Longitudinal distribution of cladocerans (Crustacea) in a Brazilian tropical reservoir.

TAKAHASHI[1], E.M., LANSAC-TÔHA[1], F.A., VELHO[1], L.F.M. & BONECKER[1],C.C.

[1] Nupélia, Postgraduate Course in Ecology of Continental Aquatic Environments, State University of Maringá. Av. Colombo, 5790, Maringá-PR, 87020-900, Brazil. e-mail: fabio@nupelia.uem.br

ABSTRACT: Longitudinal distribution of cladocerans (Crustacea) in a Brazilian tropical reservoir. This paper compares patterns of longitudinal variation in species richness and abundance of planktonic and non-planktonic cladocerans in a Brazilian tropical reservoir. We also tested if the spatial distribution exhibited by planktonic cladocerans is in accordance with one of the patterns proposed by Marzolf (1990). Samples were taken in the pelagic region, at eight stations along the longitudinal axis of the reservoir, during two hydrological periods (wet and dry seasons of 1998 and 1999). Twelve species of seven families were identified. Highest species richness and abundance of planktonic cladocerans were recorded in the transition zone during both seasons. The ANOVA results showed significant differences in planktonic species richness and abundance among zones. Planktonic species richness was significantly greater in the wet season than in the dry season, whereas abundance did not significantly differ among seasons. For non-planktonic species, higher values of abundance and species richness were observed in fluvial zone. Our results suggest that in the transition zone, a combination of hydraulic effects and the contribution of river discharge, nutrients and food resource supply promote the establishment and development of large planktonic cladoceran populations. On the other hand, the high current velocity in the fluvial zone determines the input of non-planktonic species into this zone.

Key words: Cladocera, abundance, species richness, longitudinal distribution, reservoir.

RESUMO: Distribuição longitudinal de cladóceros (Crustacea) em um reservatório tropical brasileiro. Este trabalho compara padrões de variação longitudinal da riqueza de espécies e abundância de cladóceros planctônicos e não-planctônicos em um reservatório tropical brasileiro. Também foi testado se a distribuição espacial exibida pelos cladóceros planctônicos está de acordo com um dos padrões propostos por Marzolf (1990). As coletas foram realizadas na região pelágica, em oito estações, ao longo do eixo longitudinal do reservatório, em dois períodos hidrológicos (períodos de estiagem e chuvoso de 1998 e 1999). Foram identificadas doze espécies pertencentes a sete famílias. Maiores valores de riqueza de espécies e abundância de cladóceros planctônicos foram registrados na zona de transição em ambos períodos hidrológicos. Através dos resultados da ANOVA, foi possível verificar diferenças significativas da riqueza e abundância de cladóceros planctônicos entre as zonas. A riqueza de espécies planctônicas foi significativamente maior no período chuvoso, enquanto a abundância não foi significativamente diferente entre os períodos. Para as espécies não-planctônicas, maiores valores de abundância e riqueza de espécies foram observados na zona fluvial. Os resultados obtidos sugerem que na zona de transição, uma combinação dos efeitos hidráulicos e a contribuição da descarga do rio, em termos de nutrientes e recursos alimentares, promovem o estabelecimento e desenvolvimento de grandes populações de cladóceros planctônicos. Por outro lado, a alta velocidade de corrente na zona fluvial determina o aporte de espécies não-planctônicas nesta zona.

Palavras-chave: Cladocera, abundância, riqueza de espécies, distribuição longitudinal, reservatório.

Introduction

Reservoirs are dynamic systems with relatively rapid changes in functioning mechanisms and horizontal and vertical gradients of limnological variables such as water temperature and nutrient concentrations. The formation of reservoirs causes an increase in residence time of the water in the dammed area (Straskraba & Tundisi, 1999), and a reduction in flow, which causes an increased sedimentation rate of incoming suspended material along the longitudinal axis of the new ecosystem from the river towards the dam (Thornton, 1990). Studies on the structure and dynamics of planktonic communities facilitate the understanding of response patterns to cyclic variations and periodic disturbances, and aid to evaluate the resilience of this kind of ecosystem, which can have major changes in limnological features in relatively short periods (Nogueira, 2001). The contribution of non-planktonic species to species richness and abundance is also important to the structure and dynamics of the zooplankton community (Lansac-Tôha et al., 1999).

