Horizontal distribution and temporal variation of the zoobenthos of a tropical Brazilian lake.

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ABSTRACT: Horizontal distribution and temporal variation of the zoobenthos of a tropical Brazilian lake. The community of benthic macroinvertebrates of Lake Monte Alegre (Ribeirão Preto, SP, Brazil) was studied from March 2001 to December 2002. Zoobenthos samplings and measurements of physical and chemical factors, such as temperature, dissolved oxygen, electrical conductivity, and pH of the water column, were carried out every three months in two transects (longitudinal and transversal) at 1, 2, 3, 4 and 5 m depths. The same physical and chemical factors were also measured every month in the water column at the maximum depth (5 m). Granulometry and organic matter content of the sediment were also analyzed twice at each transect. More stable thermal stratification was established in the lake during the warm season and periods of total circulation occurred during the cool one. Temperature, dissolved oxygen, coarse particles of the sediment decreased, whereas electrical conductivity, fine particles and the relative organic matter content increased toward the deep region. The distribution pattern of benthic organisms, expressed in densities and biomass, was similar in both transects, with dominance of Chaoboridae (Chaoborus brasiliensis) in the deep zone and Chironomidae in the shallow one. Biological (diversity, richness, evenness and similarity) indices reflected the distribution pattern with higher richness and diversity in the shallow zone of the lake, mostly influenced by Chironomidae.
Key-words: benthic macroinvertebrates, Lago Monte Alegre, tropical lake, Chaoboridae, Chironomidae.

RESUMO: Distribuição horizontal e variação temporal do zoobentos em um lago tropical brasileiro. A comunidade de macroinvertebrados bentônicos do Lago Monte Alegre (Ribeirão Preto, SP, Brazil) foi estudada de março de 2001 a dezembro de 2002. As coletas dos organismos e as medidas dos fatores físicos e químicos tais como temperatura, oxigênio dissolvido, condutividade elétrica e pH da coluna da água foram feitas a cada três meses em dois transectos (longitudinal e transversal) nas profundidades de 1, 2, 3, 4 e 5 m. Os mesmos fatores físicos e químicos foram também medidos, mensalmente, na coluna de água no ponto mais profundo do lago (5 m). Granulometria e matéria orgânica do sedimento foram analisadas em duas ocasiões distintas em cada transecto. Estratificação térmica mais duradoura e estável estabeleceu-se no lago durante a estação quente, enquanto períodos de circulação total ocorreram na estação fria. Temperatura, oxigênio dissolvido, pH e a fração mais grossa do sedimento diminuíram, enquanto a condutividade elétrica, fração fina e matéria orgânica do sedimento aumentaram com a profundidade. A densidade e a biomassa do zoobentos foram semelhantes nos dois transectos, com dominância de Chaoboridae (Chaoborus brasiliensis) nas regiões profundas e Chironomidae nas mais rasas. Os índices biológicos (diversidade, riqueza, equitabilidade e similaridade) refletiram o padrão de distribuição com maiores riqueza taxonômica e diversidade nos pontos mais rasos do lago e influenciados, principalmente, por Chironomidae.
Palavras-chave: macroinvertebrados bentônicos, Lago Monte Alegre, lago tropical, Chaoboridae, Chironomidae.

Introduction

The community of freshwater benthic invertebrates is composed of widely distributed organisms, which inhabit the sediment or its surface (Jónasson, 1978). They can be also associated with other submerged substrates such as aquatic macrophytes, leaves, stones, branches, twigs, which provide food, shelter, and place for egg deposition and emergence of some species (Hynes, 1970).

Insects are the dominant group, in number and biomass, in most tropical lakes (Ward, 1992), where Diptera Chironomidae and Chaoboridae (Strixino, 1973; Strixino & Trivinho-Strixino, 1998) predominate.

The distribution of the organisms in most environments is heterogeneous and related to several factors, such as depth, food quality and availability, particle size and the organic matter content of the sediment, type of substrate, water temperature, dissolved oxygen concentrations, among others (Merritt & Cummins, 1996).

Tropical lakes have low thermal variation between surface and deep waters and low and variable thermal stability, and constant oxygen deficits near the bottom (Henry et al., 1997). The horizontal distribution pattern of the benthos is well defined from the littoral to the profundal zone (Jónasson, 1978). Higher habitat diversity and dissolved oxygen concentrations in the littoral are favorable to the organisms, contributing to increase diversity and richness, and productivity (Albuquerque, 1990). The profundal zone, on the other hand, is a homogeneous habitat, with frequent dissolved oxygen deficits, heterotrophic production, and low organism diversity and predominance of few species of chaoborids and chironomids (Strixino, 1973; this study) resistant to low dissolved oxygen concentrations.

In this study the spatial and temporal distribution of the benthic macroinvertebrates of Lake Monte Alegre were studied in two consecutive years, every three months. Composition, diversity, richness, evenness, dominance, and biomass of the most representative groups were evaluated in several depths in two transects. One of the purposes of the research was to investigate benthos distribution pattern in different seasons or if changes in the lake features caused shifts in the pattern. Thus, abiotic factors, such as temperature, dissolved oxygen, pH, electrical conductivity, particle size and organic matter content of the sediment were also investigated.

Methods

Study area

Lake Monte Alegre (21° 11' S, 47° 43' W) is located in the University of São Paulo campus (Ribeirão Preto, State of São Paulo), at an altitude of 500 m, resulting from the damming, in 1942, of Laureano creek, which belongs to River Pardo basin (total

