggs in a semi-arid region in Braz*il. Braz. J. Ecol*., 2003, vol. 1-2, p. 33-38.

CHATTERJEE, K and GOPAL, B. Experimental study of emergence of zooplankton in temporary water-bodies in relation to dry periods. *Verh. Internat. Verein. Limnol.*, 1998, vol. 26, p. 1309-1315.

ELMOOR-LOUREIRO, MAL. *Manual de identificação de cladóceros límnicos do Brasil*. Brasília: Universa, 1997. 155 p.

FRYER, G. Diapause, a force in the evolution of freshwater crustaceans. *Hydrobiologia*, 1996, vol. 320, no.1-3, p. 1-14.

GILBERT, JJ. Structure, development and induction of a new diapause stage in rotifers. *Fresh. Biol.*, 1995, vol. 34, no. 2, p. 263- 270.

HANSEN, AM and SANTER, B. The life cycle of *Cyclops vicinus* in Lake Sϕbygard: new aspects derived from sediment analyses. *Hydrobiologia*, 2003, vol. 510, no. 1-3, p. 1-21.

KOSTE, W. *Rotatoria die Rädertiere Mitteleuropas begründet von Max Voight. Monogononta.* Berlin: Gebrüder Borntraeger, 1978. (vol. I (673 p.) e II (474 p.)).

KREBS, CJ. *Ecology: the experimental analysis of distribution and abundance*. San Francisco: Benjamin Cummings, 2001. 695 p.

LANSAC-TÔHA, FA., VELHO, LFM., HIGUTI, J. and TAKAHASHI, EM. Cyclopidae (Crustacea, Copepoda) from the Upper Paraná River floodplain, Brazil. *Braz. J. Biol.*, 2002, vol. 62, no. 1, p. 125-133.

LANSAC-TÔHA, FA., BONECKER, CC. and VELHO, LFM. *Composition, species richness and abundance of the zooplankton community.* In: THOMAZ, SM., AGOSTINHO, AA., HAHN, NS. (Ed.). The upper Paraná river and its floodplain: physical aspects, ecology and conservation. Netherlands: Backhuys, 2004. p. 145-190.

MAIA-BARBOSA, PM., ESKINAZI-SANT'ANNA, EM., VALADARES, CF. and PESSOA, GCD. The resting eggs of zooplankton from a tropical, eutrophic reservoir (Pampulha Reservoir, south-east Brazil). *Lakes Res.: Res. Manag.*, 2003, vol. 8, p. 269-275.

MARGALEF, R. Limnología. Barcelona: Omega, 1983. 1010.

MINKOFF, G., LUBZENS, E. and KAHAN, D. Environmental factors affecting hatching of rotifer (*Brachionus plicatilis*) resting eggs. *Hydrobiologia*, 1983, vol. 104, no.1, p. 61-69.

PAGGI, JC. *Crustacea Cladocera*. In: LOPRETTO, EC. and TELL, G. (eds.). Ecosistemas de águas continentales: Metologias para su estúdio. La Plata: Ediciones Sur, 1995. p. 909-951.

PAGIORO, TA., ROBERTO, MC., LANSAC-TÔHA, FA. and VERÍSSIMO, S. Caracterização limnológica de uma lagoa (Lagoa Figueira) da planície de inundação do alto rio Paraná. *Rev. UNIMAR*, 1994, vol. 16, p. 203-215.

REID, JW. Chave de Identificação e lista de referências bibliográficas para as espécies continentais sulamericanas de vida livre da ordem Cyclopoida (Crustacea, Copepoda). *Bolm. Zool.*, 1985, vol. 9, p. 17-143.

RICCI, C. Dormancy patterns in rotifers. *Hydrobiologia*, 2001, vol. 446/447, no. 1, p. 1-11.

ROJAS, NET. *Eclosão dos ovos de repouso de Brachionus calyciflorus Pallas, 1776 (Monogononta Ploima) e Moina micrura Kurz, 1874 (Crustacea Cladocera) em função de fatores abióticos*. [Master Thesis]. São Carlos: UFSCar, 1995. 148 p.

ROJAS, NET., VERANI, JR., BASILE-MARTINS, MA. Influência de fatores abióticos na eclosão de ovos dormentes do rotífero *Brachionus calyciflorus* Pallas (Monogononta, Ploima). *Braz. J. Biol.*, 1999, vol. 16, p. 27-35.

SOKAL, RR. and ROHLF, FJ. *Biometry: The principles and practice of statistics in biological research*., New York: W.H. Freeman and Company, 1991. 859 p.

STATSOFT, INC. 2001. *Eletronic Statistics Textbook.* Statsoft, Tulsa, OK. Available from: http://www.statsoft.com/textbook/stathome.html. (Modificado)

THOMAZ, SM., ROCHA, RRA., PAGIORO, TA., ROBERTO, MC., CARVALHO, SB., NAKAMURA, AKS., CARVALHO, P., BARCEL, PSC. and TAKA, M. In: AGOSTINHO, AA., THOMAZ, SM. and NAKATANI, K. *Área de pesquisas ecológicas de longa duração.* Programa PELD/CNPq. Relatório Técnico. A planície de inundação do Alto Rio Paraná. Maringá: EDUEM: Nupelia, 2001. p. 61-74.

THOMAZ, SM., PAGIORO, TA., BINI, LM., ROBERTO, MC. and ROCHA, RRA. *Limnological characterization of the aquatic environments and the influence of hydrometric levels*. In: THOMAZ, SM., AGOSTINHO, AA., HAHN, NS. (Ed.). The upper Paraná river and its floodplain: physical aspects, ecology and conservatian. Netherlands: Backhuys, 2004. p. 75-102.

VERÍSSIMO, S. *Variações na composição da ictiofauna em três lagoas sazonalmente isoladas do rio principal, na planície de inundação do alto rio Paraná, ilha de Porto Rico, PR-Brasil*. [Master Thesis]. São Carlos, UFSCar,1994. 77 p.

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