Acta Limnologica Brasiliensia, 2011, vol. 23, no. 2, p. 154-163

Controlling factors of benthic macroinvertebrates distribution in a small tropical pond, lateral to the Paranapanema River (São Paulo, Brazil)

Macroinvertebrados bentônicos e fatores controladores de sua distribuição em uma pequena lagoa tropical adjacente ao rio Paranapanema (São Paulo, Brasil)

Erika Mayumi Shimabukuro[1] and Raoul Henry[1]

[1]Department of Zoology, Institute of Biosciences, State University of São Paulo – UNESP, CEP 18618-970, Botucatu, SP, Brazil
e-mail: erika.msh@gmail.com, rhenry@ibb.unesp.br

Abstract: Aim: The aim of the present study was to examine the benthic fauna in a marginal pond lateral to the Paranapanema River and to identify the main controlling factors of its distribution. Considering the small size of the lacustrine ecosystem, we expected that seasonal variations of the benthic community attributes are more important than spatial variations; **Methods:** Two samplings, one in March and another in August, were carried out at nine sites in the pond. Sediment samples were obtained through a Van Veen grab for invertebrate sorting, granulometric analysis, and for quantification of organic matter in sediment. Other abiotic factors were measured, such as water transparency, dissolved oxygen, pH, electric conductivity, temperature, and depth of sediment sampling sites. Regarding the comparative analysis at spatial scale, no significant variations in density of the benthic invertebrate community were found. **Results:** In relation to the studied abiotic factors, only depth presented significant differences among sampling sites; All the measured environmental parameters presented significant differences among sampling months, except depth and the physical and chemical characteristics of the sediment. The abundance of Chaoboridae and Chironomidae was the unique attribute with a significant difference in comparing the two months. A higher abundance of taxa occurred in August, especially for Oligochaeta, Nematoda, Chaoboridae, and Chironomidae; **Conclusions:** Because of the low structural complexity of the studied pond, we concluded that the changes in benthic macroinvertebrate community attributes were mainly due to seasonal effects.

Keywords: benthic fauna, environmental variables, marginal pond, spatial variation, temporal variation.

Resumo: Objetivo: O presente estudo tem por objetivo examinar a fauna bentônica em lagoa marginal ao rio Paranapanema e os principais fatores reguladores da sua distribuição. Devido ao pequeno tamanho do ambiente lacustre, procurou-se mostrar que as variações sazonais dos atributos da comunidade bentônica são mais importantes do que as variações espaciais; **Métodos:** Duas coletas, uma em março e outra em agosto foram realizadas, em nove locais na lagoa. Amostras de sedimento foram obtidas com um pegador de Van Veen, para análise dos invertebrados, da granulometria e da quantidade de matéria orgânica do sedimento. Outros fatores abióticos foram medidos, como a transparência, o oxigênio dissolvido, o pH, a condutividade elétrica, a temperatura da água e a profundidade do local de amostragem do sedimento; **Resultados:** Na análise comparativa no nível de escala espacial, não houve variações significativas na densidade da comunidade de invertebrados bentônicos. Com relação aos fatores abióticos estudados, apenas a profundidade apresentou diferença significativa entre os pontos de amostragem. Todos os parâmetros ambientais mensurados, exceto a profundidade e as características físico-químicas do sedimento, apresentaram diferença significativa entre os meses de estudo. A abundância dos táxons Chaoboridae e Chironomidae foi o único atributo a apresentar diferença significativa entre os meses. Chaoboridae foi dominante em março e Chironomidae mais abundante em agosto. Maior abundância de táxons ocorreu em agosto, com destaque para os grupos Oligochaeta, Nematoda, Chaoboridae e Chironomidae; **Conclusões:** Em função da baixa complexidade estrutural da lagoa estudada, concluiu-se que a comunidade de macroinvertebrados bentônicos é alterada mais expressivamente em razão da sazonalidade, sofrendo menos influência de modificações espaciais.

Palavras-chave: fauna bentônica, variáveis ambientais, lagoa marginal, variação espacial, variação temporal.

1. Introduction

Comparative studies of small water bodies have been used to examine the relationships between environmental factors and the structure of aquatic communities (Heino, 2000). Benthic macroinvertebrates present great importance in some ecological processes, such as energy fluxes and nutrient cycling (Leal et al., 2003; Henry and Santos, 2008). Bioturbation of sediment surface and fragmentation of leaves from riparian vegetation are some of the processes of nutrient release to water carried out by benthic organisms (Caliman et al., 2007; Callisto et al., 2009).

Considering the benthic macroinvertebrates, insects are the predominant taxonomic group in abundance and biomass in the majority of tropical lakes (França and Callisto, 2007). In all these environments, a predominance of Diptera, Chironomidae (Stenert et al., 2004; Roque et al., 2004), and Chaoboridae (Fukuhara et al., 1987) has been recorded.

According to Jonasson (1996), the distribution, composition, and diversity of macroinvertebrates, as well as of other aquatic communities, are affected by abiotic and biotic factors and also by mutual interactions among the organisms. Thus, benthic macroinvertebrate communities clearly indicate the ecological conditions of inhabited aquatic ecosystems. According to Kownacki et al. (2000), benthic fauna composition in aquatic environments depends mainly on factors such as substratum type, water trophic status, and hydro-period.