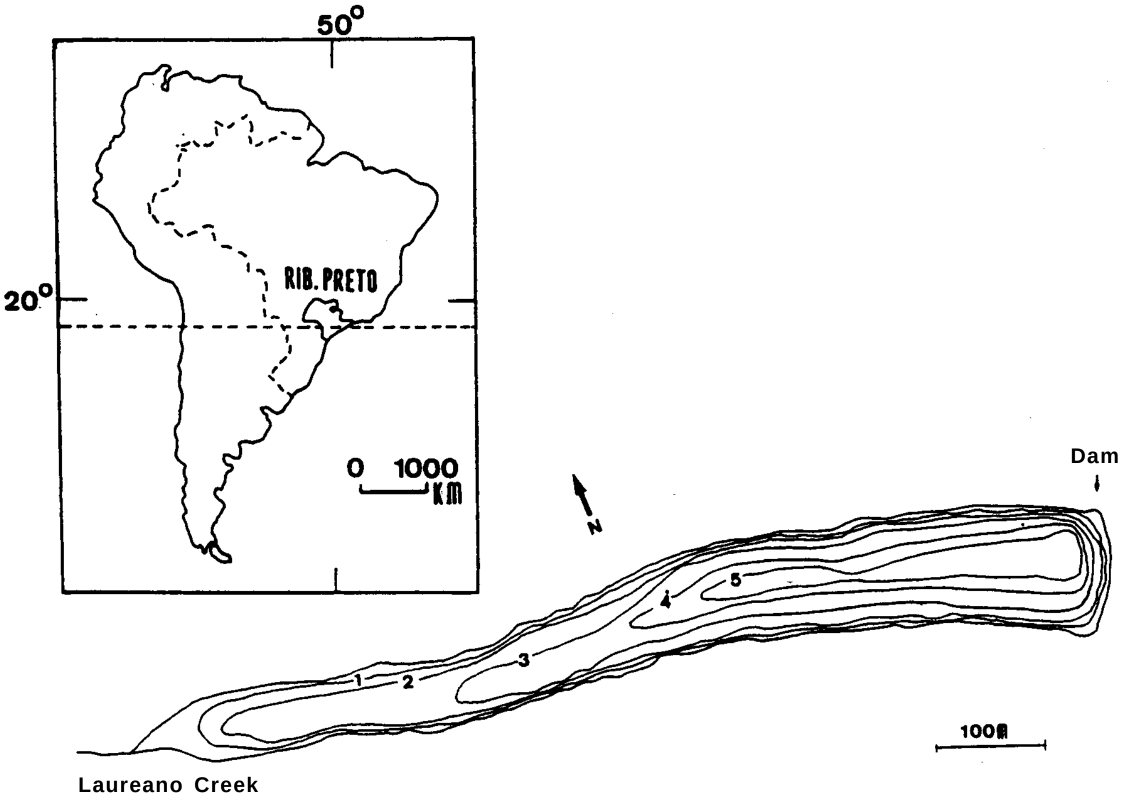

Figure 1: Upper: location of Ribeirão Preto and São Paulo State in South America. Lower: morphometric map of Lake Monte Alegre showing the transversal and longitudinal transects and the sampling stations.

drainage area = 35,400 km²) (Fig. 1). It is a small (7 ha, maximum length = 906 m and average width = 85 m) and shallow eutrophic lake (Z_{MEAN} = 2.9 m and $Z_{MAX.}$ = 5.0 m), with a retention time of 45 days at the end of summer (Arcifa et al., 1990). The lake is surrounded by grass, bushes and medium-sized to tall trees and the creek, upstream from the lake, flows through a sugar cane plantation. The lake inlet is colonized by rooted and floating macrophytes (Typha, Eichhornia crassipes and E. azurea) and bushes, comprising an area of 2,500 m². The remaining lake margins are poor in macrophytes. Sources of organic and industrial pollution are negligible as the lake is located far from urban and industrial areas; it is likely that most of the pollution contribution from the sugar cane plantation is trapped in several small reservoirs located upstream and by the dense stands of macrophytes at the lake inlet.

The region has a tropical warm to sub-warm climate (Nimer, 1989), with two seasons (warm-wet: October to April; cool-dry: May to September). Average monthly air temperature and rainfall varies respectively from 21ºC to 25ºC, and from 29 to 132 mm throughout the year (UNAERP meteorological station, Ribeirão Preto, SP).

The lack of dam manipulation, as the lake is used only for research and teaching, the surface outlet, the small dimensions, low flow of the creek, and winds of low velocity without constant direction contribute to its stability (Arcifa et al., 1990). It is warm discontinuous polymictic, the thermal stratification leading to chemical (dissolved oxygen and nitrogen compounds) and physical (electrical conductivity, pH) stratification (Arcifa, 1999).

Sampling

Samplings were carried out in two transects, every three months, from March 2001 to December 2002, and including two dry and two wet seasons. One transect was located on the main lake axis (longitudinal) and the other was perpendicular to it (transversal) (Fig. 1). Samples of the sediment were taken at 1, 2, 3, 4, and 5 m deep in each transect. The benthic fauna was collected with an Ekman-Birge dredge (0.0225 m²), in triplicate, and the data were calculated to 1 m². Samples were placed in labeled plastic bags with 4% formalin. Temperature, DO (Yellow Springs Inc., model 95), electrical conductivity, at 25ºC (YSI, model 30), and pH (YSI, model 60) were measured near the bottom concurrently with the benthos samplings. Particle size and organic matter in the sediment were analyzed twice in each transect according to Wentworth (1922) and Cunha & Guerra (1996).

Physical and chemical factors, such as temperature, dissolved oxygen, electrical conductivity, and pH were also measured every month in the water column in the deepest area (5 m), at half meter intervals.

In the laboratory the organisms were separated from the sediment through a sieve of 0.210 mm, and kept in vial with 80% ethanol. Identifications were made under a stereomicroscope, at 30 x, with the aid of literature (Trivinho-Strixino & Strixino, 1995; Merritt & Cummins, 1996; Fernández & Domínguez, 2001), and specialists.

The biomass (g dw/m²) of the most representative groups, such as larvae and pupae of Chironomidae and Chaoboridae, larvae of the Campsurus melanocephalus (Ephemeroptera), and Krendoswkia (Hydracarina), was also evaluated. The specimens were dried at 60-70ºC, for 24 h, and weighed on a microbalance to determine dry weight (dw/m²) according to Dermott & Paterson (1974).

Several indices were applied: Shannon diversity index (H'), Margalef richness index (R), Pielou evenness index (E) (Ludwig & Reynolds, 1988), and Jaccard's similarity index to compare different depths and seasons (Southwood, 1966). ANOVA (Tukey test) and Spearman's linear correlation (r) were applied for comparing data. Paired Student t-test (Bonferroni adjustment) was used for mean comparisons. Statistical analyses were made using Systat 9.0 (1998) software program using raw data. Significance level for all analyses were established as p £ 0.05.

Results

Physical and chemical factors

As a consequence of thermal stratification, which is more stable during the warm season, dissolved oxygen (DO) lowered to values below 1 mg/L at 4-5 m (Fig. 2). Temperature, DO, and pH significantly decreased and electrical conductivity increased from 1-2 m to 4-5 m in both transects, the 3 m station representing a transition zone (Fig. 3). Fine sediment and the relative contribution of organic matter increased toward the deepest station (Fig. 4).

The average temperature of the water column varied from 21.5°C, in the cool season, to 27.5°C, in the warm one. The stratification was more evident at 3-5 m in the warm season, leading to dissolved oxygen depletion, whereas at 1-2 m DO concentrations were high (› 6.5 mg/L). Accordingly, higher conductivity values, up to 92.7 mS/cm, occurred in the deepest region. At 4-5 m pH values were significantly lower (ANOVA; p = 0.001) than at 1-3 m, values ranging from 4.2 to 7.4 throughout the year.

