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Does water level affect benthic macro-invertebrates of a marginal lake in a tropical river-reservoir transition zone?

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Abstract

Benthic macro-invertebrates are important components of freshwater ecosystems which are involved in ecological processes such as energy transfer between detritus and consumers and organic matter recycling. The aim of this work was to investigate the variation in organism richness, diversity and density of benthic fauna during the annual cycle in Camargo Lake, a lake marginal to Paranapanema River, southeast Brazil. The correlation of environmental factors with community attributes of the macro-benthic fauna was assessed. Since Camargo Lake is connected to the river, we tested the hypothesis that water level variation is the main regulating factor of environmental variables and of the composition and abundance of benthic macro-invertebrates. The results indicated that lake depth varied with rainfall, being the highest at the end of the rising water period and the lowest at the beginning of this period. The sediment granulometry was more heterogeneous at the bottom of the lake by the end of the high water period. The benthic macro-invertebrate fauna was composed by 15 *taxa*. The Diptera order was represented by seven *taxa* and had greater richness in relation to other *taxa*. This group was responsible for 60% of the total abundance of organisms, followed by Ephemeroptera (22%) and Anellida (16%). Significant differences were observed over time in total richness and, in density of *Narapa bonettoi, Chaoborus, Ablabesmyia* gr. *annulata, Chironomus gigas, Larsia fittkau,* and *Procladius* sp. 2. Total *taxa* richness correlated negatively with water pH, transparency, conductivity, and bottom water oxygen. Higher positive correlations were found between the densities of some *taxa* and bottom water oxygen, conductivity and very fine sand, silt + clay of sediment, while negative correlations were recorded with organic matter, and fine, medium and coarse sand, bottom water temperature, mean temperature and rainfall. The significant temporal difference in water level was associated with changes in abiotic factors and macro-invertebrate community attributes.

Keywords: marginal lake, connectivity, water level, benthic fauna.

O nível de água afeta os macro-invertebrados bentônicos de uma lagoa marginal na região de transição rio - represa de zona tropical?

Resumo

Os macro-invertebrados são componentes importantes de ecossistemas aquáticas continentais, envolvidos em processos ecológicos como transferência de energia entre detritos e consumidores e, reciclagem de matéria orgânica. O objetivo deste trabalho foi investigar a variação na riqueza de organismos, diversidade e densidade da fauna bentônica durante um ciclo anual na Lagoa do Camargo, marginal ao Rio Paranapanema, sudeste do Brasil. Eventuais relações de fatores ambientais com atributos da comunidade macro-bentônica foram verificadas. Visto que a Lagoa do Camargo é conectada com o rio, nós testamos a hipótese de que a variação do nível de água é o principal fator regulador das variáveis ambientais e da composição e abundância dos macro-invertebrados bênticos. Os resultados indicaram que a profundidade da lagoa variou com a precipitação, sendo mais alta no final do período da enchente e mais baixa no inicio deste período. A granulometria do sedimento foi mais heterogênea no fundo da lagoa no final do período de cheia. A fauna de macro-invertebrados bênticos foi composta de 15 *taxa*. A ordem Diptera foi representada por sete *taxa* e tem maior riqueza em relação aos outros *taxa*. Este grupo foi responsável por 60% da abundância total de organismos, seguido por Ephemeroptera (22%) e Anellida (16%). Diferenças temporais significativas foram observadas na riqueza total e, na densidade de *Narapa bonettoi, Chaoborus, Ablabesmyia* gr. *annulata, Chironomus gigas, Larsia fittkau,* and *Procladius* sp. 2. A riqueza total de *taxa* correlacionou-se negativamente com pH da água, transparência, condutividade e oxigênio na água do fundo. As mais altas correlações positivas foram encontradas entre as densidades de alguns *taxa* e oxigênio da água de fundo, condutividade e areia muito fina, silte + argila do sedimento, enquanto que correlações negativas foram obtidas com matéria orgânica, e areia fina, média e grossa, temperatura da água de fundo, temperatura média e precipitação. A diferença temporal significativa do nível de água foi associada a mudanças nos fatores abióticos e nos atributos da comunidade de macro-invertebrados.

Palavras-chave: lagoa marginal, conectividade, nível de água, fauna bêntica.

1. Introduction

In flood areas marginal to lakes, water level variation is one of the main regulating factors of marginal environment communities. During the rising water period, the rivers invade marginal depressions, and when the water level decreases, lakes that are isolated or connected to the main channel are formed (Junk, 1980).

Different from that observed in floodplains, flood pulse frequency, duration and amplitude are modified at sites of confluence of lotic systems with artificial lacustrine ecosystems, such as reservoirs, where the action of hydrologic pulses of tributaries is greatly attenuated in the river-reservoir transition zone (Henry, 2005).

In the dry season, the influence of local agents (such as water input by underground flow) predominates and acts in distinct ways in each plain environment. During floods, the exchange of biological material, particulate and dissolved matter, nutrients, detritus, and biomass increases directly with the connectivity of the river to plain lacustrine environments (Thomaz et al., 2007).

Stream water velocity and depth of the marginal lakes adjacent to rivers and of the flooded area also are directly affected by the flood pulse (Thomaz et al., 2004). These are relevant factors that control the behavioural, morphological and anatomic patterns and physiological characteristics of organisms that live in these areas (Thomaz et al., 2004).