Oxygen and depth also constitute essential factors to macroinvertebrate distribution (Santos and Henry, 2001). Density of these organisms is remarkably lower at great depths, but the existence of some species tolerant to low oxygen concentrations is evidenced at these sites (Hirabayashi and Hayashi, 1994). Other important factors for benthic species distribution are the availability of food resources (Sanseverino et al., 1998) and the interspecific trophic interactions, such as competition and predation (Walker, 1998).

Habitat complexity can determine the composition of a local community. According to Barreto (1999), diversity of biological communities in more complex sites tends to increase due to the presence of environments with minor stress, ample availability of shelter against predators, and protection against physical disturbances, which serve to assist in survival, recovery, and persistence of the organisms. Therefore communities in habitats with low complexity usually present great temporal variation, as compared with the organisms in environments with high structural complexity, which can persist in these sites for a longer time. According to Formigo (1997), composition and density of macroinvertebrate communities are relatively stable from one year to the next in non-perturbed systems. However, seasonal fluctuations linked to the dynamics of vital cycles of each species can result in extreme variations in community structure in some environments.

In lakes marginal to tropical rivers, as those located in flood plains, aquatic biota is mainly influenced by the regime of flood pulses, as it was observed in the High Paraná River (Higuti and Takeda, 2002) and in the High Paranapanema River (Davanso and Henry, 2006).

The aim of the present study was to examine composition and diversity of benthic macroinvertebrates in different sites of a pond which is marginal to a river. Relationships between the different taxa of benthic macroinvertebrates and environmental factors were determined. Because it is a pond with small size, we expected seasonal variations in benthic community to be more important than spatial ones, due to the structural homogeneity of the environment.

2. Material and Methods

The environment selected for the study (Mian Pond, Figure 1) is located near the mouth zone of the Paranapanema into the Jurumirim Reservoir (São Paulo, Brazil). It is a small pond (perimeter: 1,592 m; mean depth: 3.7 m; length: 749 m; maximum width: 115 m). The Mian pond presents permanent connectivity to the river and one of the margins is formed by a riparian forest while the other is a non-preserved area next to a soybean field, being partially protected from the wind. Nine sites distributed in three transects were selected for the samplings (Figure 1).

In each site, three sediment samples were collected in March and August 2009 with a 0.064 m^2 Van Veen grab for the analysis of benthic fauna and an additional three samples for the determination of granulometric composition and quantification of organic matter in sediment. Depth profiles of the lake bottom at sampling site transects are shown in Figure 2.

In the field, sampled sediment for benthic fauna analysis was washed in 250 μm mesh net and fixed with 4% formaldehyde. Afterwards, the organisms were sorted, identified, and counted under a stereoscopic microscope. They were identified up

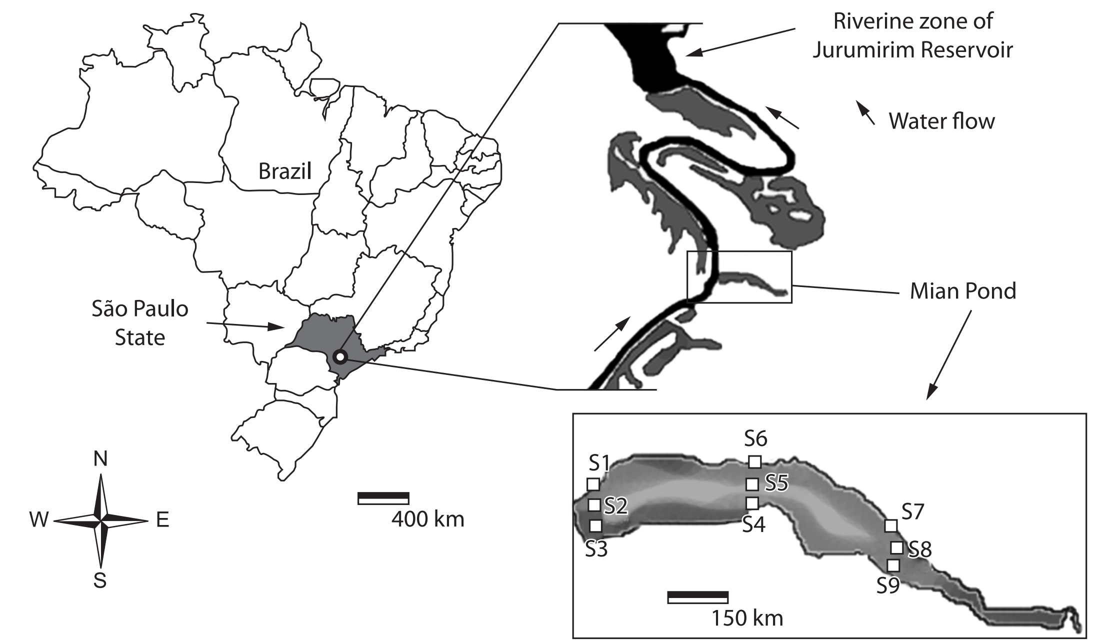

Figure 1. Mian Pond lateral to the Paranapanema River at the mouth zone into Jurumirim Reservoir, São Paulo, Brazil (S1 to S9 are the sampling sites; geographical coordinates of S2 site: 23° 29' 53" S and 48° 37' 19" W).