Sediment

The lake sediment is silty-clayish (particles ‹0.06 mm) with high organic matter content (›10%). The coarse fraction (›0.250 mm) contributed 32% and the fine one (‹0.250 mm) 68% in average; the former fraction significantly decreased (r = -0.87 in both transects) and the latter one increased (r = 0.93 in both transects) from the shallow to the deep stations (Fig. 4). Silt/clay represented ca. 60% of the sediment at 1-2 m and ca. 75% at 4-5 m. The relative contribution of the organic matter varied from 15 (1 m) to 24% (5 m). Similar values were recorded in all depths in the longitudinal transect (21.5-23.7%), in contrast with the transversal one, where higher variation was found (14.6-23.7 %).

Benthic fauna

The estimated number of specimens (24 taxa; 17 Diptera) for the two years was 326,000, with a similar distribution pattern along both transects (Fig. 5). Ninety seven percent of the macrobenthic fauna was composed of the Diptera Chaoboridae, Chaoborus brasiliensis (larvae and pupae), and Chironomidae (larvae and pupae). Ephemeroptera Polymitarcyidae (Campsurus melanocephalus), Hydracarina (Krendowskia sp.), Diptera Ceratopogonidae (Culicoides sp.), Nematoda, Hirudinea, and Oligochaeta (Limnodrilus hoffmeisteri) contributed 3%.

The macrofauna composition did not significantly differ in the two transects, dipterans prevailing over other groups. Two dipteran families contributed ca. 99% to the organisms in the transversal transect (chaoborids-79% and chironomids-20%) and ca. 96% to the longitudinal one (chaoborids-75% and chironomids-21%).

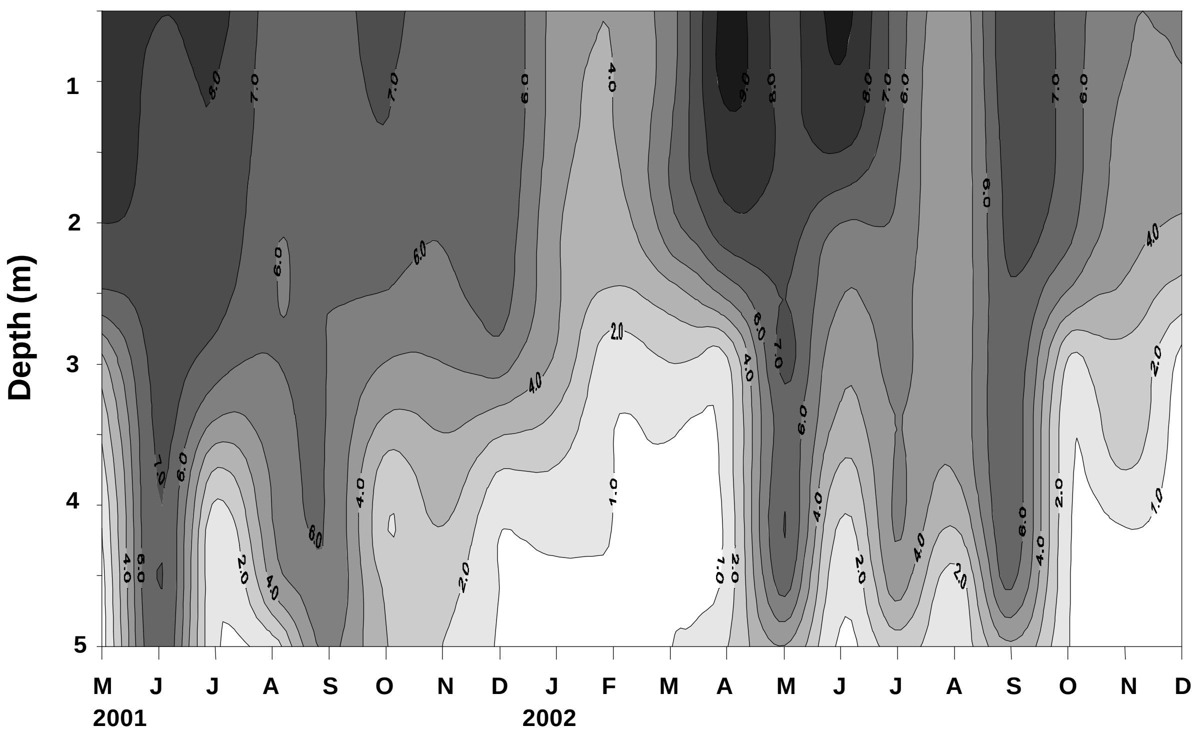

Figure 2: Depth-time diagram of dissolved oxygen isopleths, at intervals of 1 mg/L, from March 2001 to December 2002.