The temporal and spatial distribution of both benthic and planktonic populations is influenced by the water physical, chemical and biological factors. Among them, the nature of sediment, lake depth, water level fluctuation, dissolved oxygen, pH, trophic status, and the competition of different populations are the main controlling factors of benthic fauna (Ward et al., 1995; Esteves, 1998; Galdean et al., 2000). The number of benthic *taxa* tends to be greater with the heterogeneity of the types of bottom substrata, since a heterogeneous environment affords a greater number of niches (Beisel et al., 2000).

Marginal lakes in river-reservoir transition environments have permanent connections with the tributaries. Due to the temporal variation of the hydrologic pulse, water quality and the nature of the sediment of marginal lakes may vary with lateral flooding from rivers. Since the temporal variation in abundance and richness of benthic communities under hydrologic changes is little known, the benthic fauna and associated abiotic parameters were surveyed for one year. The study hypothesis was that water level variation is the main regulating factor of environmental variables and the composition and abundance of benthic macro-invertebrates in marginal lakes.

2. Material and Methods

The Paranapanema River - Jurumirim Reservoir transition region is characterised by a great rate of deposition of allochthonous material that is carried by the river (Henry and Maricato, 1996) and by a decrease in stream velocity (Casanova and Henry, 2004). The coefficient of exportation of suspended solids of the basin, characterized as having forest cover (24%), reforested areas (20%) and pastures (33%), was estimated at 13.7-15.5 t .km^2.ton^{-1} (Henry and Gouveia, 1993).

Camargo Lake, the lake selected for this study, is located at the mouth zone of Paranapanema River into Jurumirim Reservoir, São Paulo state (Figure 1). The lake is permanently connected to the river. Some studies of macro-invertebrates either associated with aquatic macrophytes (Afonso, 2002; Davanso, 2009; Fulan, 2006, 2009; Fulan and Henry, 2006, 2007, 2008; Fulan et al., 2009, 2011; Silva and Henry, 2013; Stripari and Henry, 2002) or with benthic habitats (Davanso, 2005, 2009; Davanso and Henry, 2006, 2007; Shimabukuro and Henry, 2011; Zerlin, 2011) have been conducted in this lake and in other nearby marginal lakes.

The efficiency of sediment deposition in Camargo Lake corresponds to 1% of the amount carried by the river (Henry, 2009). The presence of macrophyte stands along the entire river side, with the predominance of *Echinochloa polystachya,* is responsible for the retention of sediment in the river.

Three sites of Camargo Lake (23°30’10”S/48°42’35”W) were selected for study and sampled every month for one year. To better characterise the sampling sites, complementary physical-chemical data on the column of water and sediments were collected. Air temperature was measured with an alcohol thermometer; surface water temperature, with a Toho Dentam thermistor, and water transparency, with a Secchi disk. Oxygen dissolved in water was determined in surface and bottom water according to Golterman et al. (1978), water pH with pHmeter Micronal B-380, and water conductivity, corrected to 25 °C, with conductivimeter Hach Mod.2511. Rainfall data were obtained at Station E5-117 of the Department of Water and Electric Energy (Departamento de Águas e Energia Elétrica, DAEE), located at Angatuba, São Paulo state, at approximately 25 km from the study site.

Sediment was collected at each site using a Petersen dredge (0.0640 m^2 area) for analysis of benthic fauna (three samples) and sediment characterization (one sample). Sediment composition was determined using the Wentworth scale (Suguio, 1973) and the organic matter content, by combustion in oven (550 °C/1 h).

The sediment sample was pre-screened in the field by washing with lake water through a 250-mm mesh. The remaining material (sediment + fauna) was transferred to plastic pots, fixed with 4% formal, and dyed with Phloxine B (Mason Junior and Yevich, 1967). In the laboratory, the biota was screened with a stereoscopic microscope and the organisms were identified using the Pennak (1978), Brinkhurst and Marchese (1991), Lopretto and Tell (1995), Merritt and Cummins (1996), Mugnai et al. (2010) and Trivinho-Strixino (2011) keys. Densities of individuals per m^2 (N) were determined using cumulative values of three samples. Relative density (%) of each of the groups was obtained, and the *taxa* richness values (S) of each sampling site. The criteria used for the relative density indexes were according to McCullough and Jackson (1985). Groups with