According to the zooplankton distribution model proposed by Marzolf (1990), three patterns of abundance distribution along the longitudinal axis may be observed in reservoirs. One pattern is a non-linear increase from the river towards the dam, with an asymptote before the transition zone. Under riverine conditions, this pattern emerges when downstream displacements exceed zooplankton reproduction rates. Once current velocity decreases, the reproductive rate of the population can be increased and maintained. The second pattern is described by an exponential decrease in zooplankton abundance towards the dam. This occurs when hydraulic effects are not operating and the input of materials (silt, clays, nutrients, dissolved organic carbon, algae and bacteria) from the river into the reservoir is the dominant process. Thus, populations would increase near the source of food, in this case the rivermouth. Finally, if both processes are acting simultaneously, the zooplankton abundance along the longitudinal axis of the reservoir resembles a frequency distribution with positive asymmetry.

Some studies have shown this last pattern of spatial distribution of zooplankton abundance as the most common among various reservoirs (Bini et al., 1997; Fernández-Rosado & Lucena, 2001; Velho et al., 2001; Panarelli et al., 2003; Bernot et al., 2004; Casanova & Henry, 2004). Nevertheless, although species richness or biodiversity research has been a central topic in current ecology (Hulot et al., 2000), and several studies have focused on the relationship between biodiversity and ecosystem functioning (Loreau, 2000), there is only a few studies investigating the longitudinal distribution of zooplankton species richness.

Moreover, these studies did not show the planktonic and non-planktonic species contribution in the patterns of the species richness and abundance of the zooplankton community. Dumont & Segers (1996) considered that zooplankton studies in lacustrine environments underestimated species richness of these environments because only planktonic species are investigated. They proposed that studies of the species richness of the zooplankton community must consider both planktonic and non-planktonic species, i.e. all taxa biological inventory (ATBI). As shown in Fig. 1, we hypothesized

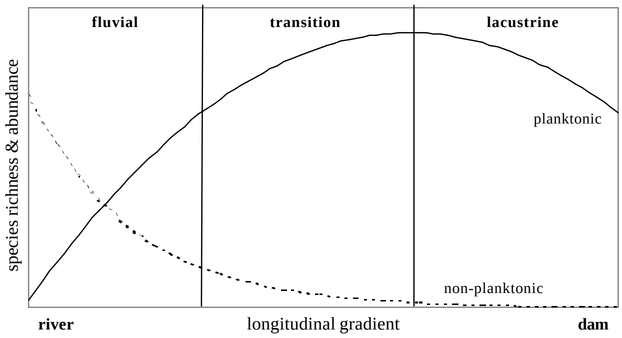

Figure 1: Hypothetical distribution of species richness and abundance of planktonic and non-planktonic cladoceran species.

that for the Corumbá Reservoir during both hydrological periods (wet and dry seasons): (i) the abundance of planktonic cladocerans presents an increase towards the dam with higher values in the transition zone, in accordance with one of the models proposed by Marzolf (1990); (ii) the species richness of planktonic cladocerans will follow this same pattern and (iii) considering the main river input, the species richness and abundance of non-planktonic cladocerans present an exponential decrease towards the dam.

Material and methods

Corumbá Reservoir is located at 15°79'S and 48°31'W, in the southern region of Goiás State, Brazil, near the border with Minas Gerais State. Corumbá Hydroelectric Reservoir drains an area of 27,800 km². The Corumbá River was dammed in November 1996, flooding an area of 65 km², approximately 60 km long with an average depth of 23 m. Mean water residence time is 30 days (Lansac-Tôha et al., 1999).

Eight sampling stations were established along the longitudinal axis of the reservoir (middle of the channel): three in the fluvial zone (stations 1,2,3), two in the transition zone (4,5) and three in the lacustrine zone (6,7,8) (Fig.2). Samples were collected during the wet season (March) and the dry season (September) of two consecutive years (1998 and 1999). Daily discharge data of the Corumbá river, used to define the wet and dry seasons, was provided by Furnas Centrais Elétricas S.A. Some limnological characteristics of each sampling station obtained during these seasons are showed in Thomaz et al. (1999; 2000).

