Composition and abundance of Chironomidae and Ephemeroptera in a lateral lake in the mouth zone of Paranapanema River into Jurumirim Reservoir (State of São Paulo).

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ABSTRACT: Composition and abundance of Chironomidae and Ephemeroptera in a lateral lake in the mouth zone of Paranapanema River into Jurumirim Reservoir (State of São Paulo). Coqueiral Lake is a marginal lake located at the southeast part of São Paulo State, Brazil in the mouth zone of Paranapanema River into Jurumirim Reservoir and it has high connectivity with Paranapanema River. This work aimed to verify the composition and, abundance of Chironomidae and Ephemeroptera in 18 sampling sites of lake bottom. The samples were taken every three months during a year; we also analyzed physical and chemical variables (water depth, transparency, dissolved oxygen, pH, and electric conductivity). Sediment samples were collected in treplicates for fauna and, also for, abiotic factors analysis (granulometric composition and organic content of sediment), using Petersen grab. The material was screened in a 250mm mesh net. Counting and identification of the organisms were accomplished and, relative abundance and taxonomic richness were calculated. The analysis revealed that Ephemeroptera dominated in the hotter period and with low lake depth and Chironomidae low density and diversity when the lake lake disconnected from the river again. Organisms distribution had as main determining factors depth, transparency, pH, and water temperature. It was observed a smaller organisms density in the deeper areas.
Key words: composition, density, Chironomidae, Ephemeroptera, lake, reservoir.

RESUMO: Composição e abundância de Chironomidae e Ephemeroptera em lagoa marginal ao Rio Paranapanema na zona de sua desembocadura, na Represa de Jurumirim (São Paulo). O presente trabalho teve como objetivo principal verificar a composição e abundância de larvas de Chironomidae e ninfas de Ephemeroptera em 18 locais no fundo da lagoa do Coqueiral, zona de desembocadura no rio Paranapanema na represa de Jurumirim, São Paulo. As coletas foram realizadas em intervalos trimestrais ao longo de um ano. Foram analisadas as variáveis físicas e químicas da água (nível, transparência, temperatura, oxigênio dissolvido, pH e condutividade elétrica). Amostras do sedimento, para análise da fauna e fatores abióticos (granulometria e conteúdo orgânico), foram recolhidas em tréplicas, utilizando como coletor o pegador de Petersen. O material foi triado em peneira com malha de 250 mm. Contagem e identificação dos organismos foram realizadas e densidade, abundância relativa e riqueza taxonômica foram calculadas. A análise mostrou um domínio de Ephemeroptera no período mais quente do ano e com baixa profundidade da lagoa e em contraste, uma diminuição da densidade e riqueza de Chironomidae no período de menor profundidade da lagoa, quando novamente se desconectou do rio. A distribuição dos organismos teve como principais fatores determinantes profundidade, transparência, pH e temperatura da água. Foi observada uma menor densidade de organismos nas regiões profundas comparado com as áreas rasas.
Palavras-chave: composição, abundância, Chironomidae, Ephemeroptera, lagoa, reservatório.

Introduction

A development of many waterbodies types is frequently found in a floodplain, in a dependence of bottom topography of aquatic systems and the connectivity with the main channel of the river. Interactions between lateral lacustrine and lotic ecosystems occur with the variation of hydrological levels of the river (Montanholi-Martins & Takeda, 2001). Composition and structure of benthic communities are more sensible to hydrological fluctuations than to the changes on nutrients avaibility (Higuti & Takeda, 2002).

Temporary lakes are considered environments that dry completely or no, during the low water periods and can to segment shaping many isolated waterbodies with reducted areas and depths. Considering all the freshwater ecosystems, temporary lakes present the greatest temporal fluctuations of limnological factors, specially in relation to total alkalinity and electrical conductivity in water column and, to Secchi disk transparency (Thomaz et al.,1997).

Sediment composition, water quality, depth, dissolved oxygen and food availability are the main factors determining the structure and distribution of macrobenthic community in lentic environments (Corbi & Trivinho-Strixino, 2002). The bottom heterogeneity and the water flux affect also the structure and distribution of benthic fauna (Roque & Trivinho-Strixino, 2001). According to Henriques-Oliveira et al. (2003), the bottom type of lakes is the main factor determining distribution and abundance of aquatic insects populations. Moreover benthic fauna is also influenced by substratum type, water trophic status and hidroperiod and, with the total desappearence of water and sediment exposition in lake, the species number is greatly reducted (Kownacki et al., 2000).

In order to understand the influence of ecosystem disturbations on macrobenthic community , it is necessary to examine the composition and diversity of fauna, as well the individual responses of species (Marshall, 1978).