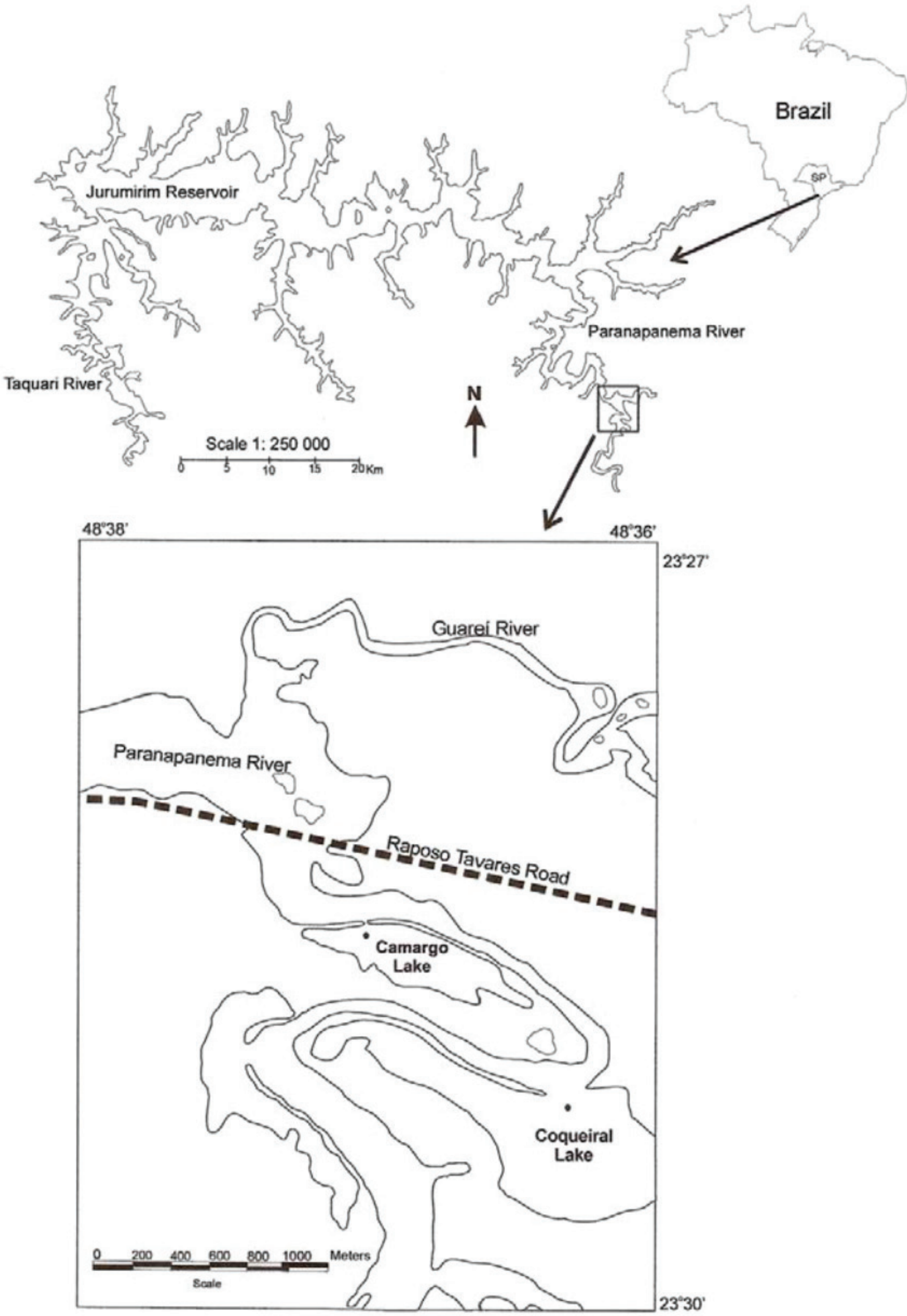

Figure 1. The study area: Jurumirim Reservoir, at the transition zone Paranapanema River/Jurumirim Reservoir, and the location of Camargo Lake (São Paulo, Brazil).

density between 50 and 100% were considered dominant, between 30 and 49%, abundant, between 10 and 29%, common, between 1 and 9%, occasional, and less than 1%, rare. Richness was expressed as the number of genera per sampling station.

Prior to statistical analysis, the data were log transformed (X+1). Significant variations (P<0.05) in environmental parameters and community ecological attributes of the macro-invertebrate community were determined by variance analysis (ANOVA) using the Statistic 6.0 (Statsoft, 2002) software after verification of requirements such as normality and variance homogeneity. Correlations between *taxa* richness and environmental variables were determined with Pearson's test, and between organism densities, by canonic correspondence analysis with 1,000 permutations using the "R" (R Development Core Team, 2009) software.

3. Results

Except for the water environmental variables, number of repetitions of which did not allow for the use of ANOVA analysis, all the other variables were significantly different on a monthly basis (Table 1). Significant temporal variations in sediment mean particle size from 7.39 ϕ (Aug. 2009) to 3.96 ϕ (Mar. 2010) were recorded (Table 2), being more heterogeneous in September 2009 (Figure 2). The six granulometric classes (very coarse sand, coarse sand, medium sand, fine sand, very fine sand, silt and clay) were found in most months; however, silt + clay predominated, with values higher than 67% (Figure 2).

Differences in density and total *taxa* richness of benthic macro-invertebrates between months were found for *Narapa*, *Chaoborus, Ablabesmyia gr. annulata, Chironomus gigas, Larsia fittkau, Procladius* sp. 2, *Campsurus* (Table 3).

The total richness varied greatly during the study period, with the lowest value recorded in July 2010 and the highest value in September 2009 (Figure 3), when the water level, depth and organic matter content were the highest. The total density did not vary greatly from October to March and June to July. In these two periods, the density remained relatively low in comparison to the highest values, which were found in September, April and May (Figure 4).

The highest densities of *Narapa bonettoi*, *Chironomus gigas,* and *Chaoborus* were observed between August and

Table 1. Differences determined by ANOVA (F and p) for environmental characteristics of sediment on the temporal scale.

Environmental variables of sediment	F	P
Depth	4.50	0.00
Organic matter	4.50	0.00
Very coarse sand	11.86	0.00
Coarse sand	20.54	0.00
Mean sand	4.23	0.00
Fine sand	4.98	0.00
Very fien sand	14.01	0.00
Silt + clay	8.51	0.00

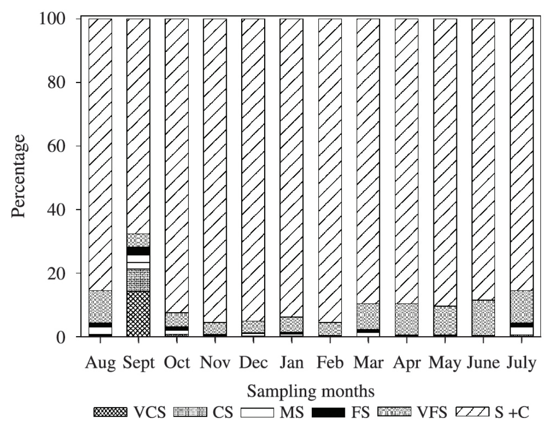

Figure 2. Granulometric composition of sediment at Camargo Lake, from August 2009 to July 2010 (For the abbreviations, see Table 4).