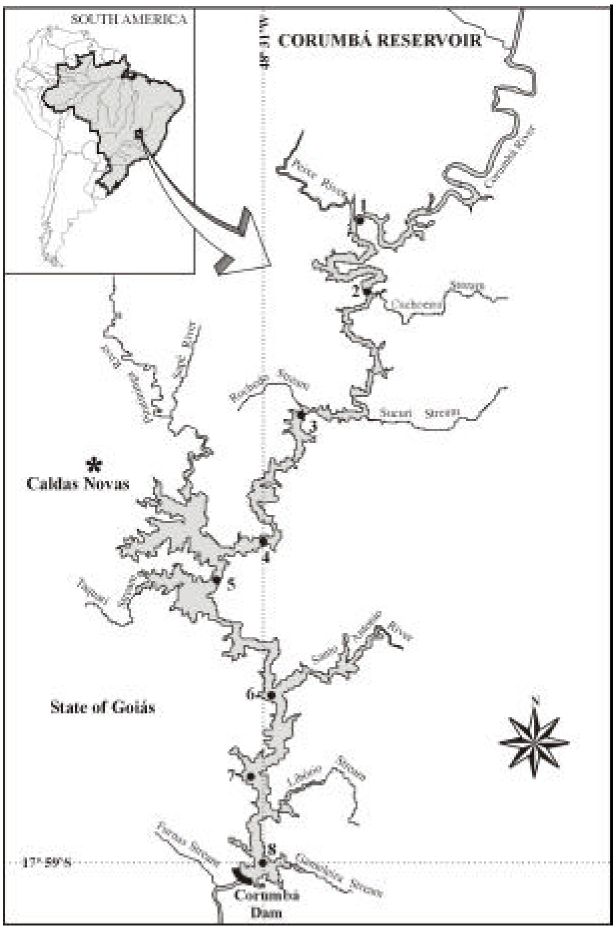

Figure 2: Reservoir of Corumbá and the location of the sampling stations.

For each sample, 1,000 L of water was collected just below the surface with a motorized pump and a 68 mm mesh plankton net. Species were identified based on specific bibliography. Cladoceran abundance was determined by counting subsamples (1.7mL) taken with a Hensen-Stempell pipette and expressed as individuals per cubic meter.

Analysis of variance (ANOVA) (Sokal & Rohlf, 1981) was used to evaluate if the abundance of planktonic species was significantly different among zones ($p<0.05$). A second analysis of variance was applied to investigate if the richness of these species differed among zones ($p<0.05$). For these analyses, we used temporal and spatial data (stations 1, 2 - fluvial zone; 4, 5 - transition zone; 7, 8 - lacustrine zone). For significant ANOVA results, the Tukey´s post hoc Test compared differences and similarities among zones. All analyses were performed using Statistica version 5.0 (Statsoft Inc., 1996).

Results

Discharge values showed well-defined seasonality in both years. Between the wet season months of January and March 1998, discharge values of up to 950 m^3/s were observed. During the dry season (May to October 1998), discharge values were in the range of 200 m^3/s, with the exception of September when discharge values less than 50 m^3/s were registered. In the following year, a similar pattern was observed with peak discharge values registered in March (1,100 m^3/s), and values less than 50 m^3/s observed between April and October (Fig.3).

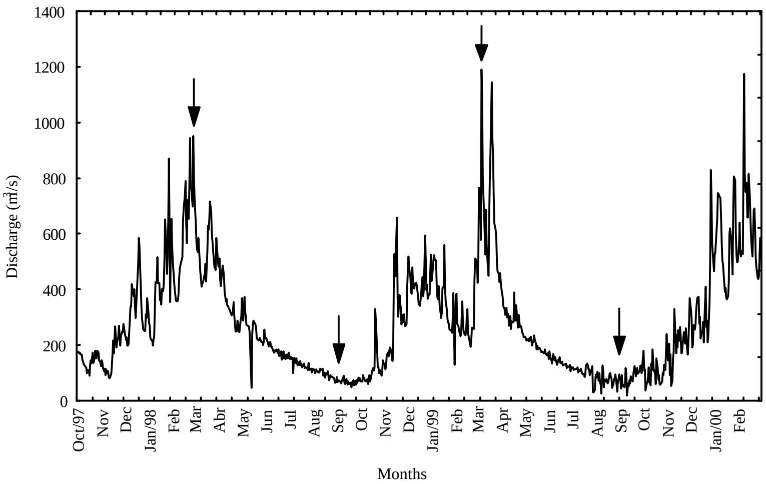

Figure 3: Daily discharge of the Corumbá River (m^3/s) between October 1997 and February 2000. The arrows indicate the sampling periods.