According to Callisto (2000), benthic fauna has adaptative mechanisms that allows to resist to the water level changes and, starts a relative quiescent state until return to favourable conditions, or they move to another site.

In Baia River, the life cycle of Campsurus violaceus is probably adapted to inundation period of Paraná River, because the majority of nymphs are small and move to the middle of river channel, near to macrophytes stands during the flood (Takeda & Grzybkowska, 1997). Nymphys with this migratory pattern withdraw from adverse conditions during the flood period of river.

Chironomids are common, abundant and important organisms (Seminara & Bazzanti, 1988). They constitute the greater taxonomic groups of Insecta, with › 50% of macrobenthos density (Verneaux & Aleya, 1998). Larvae of Chironomidae family are the more diverse and abundant components between the benthic macroinvertebrates due to the their high adaptative power to different substrata and, to food plasticity (Strixino & Trivinho-Strixino, 1998). These species present ecological adaptations in ecosystems to severe environmental situations, as high temperature, pH, organic matter content on sediment and, low concentration of dissolved oxygen in the water/sediment interface (Callisto et al., 2002).

The presence of hemoglobin – like pigment and abdominal tubes presence in Chironomidae larvae are important characteristics to their adaptation to anoxic sites. Both explain their dormancy in the high water period, mainly in bottom zone of Patos Lake, when it was observed the lowest concentration of dissolved oxygen and the highest content of organic content on sediment (Higuti & Takeda, 2002).

In a general way, a Chironomidae larvae predominance has been observed during the breakdown process of plant organic matter in freshwater ecosystems (Gonçalves et al., 2003). In Taupo Lake, Forsyth & McCallum (1981) observed that some chironomids species are adapted to deeper zones and, others to shallow areas.

The aim of this paper was to examine the composition and abundance of Chironomidae larvae and Ephemeroptera nymphae in the bottom of Coqueiral Lake in the mouth zone of Paranapanema River into Jurumirim Reservoir (São Paulo).

Area study

Coqueiral Lake is a lateral lake, located at the southeastern region of São Paulo State (Brazil), in the mouth zone of Paranapanema River into Jurumirim Reservoir (Fig. 1). The lake presents high connectivity with Paranapanema River and it is characterized by great exchange of water between the two ecosystems (Henry et al., 2005). In October 1999, a severe drought started that conduced to a disconnection, during 14 months, between Coqueiral Lake and Paranapanema River. Due to the disconnection between lake and river, it was observed a sediment exposition in shallow areas and so the lake was segmented in many small isolated waterbodies.