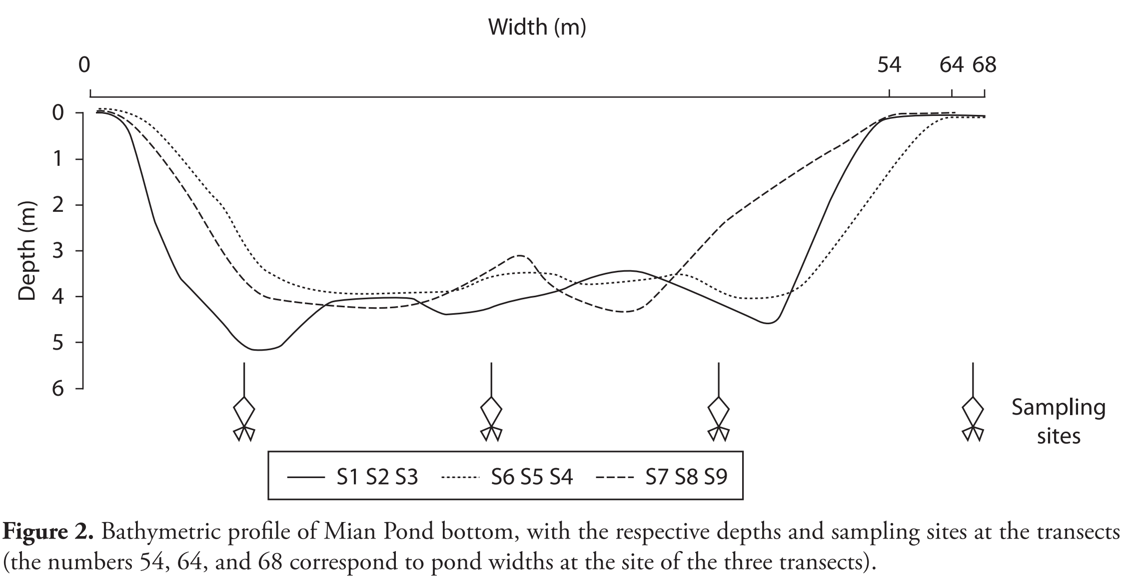

Figure 2. Bathymetric profile of Mian Pond bottom, with the respective depths and sampling sites at the transects (the numbers 54, 64, and 68 correspond to pond widths at the site of the three transects).

to the lowest taxonomic level using specialized literature (Trivinho-Strixino and Strixino 1995; Merrit and Cummins, 1996; Brinkhurst and Marchese, 1992; Mugnai et al., 2010). Density (individuals.m^{-2}) and relative abundance of benthic macroinvertebrates were computed.

The following water physical and chemical variables were determined: temperature (by mercury thermometer), transparency (by Secchi disk), dissolved oxygen (through the Winkler method, modified by azyde addition, Golterman and Clymo, 1969), electrical conductivity (through a Hach Mod. 2511 conductivimeter) and pH (through a Micronal Mod. 322 pHmeter). All of them, except the transparency, were measured at the surface and 10 cm of the bottom. Sediment granulometric composition was determined according to the Wentworth scale (Suguio, 1973) and organic matter content, through calcination loss (in a furnace at 550 °C for 1 hour).

After observation of parametric distribution, descriptive statistics (mean) were computed for the measured environmental variables and for the benthic groups (Chaoboridae, Chironomidae, Nematoda and Oligochaeta) that presented great total abundance of organisms (>4%). Next, data were log (x + 1) transformed and submitted to a two way variance analysis (ANOVA) involving sampling sites (n = 9) and periods (n = 2). Normality and variance homogeneity were obtained. A 0.1 level was used for testing the significance of ANOVA.

Pearson correlations were computed to assess significant relationships (p > 0.03) between abundance of benthic taxa and environmental data (water temperature, depth, transparency, pH, dissolved oxygen and electrical conductivity, and sediment organic matter and granulometric composition).

All the statistical analyses were carried out using the Statistica 6.0 software (Statsoft, 2002).

3. Results

A small variation in rainfall (<3 mm) was observed, between the two sampling months (Figure 3). Considering that in July there was a high level of rainfall, atypical for the dry season, no significant difference in depth was found in comparing the two studied periods (Figure 4).

In almost all the sites, silt/clay was dominant in the sediment, followed by very fine and fine sands