Twelve species of Cladocera were recorded in the different sampling stations during the dry and wet seasons, in both years (Tab. I).

For planktonic cladocerans, greatest species richness and abundance were observed in the transition zone, followed by the lacustrine and the fluvial zones, mainly during the dry season (Figs.4 and 5). Although the same trend was observed in both periods, higher values were registered during the wet season. Non-planktonic cladocerans had lower species richness and abundance than planktonic forms at all stations. In general, non-planktonic cladocerans showed greatest species richness and abundance in the fluvial zone, during both seasons, and did not occur at stations 5, 6 and 7 (transition and lacustrine zones) during the dry season, and at stations 6 and 7 in the wet season (lacustrine zone) (Figs.4 and 5).

Table I: Cladocera species found in the Corumbá Reservoir during the dry and wet seasons of 1998 and 1999.

Families	**Species**
Bosminidae	*Bosmina hagmanni Stingelin, 1904
	*Bosmina tubicen Brehm, 1939
	*Bosminopsis deitersi Richard, 1834
Chydoridae	Alona eximia Kiser, 1948
	Alona sp.
	Disparalona dadayi (Birge, 1910)
Daphniidae	*Ceriodaphnia cornuta Sars, 1886
	*Daphnia gessneri Herbst, 1967
Ilyocryptidae	Ilyocryptus spinifer Herrick, 1884
Macrothricidae	Macrothrix spinosa King, 1853
Moinidae	*Moina minuta Hansen, 1899
Sididae	*Diaphanosoma spinulosum Herbst, 1967

* Species used in the statistical analysis.

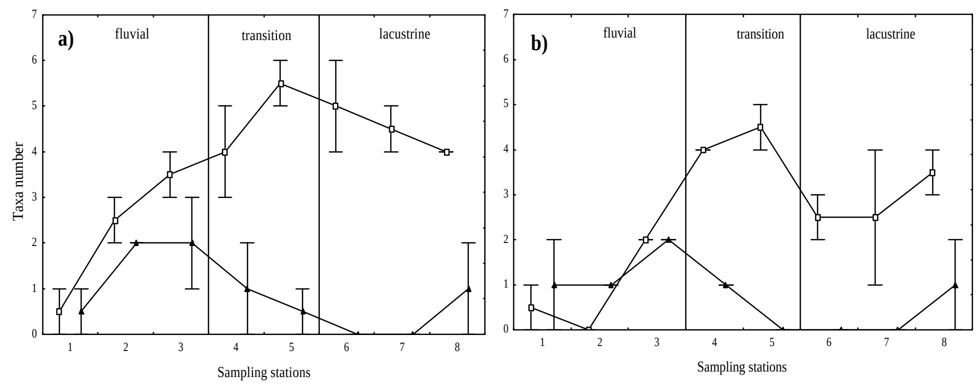

Figure 4: Species richness of the cladoceran assemblage in different zones of the Corumbá reservoir, during the wet (a) and dry (b) seasons of 1998 and 1999 (symbols=mean, bar=standard error; ð= planktonic; ▲ = non-planktonic).