Table 2. Mean size of particle (ϕ) on sediment of Lake Camargo during the study period.

Month	Aug/09	Sep	Oct	Nov	Dec	Jan/10	Feb	Mar	Apr	May	Jun	Jul
Size	7.37	7.19	6.8	7.31	6.12	4.52	4.16	3.96	6.36	6.31	5.43	6.41

Table 3. Differences determined by ANOVA (F and p) for total abundance and, of each taxa of benthic macro-invertebrates, as well as total richness on the temporal scale (in bold, significant values).

	Abbreviations	F	p		Abbreviations	F	p
Total density		10.31	**0.00**	*Larsia fittkau*	Larsi	4.59	**0.00**
Narapa bonettoi	Narap	9.35	**0.00**	*Procladius* sp2	Procl	3.94	**0.00**
Branchiura sowerbyi	Branc	1.23	0.32	Pupa Diptera	PupaD	0.73	0.70
Corbicula fluminea	Corbi	2.05	0.07	*Campsurus*	Camps	8.07	**0.00**
Ceratopogonidae	Cerat	0.91	0.55	*Batracobdella*	Batra	1.34	0.26
Chaoborus	Chaob	2.34	**0.04**	Acari	Acari	0.73	0.70
Ablabesmyia gr. *annulata*	Ablab	3.72	**0.00**	Nematoda	Nemat	0.91	0.55
Chironomus	Chiro	1.00	0.47	Total richness	Tot Rich	5.05	**0.00**
Chironomus gigas	Chi gi	3.10	**0.01**				

November 2009, together with the highest mean values of water level, rainfall, and organic matter (Figures 5, 6 and 7). In other months, the density of *N. bonettoi* decreased slightly, with the lowest values in June and July 2010. *C. gigas* presented a slight oscillation of density in the other months. High density was found for *Ablabesmyia gr. annulata* only in May 2010, apparently without any correlation with environmental factors. In other months, large variations in density were observed. The highest density of *Larsia fittkau* was observed in March, April and May, which was associated with high water level, air temperature, lake surface and bottom water temperatures, and depth. *Procladius* sp. 2 and *Campsurus* presented higher density values in April and May, when the water level and depth were higher than in the other months.

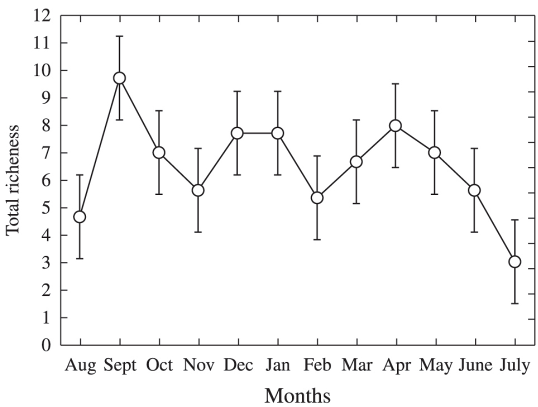

Figure 3. Variation of benthic total richness at Camargo Lake, from August 2009 to July 2010.

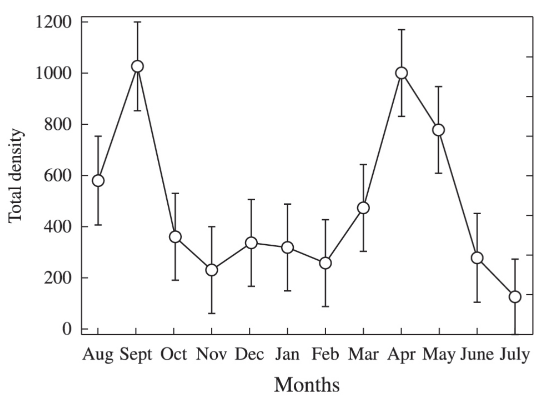

Figure 4. Variation of benthic fauna total density at Camargo Lake, from August 2009 to July 2010.

Few Pearson's correlations between total richness and environmental variables were significant (Table 4). *Taxa* total richness correlated negatively with pH, water transparency (Secchi) and conductivity, and dissolved oxygen in water at the bottom.

Table 5 presents the values of the canonic variables, canonic correlation coefficients, and significance test of macro-invertebrate richness. The canonic variables explained 69% of the data variance, considering two components (25% for VC2 and 44% for VC1) (Figure 8).

Temporal differences in the physical and chemical characteristics of sediment associated with some *taxa* and the type of sediment were observed (Figure 8).

Note that *Campsurus* correlated positively with axis 1 and was associated with oxygen dissolved in water at the bottom in April, June and July 2010, when the water level was low (Figure 8). *Ablabesmyia gr. annulata* and *Procladius* sp. 2 had the highest correlation with axis 1, positive with conductivity and very fine sand, in March and May 2010. *Procladius* sp. 2 had the strongest association in the month of May, when the water level was falling and conductivity was very high. *Batracobdella* and *Larsia fittkau* had the greatest correlation with axis 2, and positive correlation with sediment fraction silt + clay.