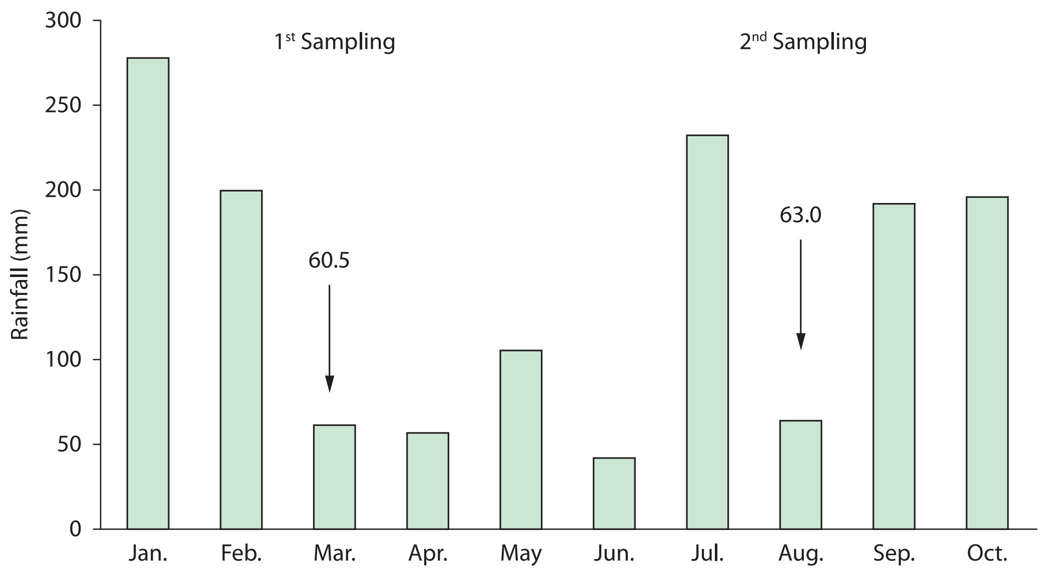

Figure 3. Monthly rainfall from January to October 2009 in Angatuba municipality, São Paulo.

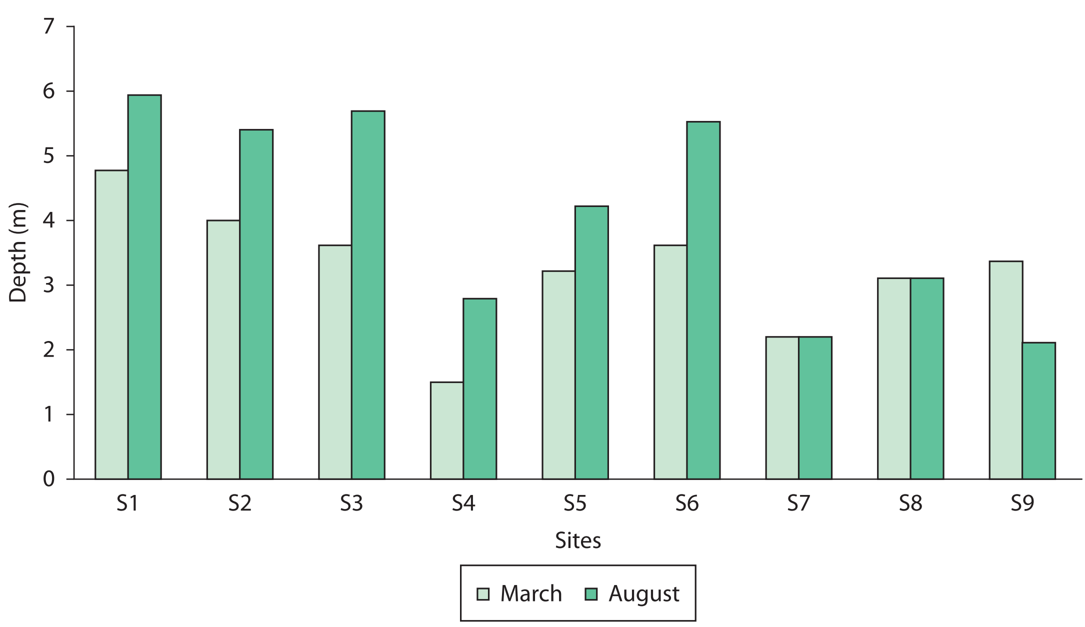

Figure 4. Depth values at the nine sampling sites of Mian Pond in March and August 2009.

(Figure 5). Higher values of silt/clay were observed in March. In site 4, sediment was composed of different fractions at the same levels as in March and August (Figure 5). In site 9, it was observed the greatest change in sediment composition from March to August. No variation pattern, regarding organic matter content in the sediment, was evidenced between sites when comparing the sampling months (Figure 6). The highest value (21.46%) was recorded in March at site 3, followed by site 5 (19.76%) in August, and the lowest value (1.99%) was found at site 9 in August.

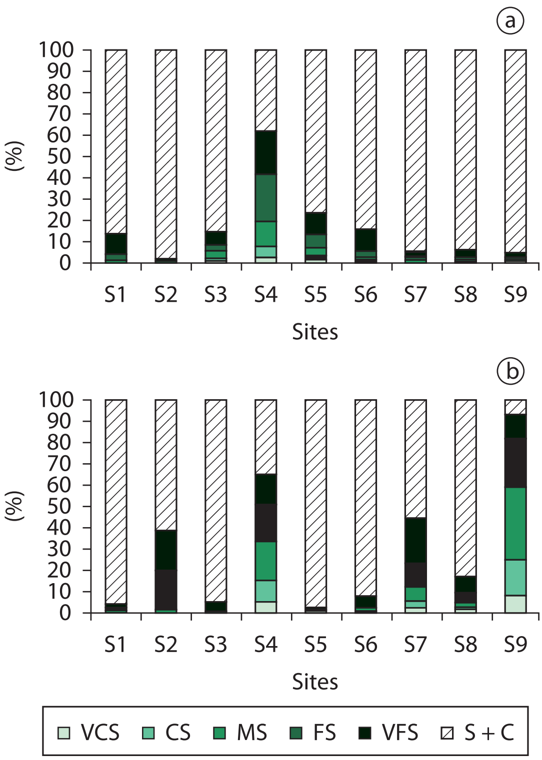

Figure 5. Mean (n = 3) sediment granulometric composition in sampled sites (S1 to S9) in March (a) and August (b) (VCS: very coarse sand; CS: coarse sand; MS: mean sand; FS: fine sand; VFS: very fine sand; S + C: silt and clay).