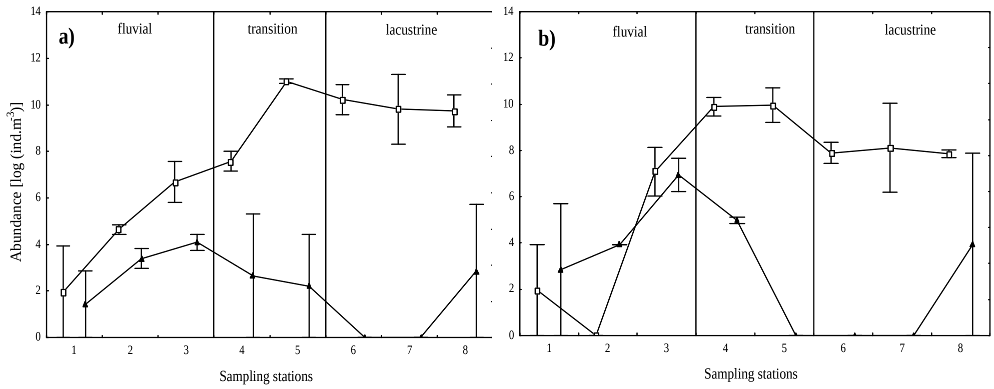

Figure 5: Abundance (log (ind.m^{-3}+1)) of the cladoceran assemblage different zones of the Corumbá reservoir, during the wet (a) and dry (b) seasons of 1998 and 1999 (symbols=mean, bar=standard error; ð = planktonic; ▲= non-planktonic).

The ANOVA showed significant differences in species richness and abundance among the different zones, and according to Tukey´s Test, all the zones were significantly different from each other. Additionally, the ANOVA used to test temporal differences showed that only species richness was significantly different between seasons (Tab. II).

Table II: ANOVA results showing the influence of variation source on planktonic cladoceran species richness and abundance. The bold-typed values indicate significant differences ($p<0.05$).

Attributes/ Effects	Df	F	p
Species Richness			
Zones	2	**30.533**	**<0.0001**
Seasons	1	**6.400**	**0.0199**
Abundance			
Zones	2	**43.036**	**<0.0001**
Seasons	1	2.5677	0.1247

Discussion

The low cladoceran species richness observed in this study is a common feature observed in reservoirs and can be related to low stability, due to reservoir management, and fewer habitats occurring in reservoirs compared to natural lakes and lagoons (Piyasiri & Jayakody, 1991). Nevertheless, we observed species richness higher than reported for other reservoirs (e.g. Capivara Reservoir, Sampaio et al. (2002)), and similar to the results obtained by Tundisi et al. (1993) in Barra Bonita Reservoir. Bosminidae, Daphniidae, Moinidae and Sididae were the most representative planktonic families collected in Corumbá Reservoir. The occurrence of non-planktonic species in reservoirs was also recorded by Lansac-Tôha et al. (1999) and Panarelli et al. (2003), and they ascribed this result to the species input from the main river and tributaries.

The highest abundance values of the planktonic cladocerans were observed in transition zone, and the lowest in the fluvial zone. These results agree with Marzolf´s (1990) third model, which establishes when both hydraulic effects and input of resources from the river are acting simultaneously. This same pattern has been observed in other studies of zooplankton in Brazilian reservoirs (Lopes et al., 1997; Lansac-Tôha et al., 1999). In environments with higher current velocity, such as the fluvial zone, the displacement rate is often superior to the reproductive rate, preventing population development. The higher turbulence occurring in fluvial zones also limits the development of cladoceran populations (Lansac-Tôha et al., 1999). Casanova & Henry (2004), studying the longitudinal distribution of copepods in the fluvial zone of Jurumirim Reservoir, observed a negative relationship between most copepod species and current velocity and suspended material. However, Fernández-Rosado & Lucena (2001), studying the zooplankton distribution in a Spanish reservoir, found highest cladoceran densities in the fluvial zone and attributed these results to the chlorophyll distribution combined with a high reproductive rate. In horizontal distributions, the existence of gradients decreasing from intake to dam is common in reservoirs and it is related to transport and dilution associated with water renewal (Threlkeld, 1982; Mayer et al., 1997).

Food resource availability also varies among the reservoir zones, thus highest production of phytoplankton, the main food resource for cladocerans, is expected to be found in the transition zone of reservoirs, due to the reduction of current velocity combined with the maintenance of nutrient concentration (Kimmel et al.,1990). Lopes et al. (1997) registered greatest cladoceran abundance in sampling stations located in the transition zone of Segredo Reservoir, Brazil, and ascribed these results to the high phytoplanktonic biomass in this zone.

In relation to longitudinal distribution of planktonic species richness, the pattern observed was similar to the abundance results. The highest values were observed in the transition zone, and the lowest in the fluvial zone. These results support the idea that the same factors influencing the longitudinal distribution of abundance, such as hydraulic effects and resource availability, also drive the distribution of species richness. ANOVA clearly showed that the spatial variation in species richness and abundance of planktonic cladocerans was significantly different between the different reservoir zones.