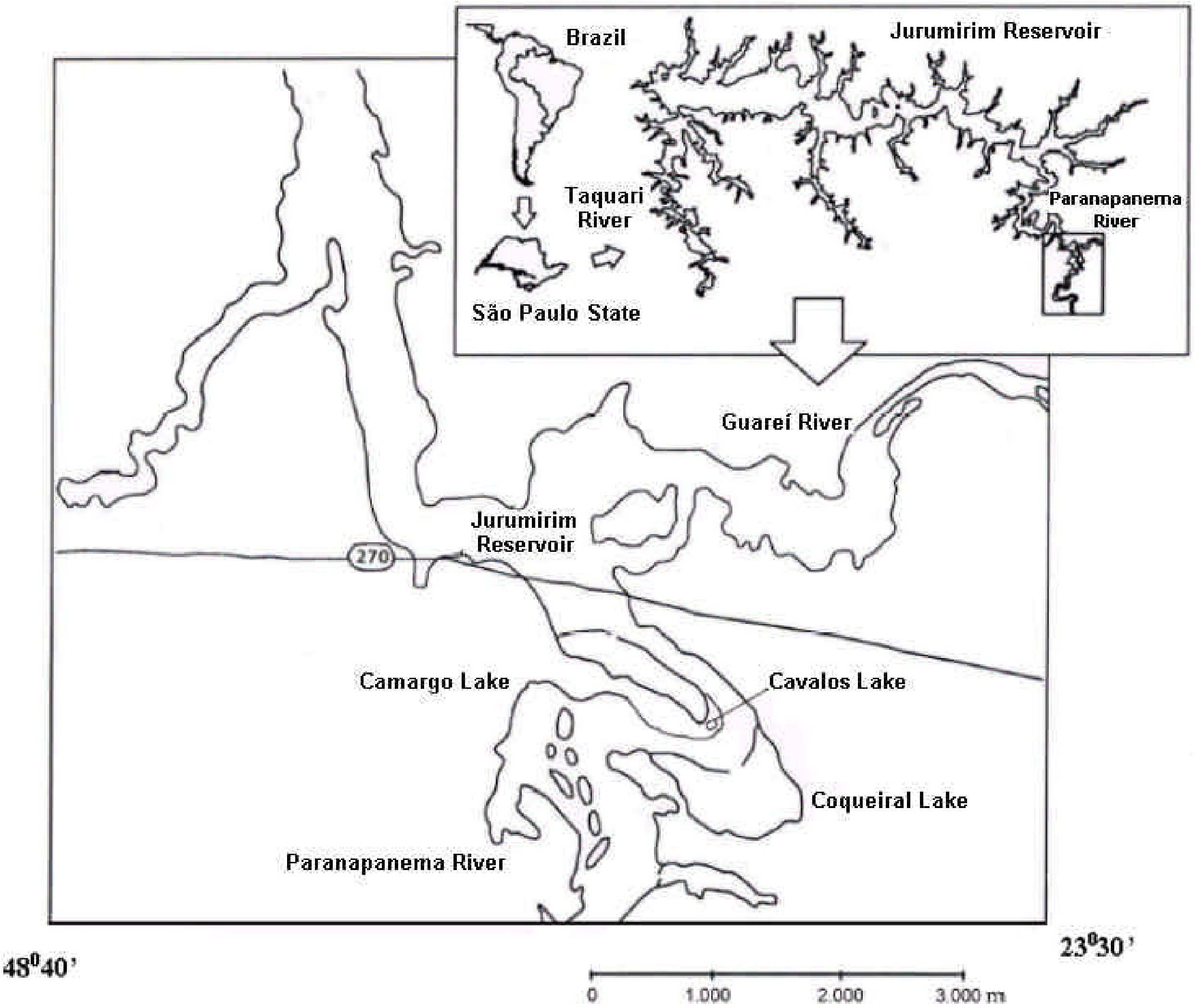

Figure 1: The study area: Lake Coqueiral in the mouth zone of Paranapanema River into Jurumirim Reservoir (São Paulo State, Brazil).

Coqueiral Lake showed a great variability on depths, ranging from a maximum depth (3.70m) to a minimum (0.10m) during the study period. Water transparency varied according to lake depth, being the maxima mean values of transparency when Coqueiral Lake presented the highest depths. Water temperature was relatively high in April and October 2002 and, in January 2003 and, relatively low in July 2002. In the first two sampling periods, water pH was below 7.0 and, in the last two, the values were near 7.0. A detailed description of the data on abiotic factors was presented in Davanso & Henry (2006).

Material and methods

Around 14 months after the severe drought, eighteen sampling sites were selected, involving shallow areas (stations 1 to 8) and, deeper areas (stations 9 to 18). (Fig. 2).

Three sediment samples (for benthic fauna analysis) and three (for characteristics sediment analysis) in each station were collected quaterly the year (from April 2002 to January 2003).

In each station the depth, mean temperature (in water column) by Toho Dentan thermistor, Secchi disk transparency, dissolved oxygen in water (Winkler method, Golterman & Clymo, 1969) were measured at surface and bottom. The granulometric composition of sediment was determined according to Wentworth'scale (Suguio, 1973) and the organic matter content by ignition loss (550°C/1 hour).

Sediment samples were collected with a Peterson grab (area: 420 cm^2). A first sorting was made in field throught a wash of samples in a 250mm mesh net. Then, the fauna was fixed in 4% formolaldehyde and died with Floxin B (Mason & Yevich, 1967). The sorting was carried out under stereoscopic microscope and the organisms were identified using Merritt & Cummins (1996) and Trivinho-Strixino & Strixino (1995).

The density (N, in individuals.m^{-2}) was determined using the cumulative value of three sampling units; the relative abundance (%) of each group and the richness of the taxonomic groups (S) of each sampled station were also computed. The relative abundance indexes were evaluated according Mc Cullough & Jackson (1985), that considered as dominant the groups having a relative abundance between 50 to 100%, as abundant the relative abundance ranging from 30 to 49%, as common the groups with 10 to 29% of the total abundance and, as rare the organisms with ‹ 1% in relative abundance.