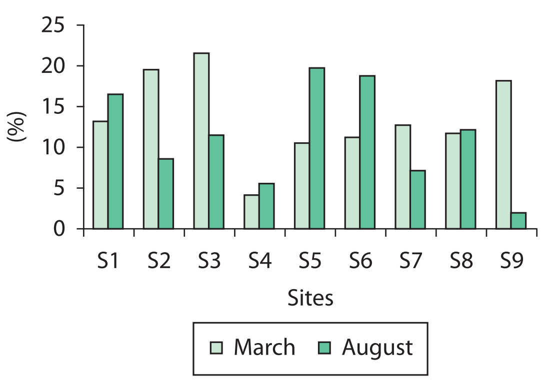

Figure 6. Mean (n = 3) organic matter content in the sediment in sampled sites and months.

The variation in density of taxonomic groups is shown in Figure 7. Groups with the highest density were Chaoboridae, Oligochaeta, Nematoda, and Chironomidae. Chaoboridae (exclusively composed of *Chaoborus* sp.) was the predominant group (relative abundance corresponding to 44% of total abundance) in relation to the other organisms. Chaoboridae constituted more than 50% of the organisms in four sites (sites 1 and 6, in both months and sites 3 and 7, only in March) and was absent only at site 9 in August. The maximum density (344 individuals.m^{-2}) was observed at site 4 in March. Oligochaeta predominated in three sites (site 2 in March and sites 8 and 9 in August). The highest densities were recorded in August (maximum of 240 individuals.m^{-2}) and rose to around 21% of all the organisms in the entire study. Nematoda occurred in almost all the sampled sites and presented the highest relative abundance (50% of the total density of organisms) at site 9 in March. The highest density (286 individuals.m^{-2}) occurred at site 2 in August. Considering both months, Nematoda density corresponded to approximately 17% of the organisms.

Chironomidae was a group with low abundance (≈2%) in the first month of the study and appeared only in two sampling sites. However, in August, Chironomidae specimens were observed in almost all the sites (except in site 9) and the highest density (260 individuals.m^{-2}) was recorded in site 3.

Only depth presented a significant difference among sampling sites ($F = 3.30$; $p = 0.04$). Comparing the two periods of the year, ANOVA showed a significant difference for water temperature (highest value in March), water electrical conductivity at surface and bottom (highest values in August), water pH at surface and bottom (highest values in August), dissolved oxygen in water at bottom (highest concentration in August), and water transparency (highest value in March) (Figure 8). Regarding the abundance of benthic macroinvertebrates, significant differences were recorded for Chaoboridae (highest value in March) and Chironomidae (highest value in August).

Significant Pearson correlations between biological and environmental variables are presented in Table 1. Chaoboridae density showed positive correlation with water temperature and silt/clay (the finest fraction of sediment) and negative correlation with larger particles in sediment (very coarse,

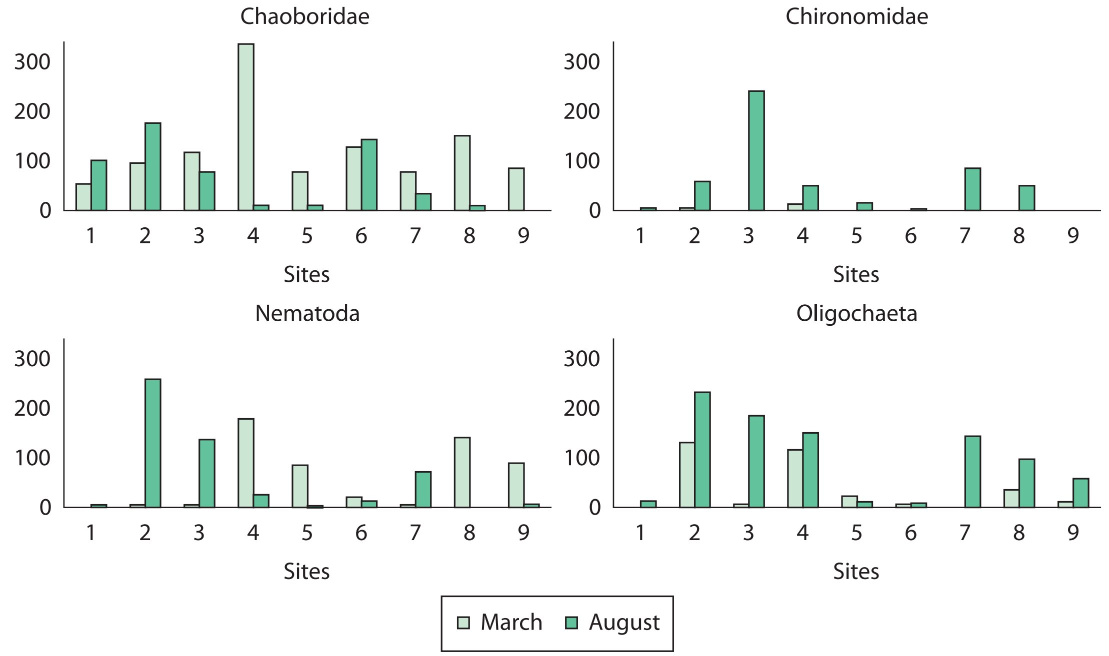

Figure 7. Variations in density (ind.m^{-2}) of benthic macroinvertebrates in the Mian Pond.