The temporal effect was important only for species richness. According to Lansac-Tôha et al. (2005), in the wet season there is a strong influence of hydraulic effects in determining species richness, due to input of species proceeding from other compartments (littoral region and sediment) caused by increases in discharge and reservoir level. On the other hand, discharge variation between seasons did not influence the abundance patterns.

Considering the distribution of non-planktonic species, higher values of abundance and species richness were observed in the fluvial zone. Lansac-Tôha et al. (1999) considered that the high current velocity in this zone promotes wash-out of organisms from the marginal vegetation and the resuspension of individuals from the sediment to the water column. We also found that in the wet season, due to higher discharge values, non-planktonic cladocerans species reach all stations of the transition zone. Thus, our results support the idea that differences among current velocities are responsible for the occurrence and abundance of non-planktonic cladocerans in the superior region of the reservoir. Contrary to our expectation, in one of the years analyzed, we recorded the occurrence of non-planktonic cladocerans in the last sampling station near the dam. A plausible explanation for this result could be the existence of tributaries near this collection site. Even so, detailed investigations must be done to clarify this finding.

In summary, our first and second hypotheses were supported. In the Corumbá Reservoir, for both hydrological periods, the abundance of planktonic cladocerans presented an increase towards the dam, with higher values in the transition zone, in accordance with one of the models proposed by Marzolf (1990), and the species richness of planktonic cladocerans follow the same pattern. However, our third hypothesis was in part rejected. We did observe a decrease of species richness and abundance of non-planktonic cladocerans towards to the dam, but we also registered an increase of species richness and abundance of non-planktonic cladocerans in the last sampling station near the dam. Further researches are needed to explain this observation.

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References

Bernot, R.J., Dodds, W.K., Quist, M.C. & Guy, C.S. 2004. Spatial and temporal variability of zooplankton in a great plains reservoir. Hydrobiologia, 525:101-112.

Bini, L.M., Tundisi, J.G., Matsumura-Tundisi, T. & Matheus, C.E. 1997. Spatial variation of zooplankton groups in a tropical reservoir (Broa Reservoir, São Paulo State-Brazil). Hydrobiologia, 357:89-98.

Casanova, S.M. & Henry, R. 2004. Longitudinal distribution of Copepoda populations in the transition zone of Paranapanema river into Jurumirim reservoir (São Paulo, Brazil) and interchange with two lateral lakes. Braz. J. Biol., 64:11-26.

Dumont, H. & Segers, H. 1996. Estimating lacustrine zooplankton species richness and complementarity. Hydrobiologia, 341:125-132.

Fernández-Rosado, M.J. & Lucena, J. 2001. Space-time heterogeneities of zooplankton distribution in La Concepción reservoir (Istán, Málaga; Spain). Hydrobiologia, 455:157-170.

Hulot F.D., Lacroix, G., Lescher-Moutoé, F. & Loreau, M. 2000. Functional diversity governs ecosystem response to nutrient enrichment. Nature, 405:340-344.

Kimmel, B.L., Linde, O.T. & Paulson, L.J. 1990. Reservoir primary production. In: Thornton, K.W., Kimmel, B.L. & Payne, F.E. (eds.) Reservoir limnology: ecological perspectives. John Wiley & Sons, New York. p.133-193.

Lansac-Tôha, F.A., Velho, L.F.M. & Bonecker, C.C. 1999. Estrutura da comunidade zooplanctônica antes e após a formação do reservatório de Corumbá-GO. In: Henry, R. (ed.) Ecologia de reservatórios: estrutura, função e aspectos sociais. FUNDIBIO/FAPESP, Botucatu. p.347-374.

Lansac-Tôha, F.A., Velho, L.F.M. & Bonecker, C.C. 2005. Estrutura da Comunidade zooplanctônica em reservatórios. In: Rodrigues, L., Thomaz, S.M., Agostinho, A.A., & Gomes, L.C. (eds.) Biocenoses em reservatórios: padrões espaciais e temporais. RiMa, São Carlos. p.115-127.

Lopes, R.M., Lansac-Tôha, F.A., Vale, R. & Serafim Jr., M. 1997. Comunidade zooplanctônica do reservatório de Segredo. In: Agostinho, A.A. & Gomes, L.C. (eds.) Reservatório de Segredo: bases ecológicas para o manejo. Eduem, Maringá. p.39-60.