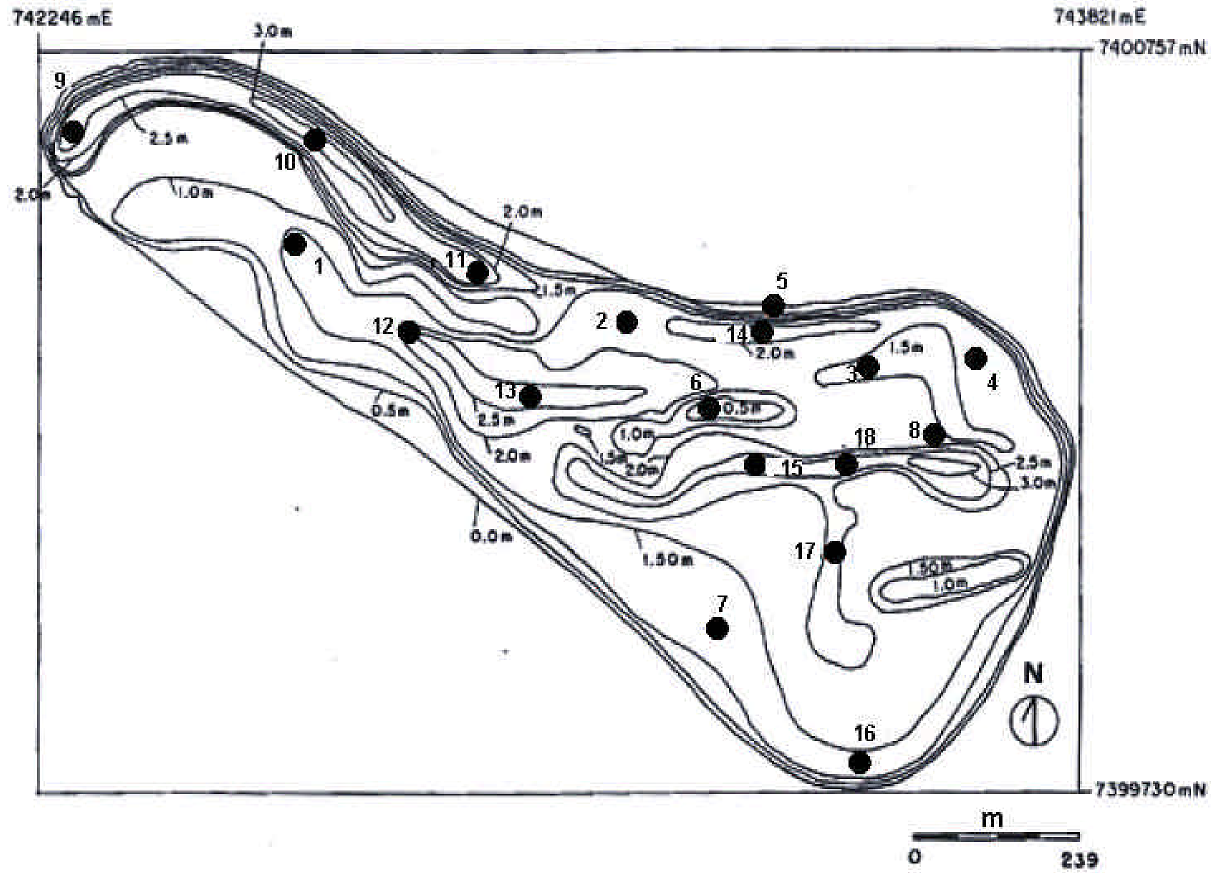

Figure 2: Distribution of the 18 sampling stations (1 to 18) in the Coqueiral Lake.

Statistical analysis

Comparisons between total number of organisms and of taxonomic groups in shallow (stations 1 to 8) and deep areas (stations 9 to 18) were carried out through a variance analysis using a hierarchic model to test the effect of site type, within each sampling month. Transformed data ($\sqrt{x+1}$) were used to assess the variance homogeneity premises and normality (Zar, 1999).

In order to examine the relationship between abiotic factors and abundance of the various taxa, a canonical correlation analysis was made. The abundance data were expressed in terms of relative frequencies ($fr_{ij} = \frac{n_{ij}}{n_i}$, where n_{ij} is the number of collected individuals in sampling i and from the taxon j and n_i is the total number of individuals in the sampling i). The canonical correlation analysis was started through computation of the first pair of scores for each sampling, one summarizes the environmental variables (W) and the other, the biotic variables (V), in order to obtain a maxima correlation between these two scores (coefficient of canonical correlation). The first pair of canonical variables explains better the relationships between biotic and abiotic factors. The second step was to compute a second pair of canonical variables to complete the explaination of the relationships. The correlations between original and canonical variables were computed in order to determine their influences on the ordination (Digby & Kempton, 1987; Gittins, 1985).

Results

Thirdteen different genera of Chironomidae and only one (Campsurus) of Ephemeroptera were found.

A range from 24 to 953 ind.m^{-2} on Ephemeroptera density and from 24 to 977 ind.m^{-2} for Chironomidae was observed (Tab. I).

Table I: Means, standard deviations and amplitudes of variation (min. – max.) of benthic macroinvertebrates densities (ind.m^{-2}) in Coqueiral Lake.