Table 1. Significant Pearson correlations ($p < 0.03$) between biological and water abiotic and sediment variables (Temp: temperature; Con/B: electrical conductivity at bottom; pH/B: pH at bottom; O_2/B: oxygen at bottom; Tr: transparency; VCS: very coarse sand; CS: coarse sand; MS: mean sand; S+C: silt and clay).

	Temp	Con/B	pH/B	O_2/B	Tr	VCS	CS	MS	S + C
Chaoboridae	0.51					–0.56	–0.58	–0.55	0.65
Chironomidae	–0.51	0.6	0.74	0.57	–0.51				

coarse, and mean sand). Chironomidae density was associated negatively with water temperature and transparency and positively with water electrical conductivity, pH (of both the depths), and dissolved oxygen at bottom.

4. Discussion

In this study, low rainfall variation was observed in the two sampling months, selected to be representative of the rainy and dry seasons. This observation can characterize an "atypical" year, considering that the precipitation in August was different from the previous occurrence in the region (Martins and Henry, 2004; Henry, 2003, 2005; Davanso and Henry, 2006, 2007). This certainly affected the environmental variables of the aquatic ecosystem, except water temperature.

Despite effects of precipitation regime on benthic fauna were slightly detectable, significant seasonal alterations in community structure were observed, mainly due to variation in temperature, dissolved oxygen and sediment composition between the seasons. Alterations in benthic fauna were not detected on a spatial scale, since depth was the only factor, considering all chemical and physical variables, with significant difference among sampling sites. Nevertheless, it was not likely to cause significant differences in ecological attributes of the community in these local. These observations evidenced great influence of seasonality on organization of the macroinvertebrate community.

In relation to benthic macroinvertebrates recorded in lakes of the same study region (Davanso and Henry, 2006, 2007), Mian Pond was the only that didn't show significance difference in spatial distribution of the fauna. This finding can be explained by the reduced size, simple shape (no dendritic), and its relatively homogeneous sediment composition, morphological characteristics which offer low habitat complexity for the colonization and permanence of new species. Therefore, the simple structure of the pond must be considered an important factor in the homogeneity of spatial composition registered in the water body, resulting in few local alterations in abiotic factors and, consequently, in benthic community.