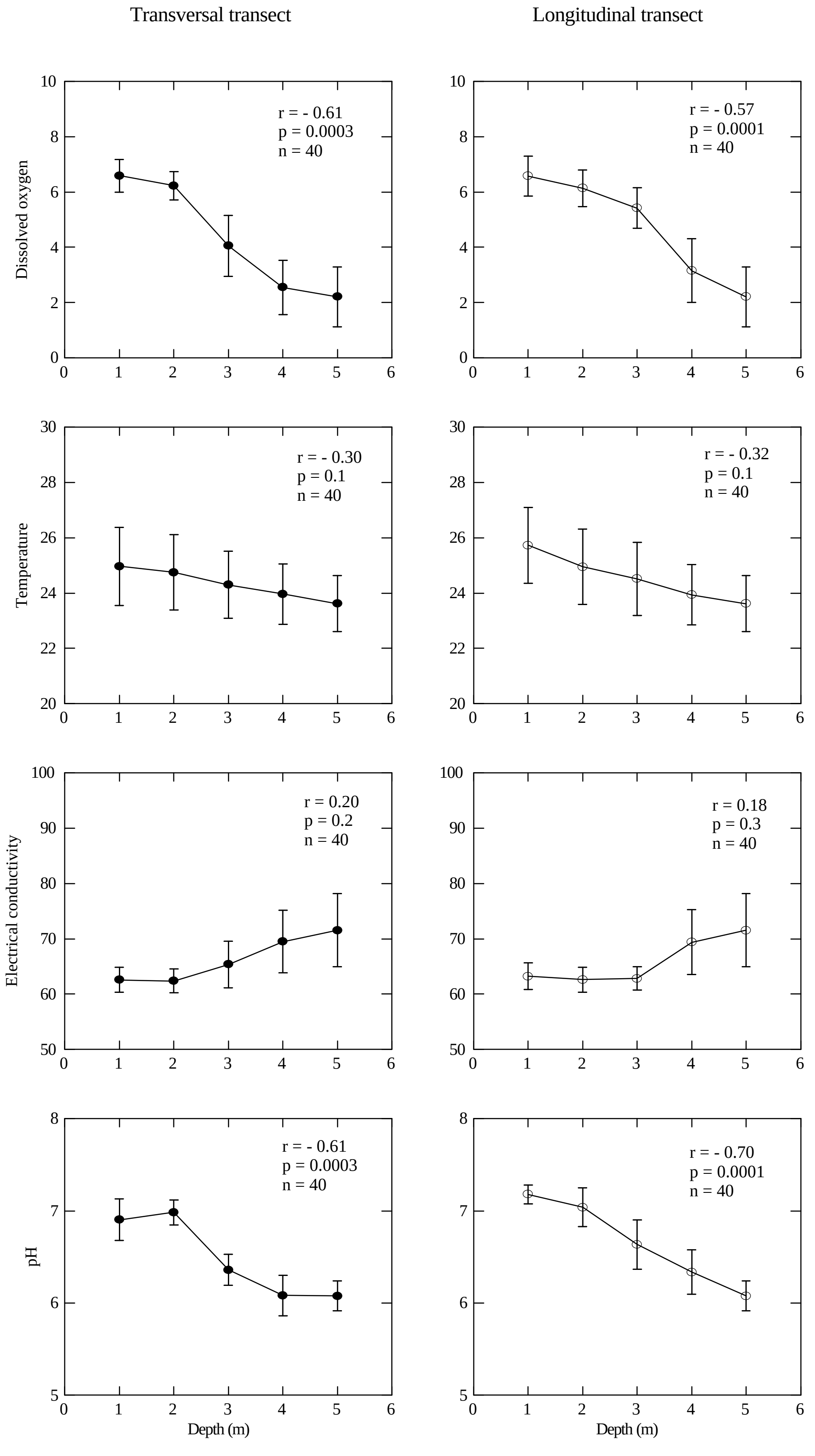

Figure 3: Mean values, standard errors, Spearman's correlation (r) for dissolved oxygen (mg/L), temperature (ºC), electrical conductivity (mS/cm), and pH in both transects, from March 2001 to December 2002. N = number of measurements; significant values for p £ 0.05.

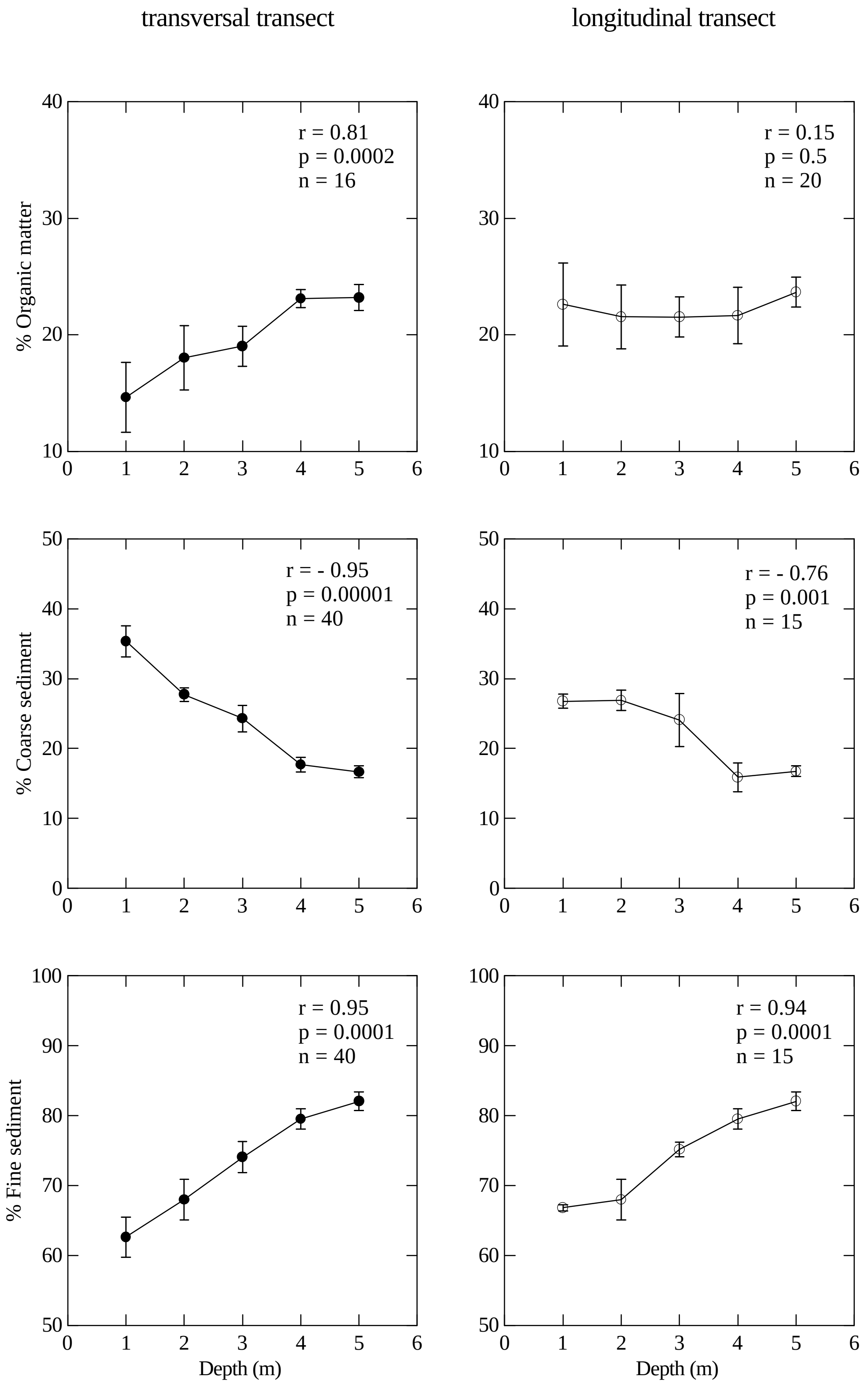

Figure 4: Mean values, standard errors, Spearman's correlation (r) for relative organic matter content, coarse (› 0.250 mm) and fine (‹ 0.250 mm) particles of the sediment in both transects, from March 2001 to December 2002. N = number of measurements; significant values for p £ 0.05.