Taxonomic Groups	Shallow Areas				Deep Areas			
	April	July	October	January	April	July	October	January
Ephemeroptera	29.8 ± 67.2	36.0 ± 31.4	83.5 ± 194.0	110.3 ± 243.0	0	114.5 ± 211.0	157.3 ± 258.0	329 ± 326.0
	0 – 191	0 – 72	0 – 358	0 – 572	0	0 – 667	0 – 762	0 – 953
Chironomidae	9.0 ± 12.4	330.6 ± 301.0	101.3 ± 221.0	15.0 ± 27.7	0	179 ± 263.0	195.8 ± 129.0	50.4 ± 28.7
	0 – 24	24 – 977	0 – 453	0 – 72	0	0 – 715	0 – 405	24 – 120
Total Density	215	1,049	811	644	0	1,382	1,167	1,073

In April 2002, Ephemeroptera and Chironomidae were only recorded in shallow areas (three of the 8 stations). Chironomidae only was found in station 2, and Ephemeroptera predominated in relation to quironomids in stations 5 and 7.

The variability of relative abundances of the two Insecta groups in the sampled sites for July and October 2002 and, for January, 2003 is presented in Fig. 3.

In July, Ephemeroptera and Chironomidae were found in all except 2 of the 18 sampling stations. Chironomidae was recorded exclusively in 5 stations (stations 2, 8, 11, 12 and 16) and dominated in 7 stations (stations 1, 3, 4, 6, 7, 17 and 18). Ephemeroptera predominance was only recorded in 3 stations (stations 13, 14 and 15). In October, Chironomidae were exclusive in 3 stations (stations 5, 9 and 11) and dominated in 4 stations (stations 1, 12, 14 and 17). In relation to Ephemeroptera, a dominance was observed in 4 stations (stations 3, 13, 15 and 18). In January, it was recorded a predominance of Ephemeroptera in relation to Chironomidae in almost all the sampling stations (stations 1, 3, 5, 9, 10, 11, 13, 14, 15 and 18). Chironomidae were only dominant in only one station and exclusive in stations 12 and 17.

In April 2002, Ablabesmyia gr. annulata was exclusive (100% of relative abundance) in stations 5 and 6 and, Chironomus was only recorded in station 2.

Figure 4 shows the relative abundance of Chironomidae genera in Coqueiral Lake in July and October 2002, and January 2003. Among the thirteen genera recorded, Chironomus and Ablabesmyia gr. annulata were the most frequent. In July, the highest richness of genera (13 genera) of the year was found. Densities of genera ranged from 24 to 2,619 ind.m^{-2}. In this period Chironomidae was recorded in just stations 9 and 10. Chironomus dominated in almost all the sites (stations 2, 3, 7, 8, 15, and 16) and, was exclusive in stations 4, 11, 17 and 18. In October, seven different genera were found and, again Chironomus dominated in four sites (stations 1, 12, 17 and 18) and was exclusive in stations 9, 10 and 11 (Fig. 4). In January, five Chironomidae genera occured and Ablabesmyia gr. annulata was dominant in only two stations (stations 3 and 13) and were exclusive in 4 sites (stations 5, 9, 14 and 17). In this period of the year, Chironomus dominated in only one station (station 12). In stations 1, 10, 11, 15 and 16, only two different genera (Chironomus and Ablabesmyia gr. annulata) occurred with 50% of relative densities (Fig. 4).