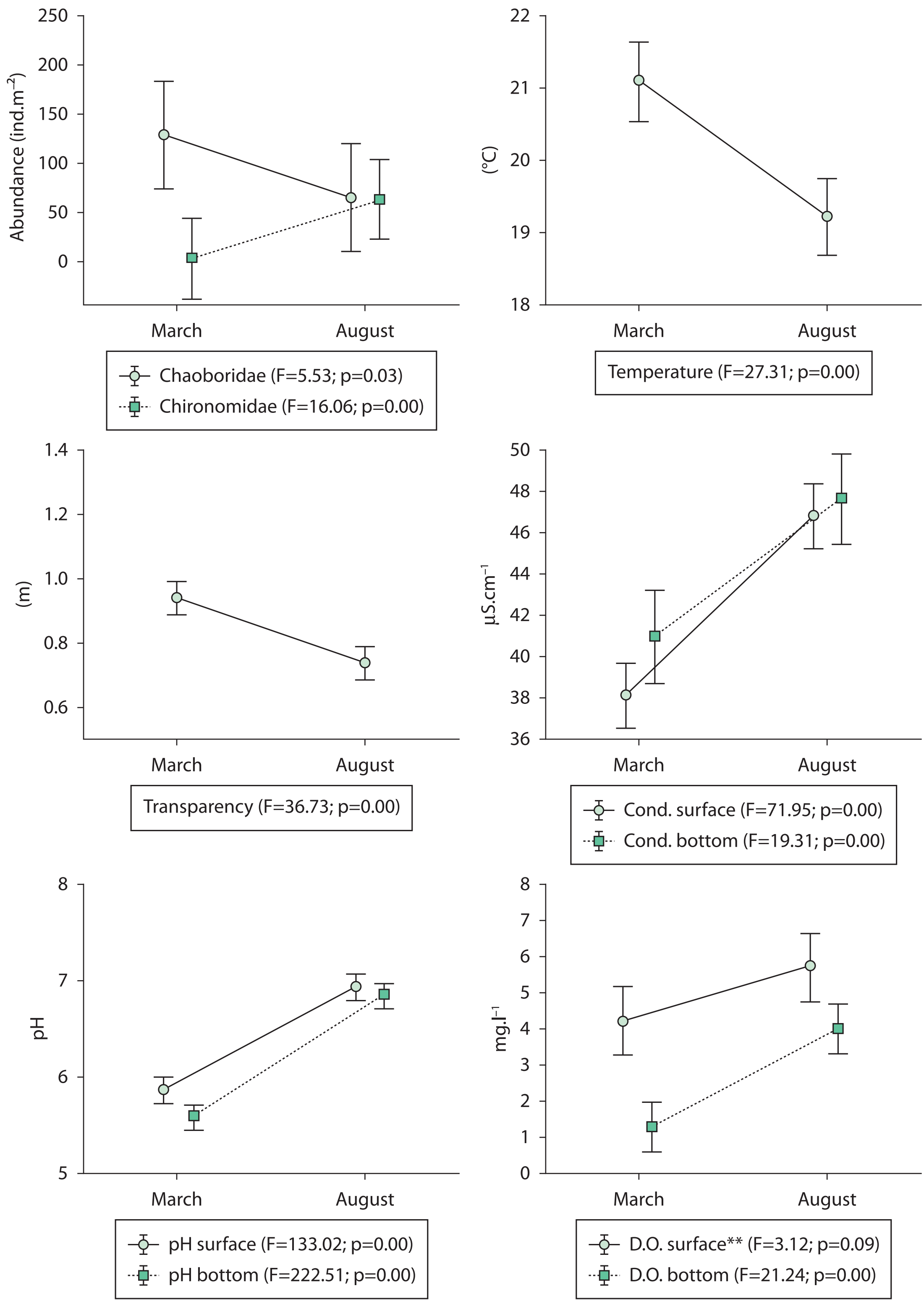

Figure 8. Mean (± standard error) values of environmental variables and Chironomidae and Chaoboridae abundance in March and August in the Mian Pond(**significance level: 0.1).

In addition to the morphometric characteristics of the pond, another aspect that contributed to the high homogeneity of the environment, especially in sediment composition, is the absence of macrophytes. According to Corbi and Trivinho-Strixino, (2002), and Beckett et al. (1992), the highest densities of benthic macroinvertebrates are recorded in environments rich in macrophytes.

Macrophytes can increase the structural complexity of the environment, as the patches produces high amount of organic matter in sediment that lies just below them and in their surrounding area. Through this, some spatial differences may be produced in benthic composition since the patches are unequally distributed along the ponds.

Low values of dissolved oxygen in the pond bottom were found in both sampling months, especially in March (in all the sampling sites <3 $mg.L^{-1}$). According to Hepp (2002), values <4 $mg.L^{-1}$ are enough to cause the mortality of many invertebrates not adapted to hypoxic conditions near sediment. The variation in pond depth appears not to directly influence the observed alterations in oxygen concentration, since the Mian Pond is a shallow environment. Differences in oxygen among sites were insignificant and appear to be unimportant for spatial distribution of the organisms. Oxygen concentrations at the bottom were lower in the first month sampled. This fact can be explained by the high amount of allochthonous matter introduced in the pond due to the high level of water flux and discharge of the Paranapanema River in January and February 2009. Organic matter deposition at the pond bottom increased biological processes, especially decomposition, producing high oxygen consumption. Then oxygen was probably the determining factor for the lower values of benthic fauna density in March (except for Choboridae).

Chaoboridae, Oligochaeta, Nematoda and Chironomidae were predominant in benthic fauna. According to Pamplin et al. (2006) and Higuti and Takeda (2002), the Diptera order, including the Chaoboridae and Chironomidae families, and the Oligochaeta class, represent the most noticeable and relevant organisms of macroinvertebrate benthic assemblies.

Considering the two sampling periods, there were significant alterations in the densities of both groups, with the Chaoboridae being the most significant in total abundance in March and Chironomidae in August. These modifications in densities can be due to significant environmental variations among the months of the study, especially in the water temperature. This observation is evidence of the powerful influence of seasonality on the distribution of these organisms.

Strixino and Trivinho-Strixino (1980) observed that aquatic ecosystems presenting low mean depths (approximately 3 m) are able to maintain a high water temperature, thus enabling a proliferation and maintenance of Chaoboridae and Chironomidae during the entire year. However, in our study, Chironomidae showed a significant negative correlation with water temperature, similarly to that observed by Davanso and Henry (2006) in a pond near the Mian Pond. On the other hand, a significant association between Chaoboridae organisms and high temperature was recorded in the present study, a condition also verified by Cleto-Filho and Arcifa (2006) who found highest densities of Chaoborus in hot periods, in the Monte Alegre Lake.

According to Roque et al. (2004) and Brito Junior et al. (2005), Chironomidae larvae are the most representative and abundant group of the benthic macroinvertebrates due to their high capacity to adapt to different environmental conditions which many other groups cannot. Therefore, anoxic conditions in March may have caused the absence of these organisms, since Chironomidae densities present significant positive correlation with bottom oxygen concentrations. With the increase in oxygen concentration in August, these aquatic insects were recorded.

Low pH values in March, significantly different from those observed in August, were probably related to the intense degradation of organic matter, since low water acidity is derived from ions released during decomposition. This fact seems to cause some disadvantaged to some taxa in the month of March, such as Chironomidae, that showed positive correlation with water pH.

Transparency was a secondary factor responsible for seasonal variation in density of these two benthic groups as it depends on the rain intensity. The rainfall peak in July, one month before sampling, was the factor responsible for re-suspension of fine material from the bottom to the water column through the continuous mixing of water. Thus, significantly higher water transparency in March, when compared to August, seems to have negatively affected the fauna. Again, Chironomidae was most affected, which was negatively correlated to the variable. Leech and Johnsen (2009) concluded that changes in transparency of freshwaters may cause alteration in species depth distribution and affect predator-prey behavior, then, increases in transparency may benefits visual predators. Possibly in this study, high transparency facilitates the visualization of Chironomidae by predators, such as fishes.

Regarding the granulometric composition of pond sediment, silt/clay was dominant in almost all the sampled sites, followed by very fine and fine sand fractions. This characteristic is another factor that enhanced the great Chaoboridae development in Mian Pond, especially in March when fine fractions was higher, as densities presented positive correlations with silt and negative correlations with coarse sand fractions.