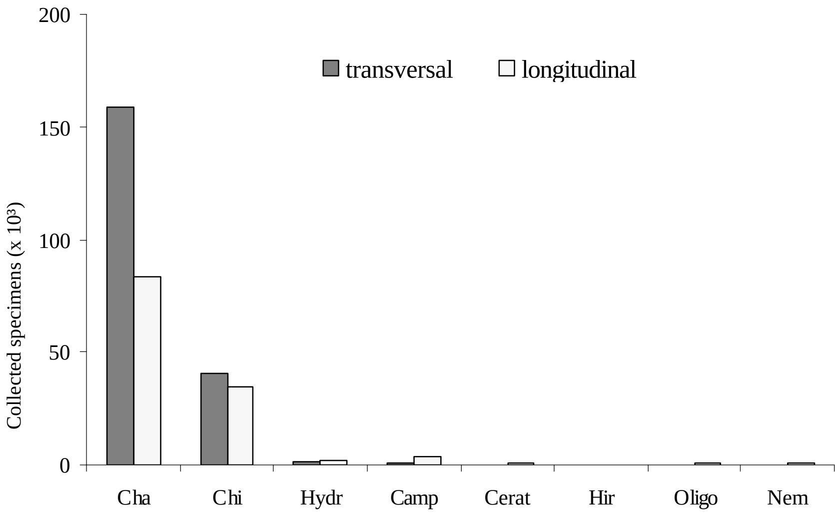

Figure 5: Total number of specimens collected (ca. 326,000) from March 2001 to December 2002 at the transversal and longitudinal transects. Cha = Diptera Chaoboridae (larvae and pupae of Chaoborus brasiliensis), Chi = Diptera Chironomidae (pupae and larvae), Hydr (Hydracarina, Krendowskia); Camp = Campsurus melanocephalus (Ephemeroptera), Cerat = Diptera Ceratopogonidae (Bezzia and Culicoides), Hir = Hirudinea, Oligo = Oligochaeta (Limnodrilus hoffmeisteri) and Nem = Nematoda.

Chaoborus brasiliensis occurred in all depths, resulting in a high average frequency of occurrence (93%). However, this species was significantly more abundant ($p = 0.001$) in the deepest region (4-5 m; ca. 7,200 ind./m²) than in the shallow one (1-2 m; 1,140 ind./m²); in the intermediate region (3 m) the average densities of Chaoborus were 2,422 ind./m².

Eighty seven percent of the chironomids concentrated from 1 to 3 m and 87% of the chaoborids from 3 to 5 m, significantly dominating at 4-5 m ($p = 0.001$) (Fig. 6). At 5 m the relative abundance of chaoborids exceeded 90%, whereas the other taxa, such as Krendowskia (Hydracarina) and Chironomus (Diptera) represented less than 1.5% each, with an average frequency of occurrence of ³ 50% (Fig. 7).

Chironomidae was more abundant in the cool-dry season than in the warm-wet one ($p = 0.02$); Chaoboridae densities did not significantly differ between the two seasons ($p = 0.7$), however, a trend for a higher numeric abundance was found in the warm-wet season. The temporal fluctuations of larvae and pupae of the subfamilies Chironominae and Tanypodinae (Chironomidae) were similar with peaks in June 2001/02 (winter), and decreases in September (spring) and December (summer). These subfamilies were mostly distributed from 1 to 3 m in both transects, where 87% of the specimens were recorded. The dominant taxa were Ablabesmyia, Chironomus, Cladopelma, Harnischia, Labrundinia, Tanytarsus, Tanypus punctipennis and Zavreliella from 1 to 3 m and Chironomus, Coelotanypus, Tanypus stellatus and Zavreliella from 4 to 5 m. Chaoboridae larvae peaked in September 2001 and December 2002, whereas pupae were most abundant in March 2002, representing 30% of the total number of specimens.

Biomass

The biomass followed the numerical dominance of the benthic groups, except Campsurus. Chaoborus (larvae and pupae) contributed 58% (13.5 g dw/m²), Chironomidae (larvae and pupae) and Campsurus larvae 20% each (4.7 and 4.6 g dw/m², respectively), and water mites ca. 2% (0.45 g dw/m²) to the total biomass (23.25 g dw/m²) (Fig. 8).

The same trend for higher abundance of most groups from 1 to 3 m was also observed in biomass. Chaoborus contributed ca. 60% and water mites 2% to the total biomass; biomass of Chaoborus (88%) and mites (99%) was higher at 3-5 m. On the other hand, 76% of the chironomid

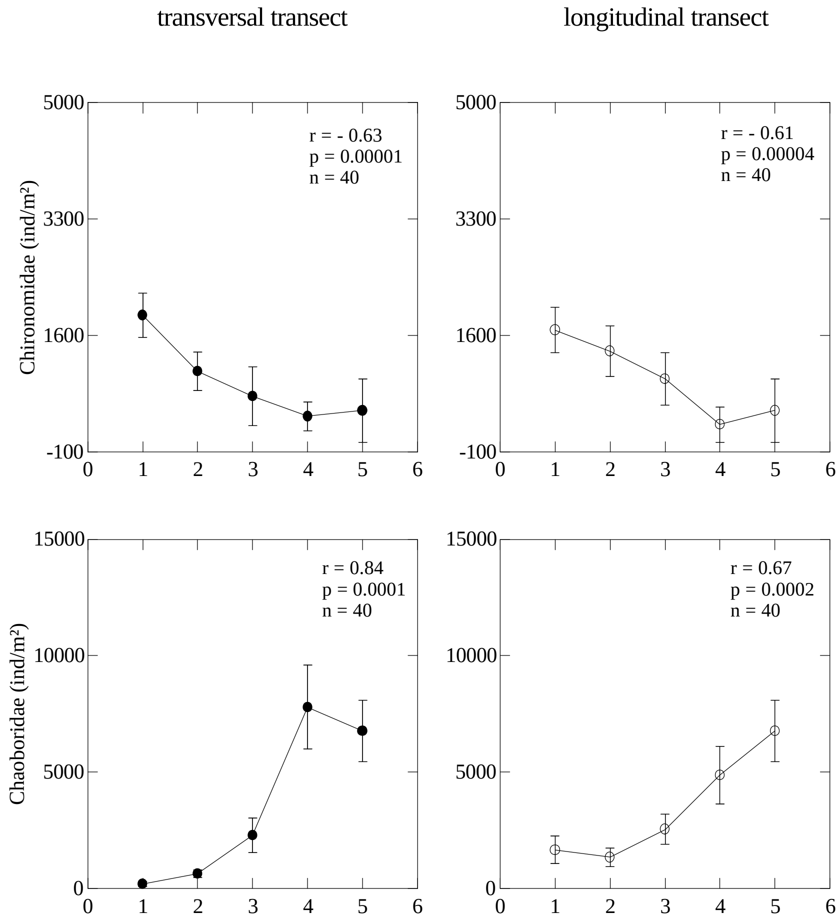

Figure 6: Mean densities (ind./m²), standard errors, Spearman's correlations (r), significant level (p) and numbers of observations (n) for Chironomidae (larvae and pupae) and Chaoboridae (larvae and pupae) in both transects at different depths from March 2001 to December 2002. Significant values for $p \leq 0.05$.