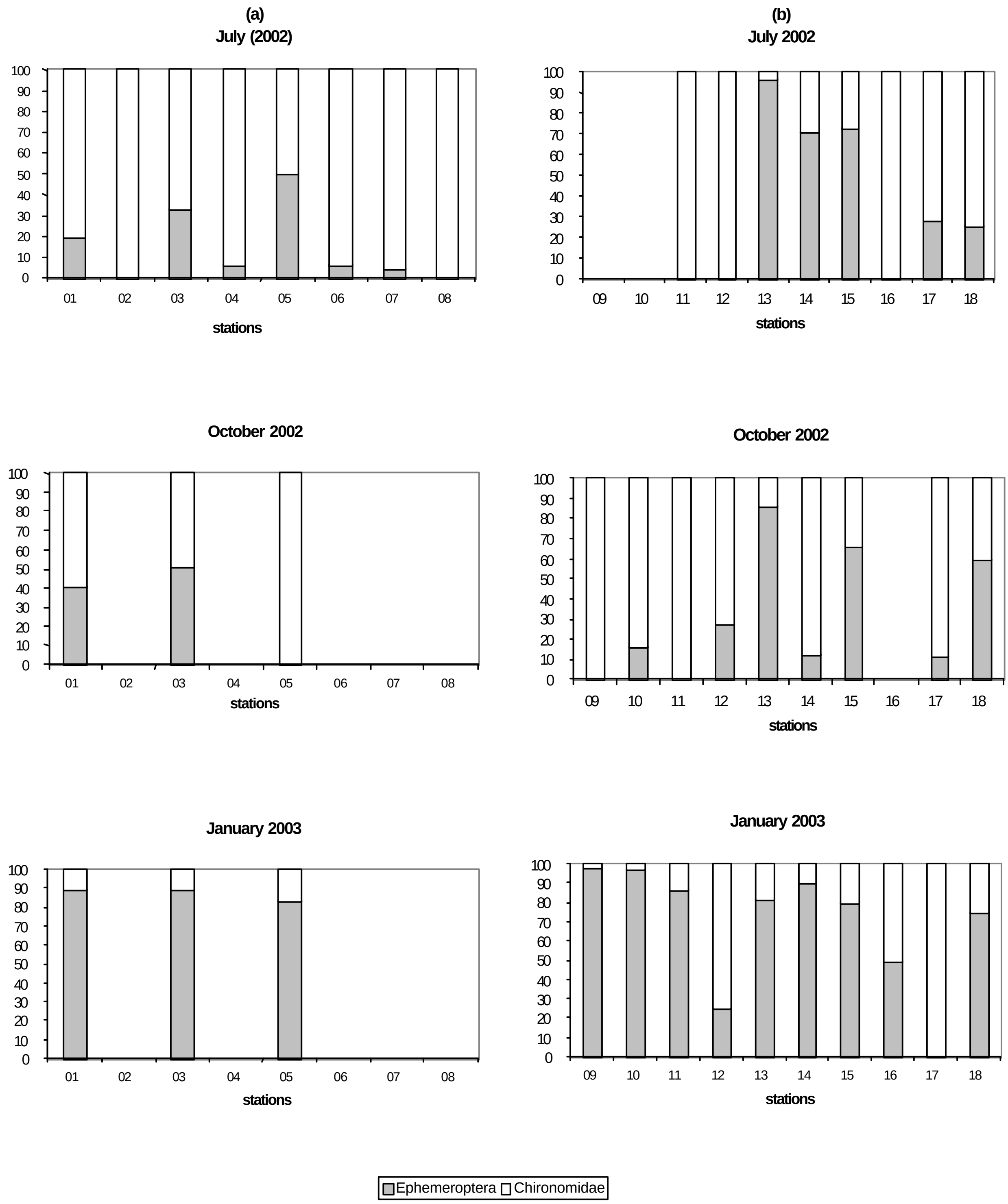

Figure 3: Relative abundance (%) of benthic macroinvertebrate in shallow (a) and deep (b) areas of Coqueiral Lake.