Analysis of the negative correlations with axis 1 showed that *Chironomus gigas, Nematomorpha* and *Corbicula fluminea* were strongly correlated with organic matter (OM). In axis 2, *Ceratopogonidae* correlated with the organic fraction of the sediment and fine, medium and coarse sand. *Chaoborus* correlated with coarse sand. All

Table 4. Pearson correlations between total richness of benthic taxa and environmental variables (in bold: significant correlations).

Environmental variables	Abbreviations	Total richness	Environmental variables	Abbreviations	Total richness
Air temperature	Air temp.	–0.04	Depth	Depth.	0.23
Mean temperature of water column	Mean temp.	0.24	Organic Matter	O.M.	0.23
Water temperature at bottom	Bottom temp.	0.31	Very coarse sand	VCS	–0.02
pH	pH	**–0.35**	Coarse sand	CS	0.04
Secchi disk transparency	Secc.	**–0.65**	Mean sand	MS	–0.05
Water conductivity	Cond.	**–0.62**	Fine sand	FS	0.05
OD at bottom	ODB	**–0.42**	Very fine sand	VFS	–0.13
Rain Precipitation	Prec.	0.31	Silt + Clay	S+C	–0.02

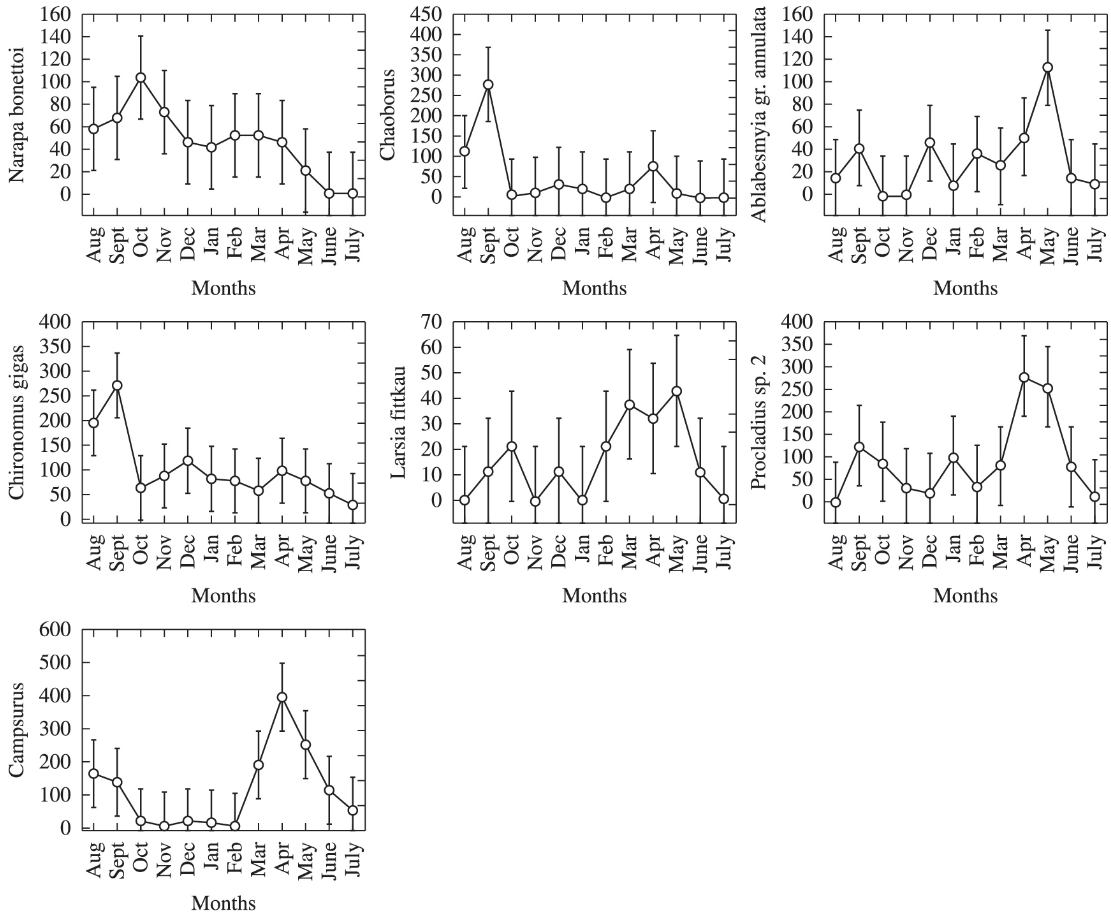

Figure 5. Significant temporal variations of *Narapa bonettoi*, *Chaoborus*, *Ablabesmyia gr. annulata*, *Chironomus gigas*, *Larsia fittkau*, *Procladius* sp. 2 and *Campsurus* densities (ind.m^{-2}) detected by ANOVA.