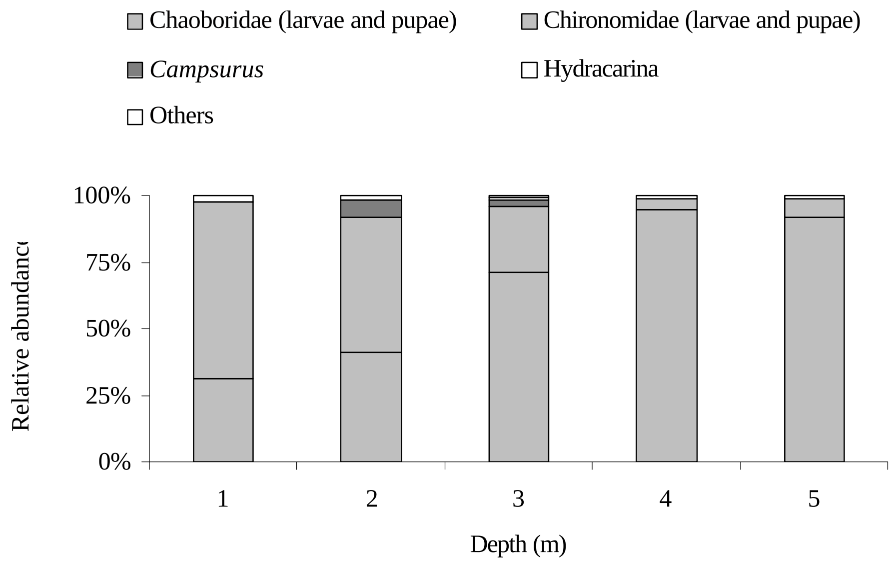

Figure 7: Relative abundance of zoobenthos in both transects, from March 2001 to December 2002. Others = Ceratopogonidae, Oligochaeta, Nematoda, and Hirudinea.

biomass was recorded at 1-2 m. Campsurus, which was numerically inexpressive, showed high biomass, contributing 20% to the total value, mostly distributed at 2-3 m.

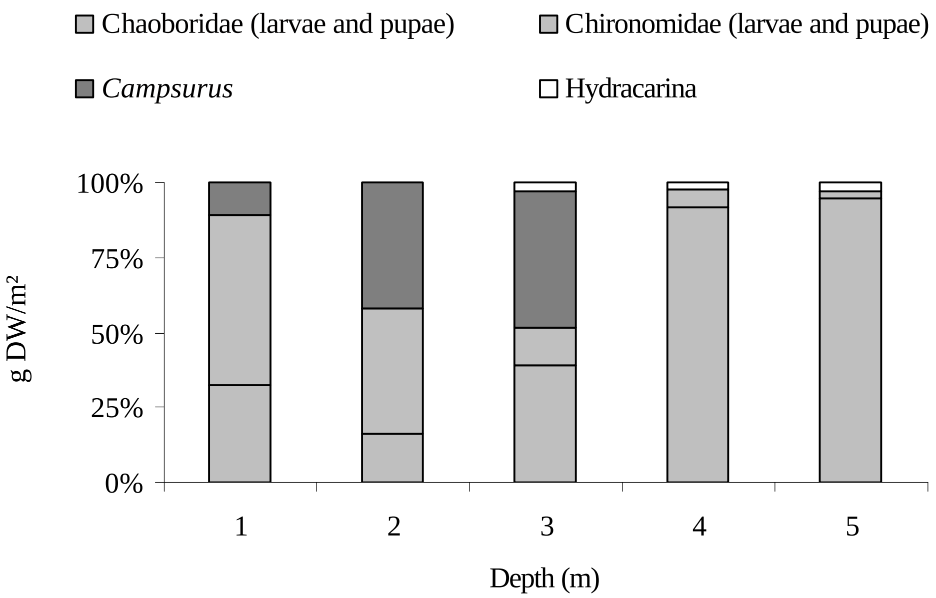

Figure 8: Relative biomass of the major zoobenthos taxa in both transects from March 2001 to December 2002. DW = dry weight.

More than 50% of the biomass of the major groups was recorded in June and September 2001 (cool-dry season) and December 2002 (warm-wet season), Chironomidae predominating in June 2001 (46%) and Chaoboridae in the following months (57 – 77%) (Fig. 9). Chaoborids and water mites were most abundant in spring and summer, whereas chironomids peaked in autumn and winter and Campsurus in winter and spring.

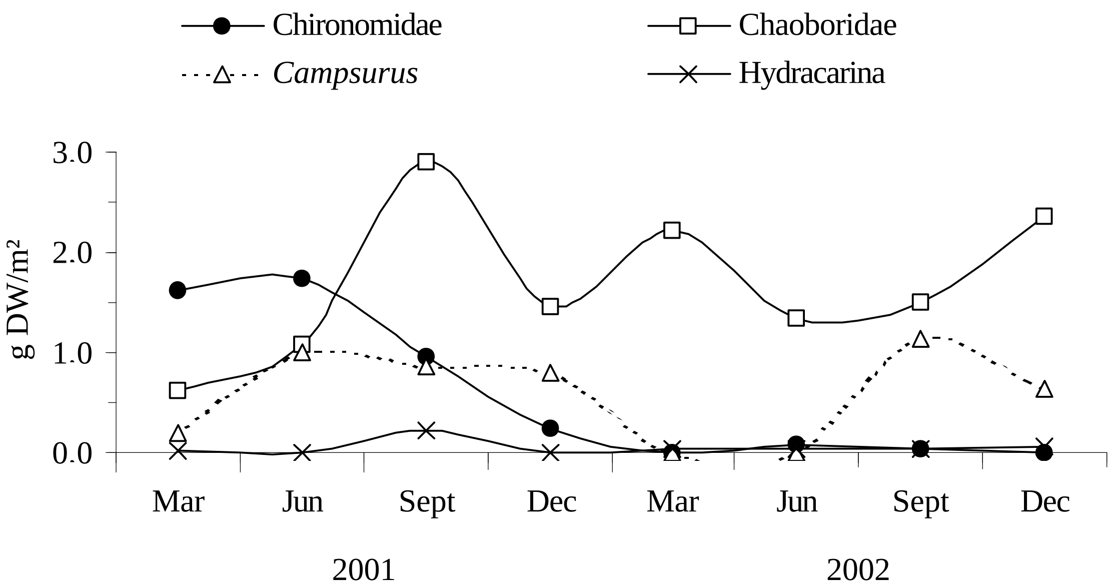

Figure 9: Temporal variation of total biomass of the major taxa in both transects, from March 2001 to December 2002. DW = dry weight.

Biological diversity

There were no significant differences of diversity, richness and evenness indices between 2001 and 2002 and between the two transects (Figs. 10, 11). Significant higher indices (ANOVA; p = 0.01 for all indices) were found in the shallow stations (1-2 m) compared to the deep ones (4-5 m). Intermediate values were obtained at 3 m, with significant higher diversity indices compared to 4-5 m in both transects (ANOVA; p = 0.04 for the transversal transect; p = 0.001 for the longitudinal one); significant lower H' was found at 3 m compared to 1-2 only in the transversal transect (ANOVA; p = 0.04).