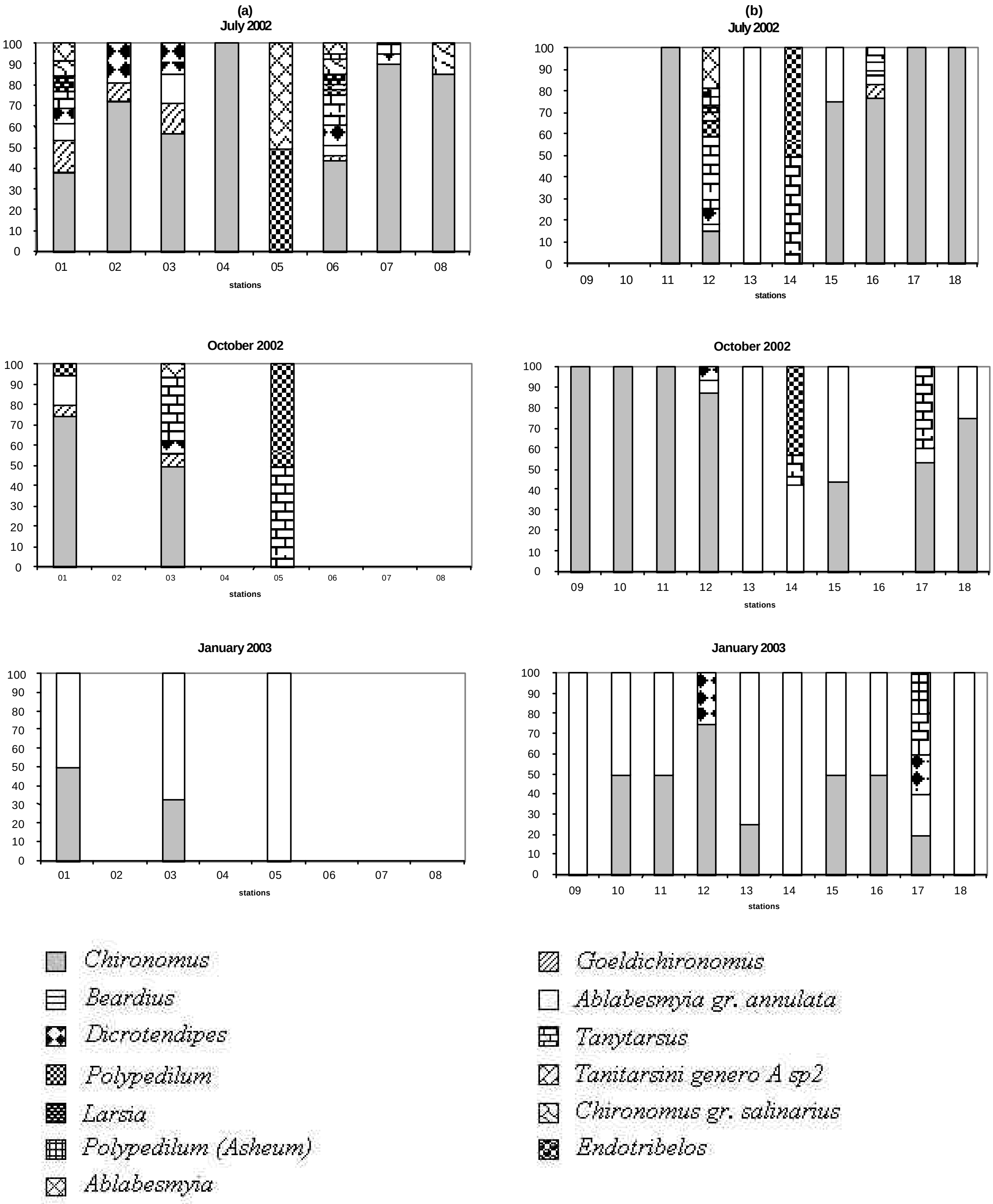

Figure 4: Relative abundance of Chironomidae genera in shallow (a) and deep (b) areas of Coqueiral Lake.

Canonical correlation coefficient between the two pairs of canonical variables was significant (Tab. II). Correlations between original and respective canonical variables are presented in Tab. III. Ephemeroptera presented a negative correlation with depth and transparency and, a positive with water pH (Tab. III). Chironomidae was negatively correlated with water temperature (Tab. III).

Table II: Coefficients of canonical correlations between benthic macroinvertebrates and physical and chemical variables.

Canonical variable	Canonical correlation	% accumulated explained variation	Standard error	Pr > F
1	0.848757	45.0	0.037365	0.0001
2	0.765825	70.0	0.055258	0.0068

Table III: Correlation between benthic macroinvertebrates abundance and the canonical variable V1 and, correlation between physical and chemical variables (water and sediment) and the canonical variable W1.

Abiotic variable	W1	W2	Biotic variable	V1	V2
Depth	-0.9116	0.0055	Ephemeroptera	0.5852	-0.4659
Transparency	-0.7254	0.4470	Chironomidae	0.4866	0.5853
Temperature	0.3503	-0.6834			
Dissolved oxygen at bottom	0.5644	-0.1068			
Bottom pH	0.8731	-0.1373			
Eletric conductivity at bottom	-0.0426	0.1544			
Organic Matter	0.0556	0.2458			
Very coarse sand	0.2039	-0.2766			
Coarse sand	-0.0123	-0.1806			
Mean sand	-0.1919	0.1549			
Silte and clay	0.1476	-0.0893			

Comparing the shallow and deep areas of the lake in the two first sampling periods (April and July 2002), the ANOVA showed that, in relation to total number of individuals, a significant difference was noticed for the second sampling period (F_{15} = 5.96; p = 0.0275). No significant difference between the areas was evidenced for the number of taxonomic groups in April (F_{15} = 3.08; p = 0.0999) and in July (F_{15} = 1.04; p = 0.3232).

Discussion

Aquatic insects are important organisms and can be used in surveys of environmental monitoring, because they are very sensitive to disturbes that occur in freshwater environments (Bispo et al., 2001),

Sheldom et al. (2002) observed that the composition of benthic community in lateral lakes to Cooper Creek varied with connectivity and hydrological level. In lakes frequently inundated, the authors observed a minor abundance and taxons richness in environments linked to river and, in disconnected lakes they found a high abundance and richness of benthic fauna. In conclusion, the hydrological variation affected significantly the biota diversity and abundance on sediment.

According to Marshall (1978), benthic fauna is affected by the fluctuation on water level because in Lake Mc Illwaine, Rhodesia, the populations of Chironomidae larvae were little abundant during the low water period, but populations increased in densities with the increase of lake depth.

After the prolonged drought, Coqueiral Lake increased in volume and the larvae population of Chironomidae presented densities higher during the high water period (April and July 2002). However, when it occurred in November 2002 a disconnection between the lake and Paranapanema River, the densities decreased.

After the disconnection of Coqueiral Lake with Paranapanema River, highest density of Chironomidae was recorded in deep areas, but before the disconnection (in April and July 2002), the highest abundance of quironomids ocurred in shallow sites.