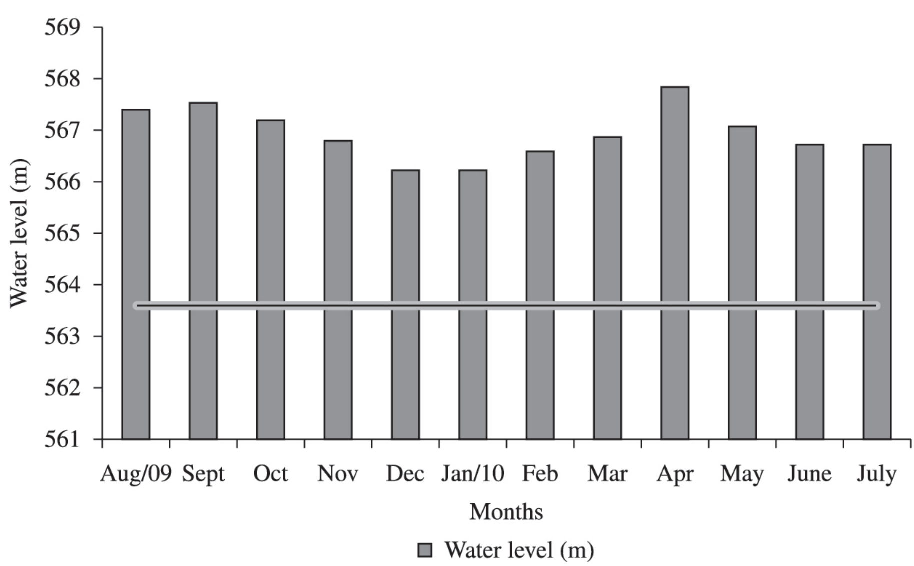

Figure 6. Water level (m) at Camargo Lake during the study period (The horizontal line at 563.60 m water level corresponds to the frontier of connection between lake and river).

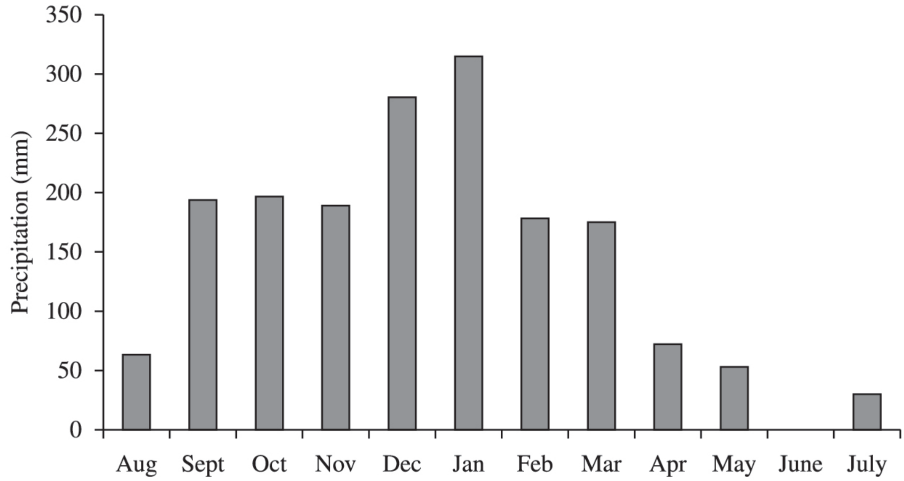

Figure 7. Monthly rain precipitation variation (mm) during the period study in the Angatuba region (São Paulo, Brazil).

Table 5. Scores of canonical variables (CA1 and CA2), adjusted canonical correlation coefficients (r^2) and, of significance levels (p) from the canonical correspondence analysis, between the abundances of benthic macro-invertebrates and environmental variables. (For abbreviations of taxa, see Table 3 and, of environmental variables, see Table 4) (*P<0.05).

Variables	CA1	CA2	r^2	p	Variables	CA1	CA2	r^2	p
Narap	–0.97	0.24	0.53	0.02*	Depth	0.99	–0.03	0.19	0.44
Branc	–0.98	–0.17	0.38	0.11	pH	0.99	0.07	0.38	0.11
Corbi	–0.75	–0.65	0.25	0.22	Mean Temp.	–0.70	0.70	0.47	0.07
Cerat	–0.75	–0.66	0.41	0.06	Bottom Temp.	–0.64	0.76	0.53	0.03*
Chaob	–0.57	–0.81	0.71	0.00*	Air Temp.	–0.92	0.37	0.14	0.53
Ablab	0.99	–0.12	0.17	0.41	Secc.	0.98	–0.15	0.26	0.23
Chiro	–0.62	–0.78	0.44	0.00*	Cond.	0.99	0.08	0.43	0.07
Chi gig	–0.70	–0.71	0.79	0.00*	ODB	0.93	–0.34	0.58	0.03*
Larsi	0.88	0.45	0.38	0.12	Prec.	–0.94	0.32	0.54	0.03*
Procl	0.98	0.14	0.26	0.23	O.M.	–0.96	–0.27	0.75	0.00*
Pupa	–0.98	0.14	0.40	0.08	VCS	–0.60	–0.79	0.76	0.00*
Camps	0.84	–0.53	0.51	0.03*	CS	–0.60	–0.79	0.79	0.00*
Batra	0.90	0.42	0.05	0.78	MS	–0.55	–0.83	0.68	0.00*
Acari	0.97	–0.22	0.28	0.22	FS	–0.58	–0.81	0.54	0.03*
Nemat	0.77	0.63	0.23	0.35	VFS	0.99	0.05	0.91	0.00*
					S+C	0.39	0.91	0.79	0.00*

taxa correlated with the months of August and September 2009, when the water level began to rise.

Lastly, the bottom temperature also had a strong negative correlation with axis 2 for *Narapa bonettoi* and Acari in November 2009 and February 2010, when the water level of Camargo Lake was nearly stable. The mean temperature of the column of water and rainfall had a strong correlation with *Branchiura sowerbyi* in December 2009 and January 2010, when lake depth was relatively low despite the high rainfall.

4. Discussion

According to Costa and Henry (2002), the intensity and frequency of the flood pulse in marginal lakes are related to the location of lakes on floodplains and their degree of connection with rivers. These factors also affect the limnological characteristics of these sites, since marginal lakes are very susceptible to flood and drought events.