Loreau, M. 2000. Biodiversity and ecosystem functioning: recent theoretical advances. Oikos, 91:3-17.

Marzolf, G.R. 1990. Reservoirs as environments for zooplankton. In: Thornton, K. W., Kimmel, B.L. & Payne, E. (eds.) Reservoir limnology: ecological perspectives. John Wiley & Sons, New York. p.195-208.

Mayer, J., Dokulil, M.T., Salbrechter, M., Berger, M., Posch, T., Pfister, G., Kirschner, B. Velimrov, A.K.T., Steiz, A. & Ulbricht, T. 1997. Seasonal successions and trophic relations between phytoplankton, zooplankton, ciliate and bacteria in a hypertrophic shallow lake in Vienna, Austria. Hydrobiologia, 342/343:165-175.

Nogueira, M.G. 2001. Zooplankton composition, dominance and abundance as indicators of environmental compartmentalization in Jurumirim Reservoir (Paranapanema River), São Paulo, Brazil. Hydrobiologia, 455:1-18.

Panarelli, E., Casanova, S.M.C., Nogueira, M.C., Mitsuka, P.M. & Henry, R. 2003. A comunidade zooplanctônica ao longo de gradientes longitudinais no rio Paranapanema/Represa de Jurumirim (São Paulo, Brasil). In: Henry, R. (ed.) Ecótonos nas interfaces dos ecossistemas aquáticos. RiMa, São Carlos. p.129-160.

Piyasiri, S. & Jayakody, J.K.U. 1991. Ecology of zooplankton in Victoria Reservoir, Sri Lanka: I. Composition and population structure of the zooplankton. Verh. Int. Verein. Limnol., 24:1430-1435.

Sampaio, E.V., Rocha, O., Matsumura-Tundisi, T. & Tundisi, J.G. 2002. Composition and abundance of zooplankton in the limnetic zone of seven reservoirs of the Paranapanema river, Brazil. Braz. J. Biol., 62:525-545.

Sokal, R.R. & Rohlf, F.J. 1981. Biometry: the principles and practice of statistics in biological research. W.H. Freeman and Company, New York. 857p.

Statsoft. 1996. Statistica for Windows – versão 5.0. Statsoft Inc.,Tulsa.

Straskraba, M. & Tundisi, J.G. 1999. Reservoir ecosystem functioning: theory and application. In: Tundisi, J.G. & Straskraba, M. (eds.) Theoretical reservoir ecology and its spplications. Brazilian Academy of Sciences/International Institute of Ecology, São Carlos. p.565-583.

Threlkeld, S.T. 1982. Water renewal effects on reservoir zooplankton communities. Can. Water Res. Assoc. J., 7:151-167.

Thomaz, S.M., Pagioro, T.A., Takeda, A., Bonecker, C.C., Lansac-Tôha, F.A., Higuti, J., Leandrini, J.A., Rodrigues, L., Velho, L.C., Train, S. & Jati, S.M. 1999. Estudos limnológicos na área de influência do reservatório de Corumbá (GO). Maringá. 341p. (Relatório parcial).

Thomaz, S.M., Pagioro, T.A., Takeda, A., Bonecker, C.C., Lansac-Tôha, F.A., Higuti, J., Leandrini, J.A., Rodrigues, L., Velho, L.C., Train, S. & Jati, S.M. 2000. Estudos limnológicos na área de influência do reservatório de Corumbá (GO). Maringá. 321p. (Relatório final).

Thornton, K.W. 1990. Sedimentary processes. In: Thornton, K.W., Kimmel, B.L. & Payne, E. (eds.) Reservoir limnology: ecological perspectives. John Wiley & Sons, New York. p.195-208.

Tundisi, J.G., Matsumura-Tundisi, T. & Calijuri, M.C. 1993. Limnology and Management of Reservoirs in Brazil. In: Straskraba, M., Tundisi, J.G. & Duncan, A. (eds.) Comparative reservoir limnology and water quality management. Kluwer Academic Publishers, Dordrecht. p.25-55.

Velho, L.F.M., Lansac-Tôha, F.A., Bonecker, C.C., Bini, L.M. & Rossa, D.C. 2001. The longitudinal distribution of copepods in Corumbá Reservoir, State of Goiás, Brazil. Hydrobiologia, 453/454:385-391.

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