According to Heins & Crommentuijn (2002), benthic organisms are controlled by water temperature, food, granulometric composition of sediment and, dissolved oxygen content. After Takeda et al. (2003), the oxygen shortage determines a reduction on density and, a prevalence of species tolerant to hypoxic condictions. Santos & Henry (2001) observed no Chironomidae in a site the transition zone between Paranapanema River and the Jurumirim Reservoir with low concentration of oxygen dissolved in water. But in Coqueiral Lake, there was a significative negative correlation between Chironomidae density and temperature (r= -0.68), suggesting that this was the most important factor controlling benthic invertebrates.

Ephemeroptera are organisms extremely sensitive to environmental impacts (Marques et al., 1999). These organisms inhabit in streams and lakes with well oxygenated waters and, also in temporary lakes, with high temperature and low dissolved oxygen content. Some species can occur in environments polluted by domestic wastes (Callisto, 2000). In Coqueiral Lake, only Campsurus was observed in great densities in October 2002, when the lake depth was reduced after the disconnection between lake and river. A negative significant correlation between Ephemeroptera density with depth (r = -0.91) and transparency (r = -0.72), and a positive with pH (r = 0.87) were recorded.

According to Hawkins et al. (1997), changes on temperature affect distribution and abundance of benthic organisms. Ribeiro et al. (1998) pointed out that the substratum is the main regulator factor of distribution and abundance of benthic invertebrates because it is a food resource, habitat and shelter site. Henriques-Oliveira et al. (2003) observed that organic matter content on sediment is the main abiotic factor affecting Chironomidae distribution in Fazenda stream, Rio de Janeiro.

According to Strixino & Trivinho-Strixino (1980), the Chironomidae distribution is greatly influenced by sediment composition and local depth. Higuti et al. (1993) found that the sediment type presented a relationship with the Chironomidae occurrence, but only the Polypedilum genus was affected by depth, being limited to shallow sites. Santos & Henry (2001) observed also the highest abundance of these larvae in low depths (@ 1.9m). In Coqueiral Lake, the Polypedilum genus was also found in sampling stations with low depth and the highest density of these larvae were recorded in October, in a station (station 11) presenting 0.80m depth.

The number of Chironomidae species co-existing in any continental water body is higher than any other taxonomic group (Callisto et al., 1998). Chironomidae larvae present adaptative mechanisms of physiological, morphological or behavioural nature, that enable to survival in environments with low dissolved oxygen concentrations. Chironomids are able to tolerate anoxic conditions in short time periods or to low oxygen concentrations during prolonged time periods. Many Chironomidae species synthetize a respiratory pigment similar to hemoglobine that transport and stock oxygen. In some conditions, as low dissolved oxygen concentrations, Chironomidae can be the unique insects larvae in sediment. Chironomus and Polypedilum are found in high densities in environments with organic sediment, when many other Chironomidae genera were no recorded (Callisto et al., 2001).

In Coqueiral Lake, 13 different genera of Chironomidae larvae were identified and, the more abundant genus (4,761 ind.m^{-2}) was Chironomus. According to Higuti et al. (1993), Chironomus is characteristic of highly productive lakes and, is also dominant in many shallow lentic systems, as ponds and swamps. They found high abundance of Chironomus in sites with predominance of pebbles with great amount of mud, that are important for food and tubes construction. Callisto & Esteves (1998) observed the Chironomus, Goeldichironomus and Polypedilum genera in sites with high contents of organic matter. According to Strixino & Trivinho-Strixino (1980), in sites with high organic matter content on sediment, it can note a rise of benthic organisms. Henriques-Oliveira et al. (2003) recorded also the highest chironomids densities in sites with high organic matter content. However, Ablabesmyia, Chironomus and Endotribelos are typical genera of lentic habitats. In Coqueiral Lake, Chironomus and Ablabesmyia gr. annulata were the more frequent genera.

Chironomidae larvae from Chironomus genus are commonly found in deep zones of lakes and reservoirs and, are able to survival in sites with low dissolved oxygen concentration due to its peculiar metabolism. Organisms of Chironomus genus are employed as ecological indicators of lakes and reservoirs, in advanced conditions of eutrophication (Real et al., 2000). In Coqueiral Lake, Chironomus was observed in April only in two shallow (1.30 and 1.10 m depth) stations (stations 10 and 12, respectively) when compared with the other 16 stations.

Autochthonous and allochthonous organic matter is a food resource for many aquatic organisms in freshwaters. Chironomids larvae are the more abundant invertebrates and, their abundance and distribution are greatly influenced by quantity and quality of particles in the ecosystem (Hirabayashi & Wotton, 1998). In Coqueiral Lake, chironomids were the organisms found with great frequence in density and richness.

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