The changes in the physical, chemical and biological factors observed in this study were related to the connection between Camargo Lake and Paranapanema River. The hydrological regime of the lake is also regulated by the operation of Jurumirim Reservoir and rainfall, which is marked by well-defined dry and rainy periods in this region (Moschini-Carlos et al., 1998).

From April to July 2010 rainfall was very low. Considering that this period is within the low water period, we observed that the total abundance of benthic organisms was higher than in the high rainfall period (December to January 2010), the end of the falling water

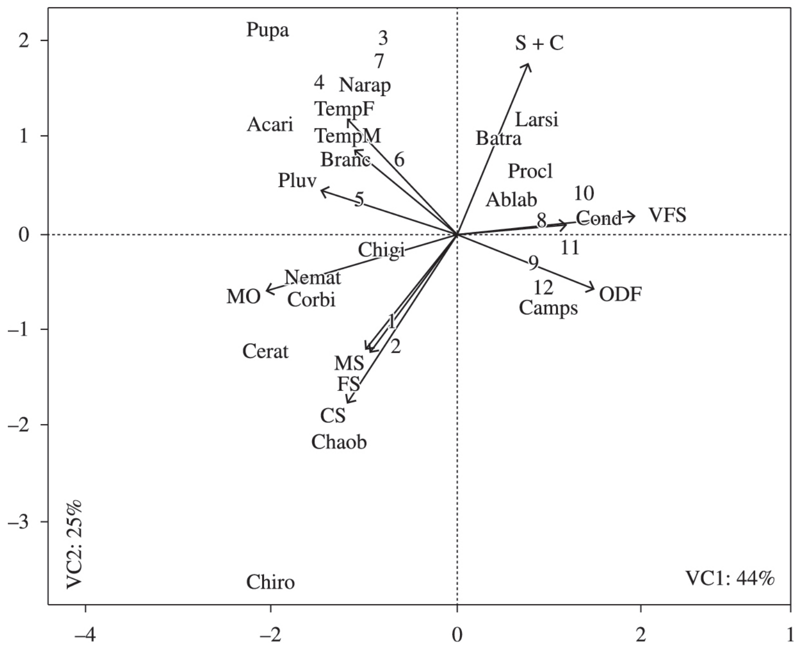

Figure 8. Biplot graphic from the canonical correspondence analysis between the environmental variables and the abundances of benthic macro-invertebrates. (For abbreviations of taxa, see Table 3 and Table 4; the numbers correspond to months: 1 (Aug), 2 (Sep), 3 (Oct), 4 (Nov), 5 (Dec), 6 (Jan), 7 (Feb), 8 (Mar), 9 (Apr), 10 (May), 11 (Jun), 12 (Jul).

and beginning of the rising water periods. In contrast, greater genus richness values were observed in the months with high rainfall. The increase in rainfall from December 2009 to January 2010, associated with high water and air temperatures, may have contributed to the eclosion of macro-invertebrates' eggs, and, therefore, to an increase in *taxa* richness (Panarelli et al., 2008).

Camargo Lake was continually connected to Paranapanema River during this study, as the water level was higher than the connection/disconnection threshold (563.60 m) with Paranapanema River (Henry, 2005).

In the months of greatest lake depth (September 2009 and April 2010), *taxa* density was the highest, with the predominance of *Chaoborus* and *Procladius* sp.2. When the lake was the shallowest (January 2010), at the end of the falling water and beginning of the rising water periods, the density of individuals was the lowest and the number of *taxa*, the highest.

In some months, positive correlation between water depth and transparency was recorded at Camargo Lake. Similar results were observed by Moschini-Carlos et al. (1998), Costa and Henry, (2002), Henry et al. (2005) and Mortari (2009). This variation during the year may be related to various factors, such as daily exchange of allochthonous matter in the river, sediment re-suspension during the drought period, outflow of allochthonous material from the lake bank in the rainy period (Henry, 2009; Moschini-Carlos et al., 1998). However, Camargo Lake presented a small variation in transparency during the study. The highest water transparency values were observed in the months of low water (August 2009 and May, June and July 2010). In contrast, in the months when the river covered the lake completely, transparency was lower (September 2009 and January and February 2010) during the periods of rising and high water. Water level correlated significantly and negatively with total *taxa* richness, which was attributed to the lower transparency. However, organisms inhabit these sites, which present a high level of sediment organic matter.

Relative to the water temperature at the bottom of the lake, the lowest values were recorded in the low water period. From the middle of the falling water up to the end of the rising water period, the water temperature was the highest. The surface and bottom water temperatures were the lowest in the same period, in contrast to that observed by Granado and Henry (2008), who reported lower temperatures during the falling water period.

The highest pH values at both depths were recorded in the low water periods, which may have been related to the low rainfall and the pronounced degradation of organic matter in the lake that resulted from the submersion of the vegetation and/or water exchange with Paranapanema River (Thomaz et al., 1992; Esteves, 1998; Costa and Henry, 2002). The interactions of organic matter in the soil and the geological profiles lead to the formation of free organic acids, which increase the acidity of the aqueous medium (Custodio and Llamas, 1976; Stevenson, 1982). Likewise, the lowest pH values found in the rising water period may have been associated with high rainfall and possibly its diluting effect. This variable correlated significantly and negatively with total *taxa* richness.