Biological indices were significantly higher (ANOVA; $p \leq 0.05$ for all indices) in the cool-dry season (June and September 2001/02) than in the warm-wet one (March and December 2001/02) (Fig. 11). Diversity index was largely influenced by Chironomidae (Fig. 12; Tab. I), as a consequence of the higher number of taxa (n = 14) presented by this group. The number of specimens of Chironomidae was 2.3 fold higher in the cool-dry season than that in the warm-wet one.

In agreement with the distribution pattern of the organisms along the transects, Jaccard similarity index was 75% at 1-3 m stations and ca. 90% at 4-5 m ones.

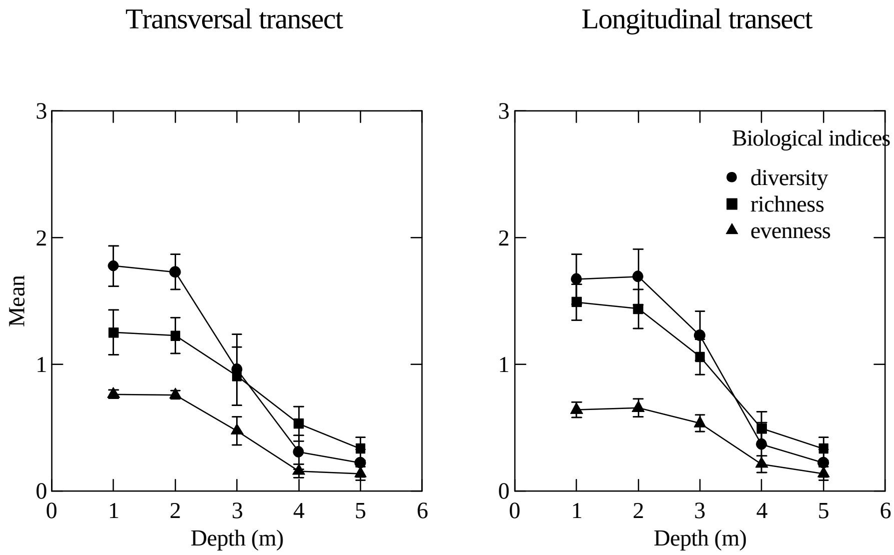

Figure 10: Spatial variation of diversity, richness, and evenness indices for zoobenthos in both transects, from March 2001 to December 2002.

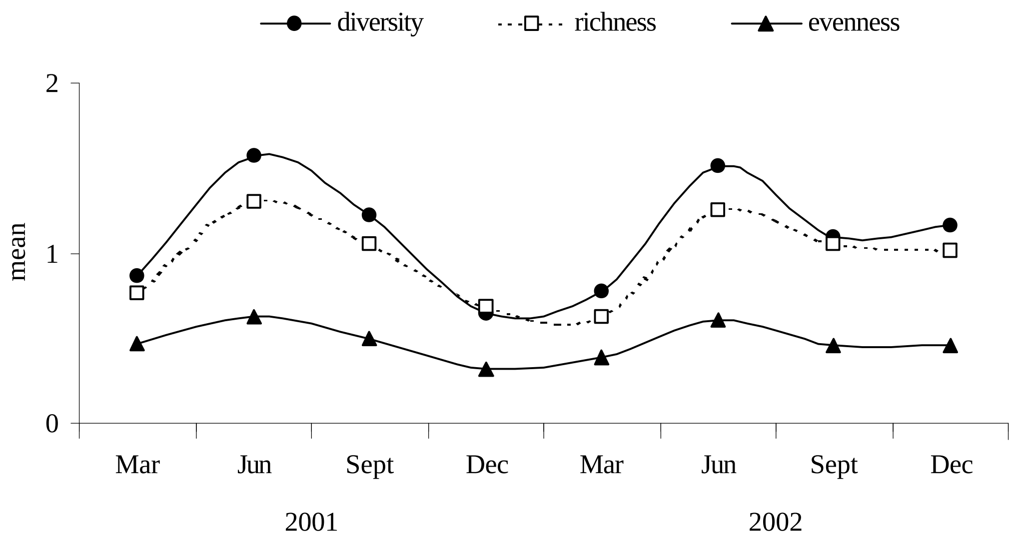

Figure 11: Temporal variation of average diversity, richness, and evenness indices for zoobenthos in both transects, from March 2001 to December 2002.

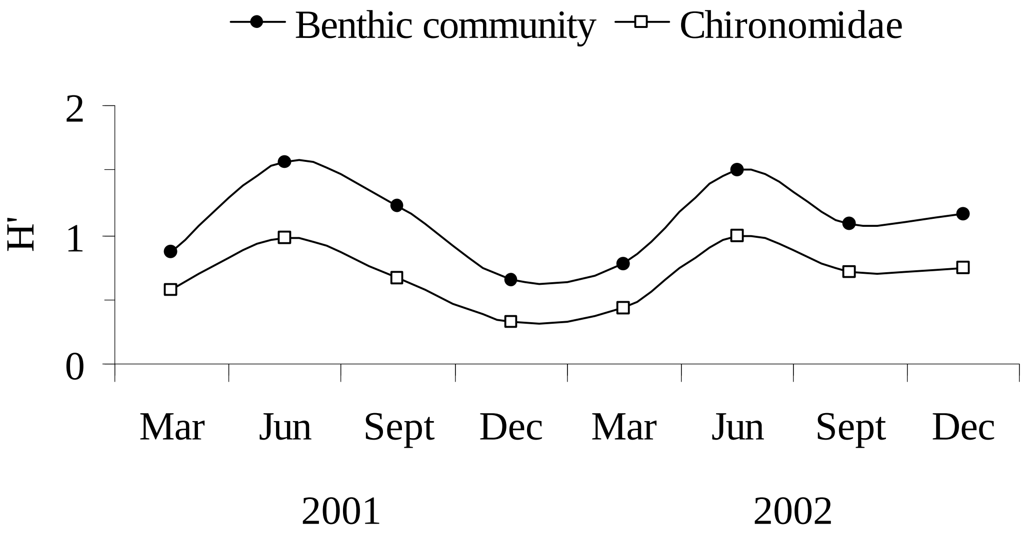

Figure 12: Temporal variation of the average diversity index for zoobenthos and Chironomidae in both transects, from March 2001 to December 2002.

Table I: Values, minimum and maximum, for taxonomic richness (number of taxa), evenness Pielou (E), dominance Simpson (S), Shannon-Weaver diversity (H') and density (ind./m²) for organisms found during the study at different depths in the lake Monte Alegre. Chironomidae represented 60% of total collected at 1-2 m depths while Chaoborus brasiliensis represented 94% at 4-5 m depths.

	Depths (m)				
	1	**2**	**3**	**4**	**5**
richness	24	22	19	16	11
E	0.39 – 0.88	0.36 – 0.86	0.07 – 0.77	0.02 – 0.61	0.0 – 0.44
S	0.3	0.3	0.5	0.9	0.9
H'	1.03 – 2.48	0.71 – 2.34	0.09 – 1.85	0.03 – 1.41	0 – 0.85
density	15 – 5,319	15 – 3,141	15 – 5,659	15 – 25,170	15 – 12,148

Discussion

The macrobenthic community of Lake Monte Alegre was strongly dominated, in density and biomass, by dipterans, mainly chironomid and chaoborid larvae, as found in other Brazilian lentic water bodies (Strixino, 1973; Santos et al., 1998; Higuti & Takeda, 2002). The dominance of Chaoborus in the deep zone observed in our study has been pointed out by a few authors (Fukuhara et al., 1997; Moreno & Callisto, 2006). The sediment of the lake is suitable for the establishment of detritivorous organisms such as chironomids (Ferrington, 1992), the mayfly Campsurus (Pereira & Da Silva, 1991; Fonseca-Leal & Esteves, 2000), and is an ideal substrate for Chaoborus (Bezerra-Neto, 2001).

The spatial distribution of macrobenthic organisms in Lake Monte Alegre showed a similar pattern in two consecutive years and through the two transects; chironomids predominated in the shallow zone (1-2 m), chaoborids in the deep zone (4-5 m), with a transition zone (3 m), where the first group starts to decline and the second one to increase.

Higher density, biomass, diversity and richness in the shallow zone of the lake followed a classical pattern for zoobenthos (Jónasson, 1978; Marques et al., 1999). Determinant factors for the distribution and abundance of several groups, particularly dipterans, are higher heterogeneity of microhabitats in the shallow zone, which provides refuge from predators, food sources from periphyton developed on macrophytes, as well as carbon contribution from the surrounding terrestrial environment (Nessimian & Lima, 1997; Takeda et al., 2003).

The benthos distribution in the lake seems to be primarily limited by dissolved oxygen (DO); other physical and chemical factors, such as electrical conductivity, pH, organic matter content and texture of the sediment played a secondary role. There is no indication that the organic matter content of the sediment is of major importance for the benthos distribution as the same pattern occurred in both transects, even when no differences in organic matter content were found, as in the longitudinal one.

The discontinuous polymictic pattern of circulation of Lake Monte Alegre was confirmed in several studies (Arcifa et al, 1990; 1998), as well as its trend for a quick stratification reestablishment (Arcifa et al., 1990). Partial or total circulation take place during the cool season, the stratification being more stable during the warm one. However, DO is usually unevenly distributed in the water column, evidencing that oxygen demand is high in deep layers due to intense microbial metabolism at the high temperatures prevailing in the tropics, particularly in eutrophic conditions. As a consequence, the deeper sediment (3-5 m) is a selective habitat for benthic organisms, influencing their distribution pattern, with predominance of anoxia-resistant organisms.

Some groups of organisms are known to be resistant to low DO concentrations or anoxia, and are able to survive for long periods in oxygen-free microhabitats. Chaoborids are known to support anoxic conditions (Cressa & Lewis, 1986; Fukuhara et al, 1997; Bezerra-Neto, 2001), especially instars III and IV, which dominated the deep benthos of Lake Monte Alegre during the day. At night, most of the larvae migrate to the water column for preying on zooplankton (Arcifa, 1997). A few taxa of chironomids such as Chironomus and Tanypus stellatus, the oligochaete Limnodrilus hoffmeisteri, and the water mite Krendowskia can also resist to low DO concentrations (Brinkhurst, 1966; Strixino & Trivinho-Strixino, 1982, 1998; this study). Although frequent in the lake Chironomus, Tanypus stellatus, and T. punctipennis were not abundant, as well as L. hoffmeisteri and the water mite Krendowskia. The reason for their low abundance was not evaluated here, but one possibility is competition for space with chaoborids emerging as superior competitors. Chironomids are known as inhabitants of the sediment and chaoborids as epibenthic; however, our observations with chaoborids in Lake Monte Alegre showed that they burrow into the sediment as well, then sharing the same habitat.

The deep layer of Lake Monte Alegre, with low dissolved oxygen concentrations, offers the advantage of a lower predation risk. Arcifa (1997) suggested that the avoidance of diurnal predators would be the best hypothesis to explain migration of chaoborid larvae to the substrate during the day. Adult and young fish are mostly distributed in the shallow zone of the lake (Arcifa & Meschiatti, 1993; Meschiatti & Arcifa, 2002), adult and large juveniles moving to the deep zone to search for food only when DO concentrations increased during circulation episodes. Chaoboridae instars III and IV are the main item among the aquatic insects in the overall diet of the fish fauna (mainly for Astyanax, Cichla, and Geophagus) in the lake (Arcifa & Meschiatti, 1993), and predation pressure upon them could be higher if they did not burrow into the oxygen-free sediment at daytime (Arcifa, 1997).

Compared to other Brazilian water bodies (Irmler, 1975; Fittkau et al., 1975; Reiss, 1977) intermediate values of benthic biomass were recorded in Lake Monte Alegre, indicating that benthic secondary productivity is not so high. Chironomidae had a larger influence on the benthos biomass fluctuations throughout the year, whose peaks in the cool-dry season also resulted in higher values of richness and diversity indices.

Highest diversity and richness were found in the shallow zone compared to the deep one in Lake Monte Alegre, following the same tendency of densities and biomass. The diversity indices were mostly influenced by Chironomidae, due to its higher number of taxa ($H'_{ZOOBENTHOS} = 2.48$; $H'_{CHIRONOMIDAE} = 2.06$).

The maximum diversity index recorded ($H' = 2.48$) was slightly higher in Lake Monte Alegre compared to other Brazilian water bodies (Albuquerque, 1990; Strixino & Trivinho-Strixino, 1998; Henry & Nogueira, 1999; Marques et al., 1999), where the maximum value was 2.1 in shallow zones. On the other hand, lakes impacted by domestic and industrial pollution, such as Ibirité Reservoir (Moreno & Callisto 2006) have even lower values (richness: 5-9 species; $H'_{HIGHEST}$: 1.54). Moreno & Callisto (2006) recorded in that reservoir the genera Chironomus, Coelotanypus, Dicrotendipes, Goeldichironomus, Labrundinia, Tanypus and Tanytarsus, which they suggested to be indicatives of its eutrophic situation. The same genera occurred in Lake Monte Alegre, which is also eutrophic, although not strongly influenced by human activities. However, diversity and richness in different ecosystems are related to several factors, as pointed out by Roque & Trivinho-Strixino (2001) and Roque et al. (2003), such as: differences in size, sampling frequency, particular features of each environment, as well as their histories.

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