Mortari (2009) and Fulan and Henry (2007) found low values of oxygen dissolved in water in April 2006 and February and March 2007, after an intense rising water period, in contrast to the values found in this study, which lowest values were found in October 2009, the month with the highest water level, rainfall and organic matter. The highest values found are similar to those reported by Granado and Henry (2008) for the low water period (June and July 2010), with low rainfall and organic matter values.

Low conductivity values were observed at the end of the falling water period, possibly related to an increase in rainfall and a greater water input, a decrease in the amount of ions and a dilution effect (Pompêo et al., 1997; Moschini-Carlos et al., 1999). High water conductivity values were recorded in the low water period, possibly related to pronounced degradation of organic matter in the lake due to submersion of vegetation and/or water exchange with Paranapanema River (Thomaz et al., 1992; Costa and Henry, 2002).

According to Amorim et al. (2009), aquatic environments are depositional ecosystems and sediment records the processes that occur in the drainage basin. In recent years, sediment analysis has become more and more important in the evaluation of the quality of aquatic ecosystems due to its historical significance for the drainage basin. The importance of the processes of reutilisation of autochthonous and allochthonous matter and exchange and/or interaction of different chemical species with the column of water and the resident biota is also acknowledged (Håkanson and Jansson, 1983; Mozeto and Zagatto, 2006).

According to Fidelis et al. (2008), the abundance and diversity of macro-invertebrates are strongly influenced by the type of substratum. The Camargo Lake sediment is formed predominantly by silt and clay (>67% of the total). Greater bottom substratum heterogeneity was recorded in September 2009, together with the highest values for organic matter, water level and rainfall. Likewise, Davanso (2005) found silt and clay contents above 70% in Coqueiral Lake, which is located in the same region. Santos and Henry (2001) proposed that the main environmental factors affecting the benthic community of Jurumirim Reservoir, São Paulo State, are depth and sediment composition.

Hynes (2001) pointed out the existence of many types of organic matter in lotic systems, from fine fragments to filamentous algae to roots to whole trees and animals. In our study, Camargo Lake presented predominantly organic sediments in almost every month of the high water, falling water, and rising water periods, when autochthonous material was probably introduced into the Lake from the River.

According to Suriani et al. (2007), Oligochaeta are the most common and abundant benthic macro-invertebrates, and some species are considered good bioindicators, especially in water bodies with organic pollution. Many species prefer eutrophic water, living in sediment with abundant organic matter. In this study, the highest density was found in the months with the highest percentages of organic matter in the sediment.

Procladius sp. 2, one of the dominant taxa of Diptera in Camargo Lake, was also found in reservoirs (Brandimarte et al., 1999) and swamps, given its feeding plasticity (Nessimian, 1995).

Chaoborus, also predominant in Camargo Lake, is represented by cosmopolitan and predator organisms that live in high-latitude temperate environments and in tropical ecosystems (Borkent, 1993; Halat and Lehman, 1996). They are voracious predators of other benthic invertebrates, especially zooplankton, and can be found in sediment during the day and in the column of water at night (Hare and Carter, 1986; Hare, 1995). The preference of these organisms for environments with low oxygen concentration and deeper zones of lakes and reservoirs is well documented (Larow, 1970; Strixino, 1973; Strixino and Strixino, 1980; Rahel and Nutzman, 1994; Rabette and Lair, 1998; Corbi and Trivinho-Strixino, 2002; Jager and Walz, 2002).

In the temporal scale, besides *Chironomus gigas, Branchiura sowerbyi* and *Chironomus* were also constant. *Branchiura sowerbyi,* which had high densities during the whole year, has been reported as an indicator of organic pollution. They predominate in environments under environmental stress (Pamplin et al., 2006; Pamplin and Rocha, 2007; Suriani et al., 2007). In this study, they were in greater numbers in the high water period, when the sediment had a large quantity of organic matter.

According to Takeda et al. (2003), nymphs of *Campsurus* burrow into fine sediment and predominate in the high water period, when the concentration of dissolved oxygen in lakes is lower. Davanso and Henry (2007) observed a higher density of *Campsurus* in Coqueiral Lake when it was disconnected from the river and lake depth was low. In the present study, the density of *Campsurus* larvae correlated positively with lake depth, which varied with the river water level. On the other hand, it correlated negatively with water temperature and rainfall, making evident that the increase in abundance is related to a reduction in the lake volume in the coldest season of the year.

The greatest occurrence of macro-invertebrates was recorded in September 2009, when the water level, depth, and organic matter content were high and the sediment had a more heterogeneous granulometric composition. According to Van Brink et al. (1994), flood may remove macro-invertebrates from flooded lakes and carry them to the main river channel. At the same time, other river species are introduced into the lake environments. This can explain the fact that in the months with high water, *taxa* richness was low, since some macro-invertebrates may have been removed. The connectivity of the different habitats, such as rivers and lakes, can alter the dispersion, movement, and migration of organisms and thus determine the exchange of nutrients and organic matter between habitats (Sheldon et al., 2002).

No evident pattern was observed in the present work in the temporal variation of benthic macro-invertebrates, which raises questions on the tendency of seasonal variation of these organisms. The richness of the macro-invertebrate *taxa* studied did not vary much, suggesting that greater sampling of the studied environment is required to determine such tendency.

5. Conclusions

The variation in the volume of Camargo Lake with the flooding of Paranapanema River into the lake resulted in alterations of limnological variables and, consequently, of species. A significant difference was also observed for organisms subject to the influence of water abiotic factors, such as water level and transparency, suspended matter, dissolved oxygen, pH, electric conductivity and temperature.

Variations were also observed in abundance. The months with the highest rainfall had higher genus richness and diversity than the low rainfall period.

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