Considering the associations between benthic macroinvertebrate distribution in the aquatic environment and abiotic factors described previously, we concluded that reduced spatial variation of benthos occurred in the Mian Pond. Despite the fact that in 2009, no evident hydrologic variations were observed between rainy and dry seasons due to "atypical" rainfall in July, the seasonality effects on benthic fauna were more expressive than spatial ones, mainly because of this community response to some environmental factors, like water temperature, dissolved oxygen at deep zones, and characteristics of bottom sediment. Even though there was a wide variation in depth among the sampled sites, it was not able to change the structure of benthic community, reinforcing the idea that in environments with low structural complexity, physical and chemical factors of water and sediment are more homogeneous, having smaller effect on fauna.

Acknowledgements

We would like to thank Hamilton Rodrigues for helping in the field work, as well as to Dr. Gilmar Perbiche Neves for the support with statistical analysis. We are also grateful to Angatuba city hall for providing the rainfall data, to Laerte José da Silva for the English revision and to the anonymous reviewer for the comments and suggestions.

References

BARRETO, SS. 1999. Heterogeneidade especial do habitat e diversidade específica: Implicações ecológicas e métodos de mensuração. In SILVA, SHG. and LAVRADO, HP., eds. *Ecologia dos Ambientes Costeiros do Estado do Estado do Rio de Janeiro*. Rio de Janeiro: PPGE-UFRJ. vol. 7, p. 121-153. Série Oecologia Brasilliensis.

BECKETT, DC., AARTILA, TP. and MILLER, AC. 1992. Invertebrate abundance on *Potamogeton nodosus*, effects of plant surface area and condition. *Canadian Journal of Zoology*, vol. 70, no. 2, p. 300-306. http://dx.doi.org/10.1139/z92-045

BRINKHURST, RO. and MARCHESE, M. 1992. *Guia para la identificacion de Oligoquetos acuáticos continentales de Sud y Centroamerica*. 2th ed. Santo Tomé: Associación de Ciencias Naturales del Litoral. 207 p. Colección Climax, no. 6.

BRITO JUNIOR, L., ABILIO, FFP. and WATANABE, T. 2005. Aquatic insect of São José dos Cordeiros dam (Paraiban semi-arid) with emphasis in Chironomidae. *Entomología y Vectores*, vol. 12, no. 2, p. 149-157.

CALIMAN, A., LEAL, JJF., ESTEVES, FA., CARNEIRO, LS., BOZELLI, RL. and FARJALLA, VF. 2007. Functional bioturbator diversity enhances benthic-pelagic processes and properties in experimental microcosms. *Journal of the North American Benthological Society*, vol. 26, no. 3, p. 450-459. http://dx.doi.org/10.1899/06-050.1

CALLISTO, M., LEAL, JJF., FIGUEREDO-BARROS, MP., MORENO, P. and ESTEVES, FA. 2009. Effect of bioturbation by *Chironomus* on nutrient fluxes in an urban eutrophic reservoir. In *Proceedings of the VII International Symposium on Ecohydraulics*, 2009. Concepcion: Universidad de Concepcion. vol. 1, p. 76-86.

CORBI, J J. and TRIVINHO-STRIXINO, S. 2002. Spatial and bathymetric distribution of the macrobenthic fauna of the Ribeirão das Anhumas reservoir (Américo Brasiliense-SP, Brasil). *Acta Limnologica Brasiliensia*, vol. 14, no. 1, p. 35-42.

CLETO-FILHO, SEN. and ARCIFA, MZ. 2006. Horizontal distribution and temporal variation of the zoobenthos of a tropical Brazilian lake. *Acta Limnologica Brasiliensia*, vol. 18, no. 4, p. 407-421.

DAVANSO, RCS. and HENRY, R. 2006. A biodiversidade bentônica em lagoa marginal ao rio Paranapanema na zona de sua desembocadura, na represa de Jurumirim. *Acta Scientiarum. Biological Sciences*. Maringá, vol. 28, no. 4, p. 347-357.

DAVANSO, RCS. and HENRY, R. 2007. 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). *Acta Limnologica Brasiliensia*, vol. 19 no. 2, p. 131-142.

FORMIGO, N. 1997. A *bacia hidrográfica do rio Âncora*: caracterização ecológica e potencialidades bio-económicas para a prática da pesca desportiva. Porto: Faculdade de Ciências, Universidade do Porto. 500 p. [Tese de Doutorado].

FRANÇA, JS. and CALLISTO, M. 2007. Benthic macroinvertebrates collection : a tool for the knowledgement of freshwater biodiversity. *Neotropical Biology and Conservation*, vol. 2, no. 1, p. 3-10.

FUKUHARA, H., TORRES, GE. and CLARO, SM. 1987. The rainy season standing crop of zoobenthos in lakes Dom Helvécio and Jacaré. In SAIJO, Y. and TUNDIDI, J., eds. *Limnological Studies in Central Brazil.* Nagoya. 185 p.

GOLTERMAN, HL. and CLYMO, RS. 1969. *Methods for chemical analysis of freshwaters*. Oxford: Blackwell Scientific Publications. 180 p. IBP Handbook, no. 8.

HEINO, J. 2000. Lentic macroinvertebrate assemblage structure along gradients in spatial heterogeneity, habitat size and water chemistry. *Hydrobiologia*, vol. 418, no. 1, p. 229-242. http://dx.doi.org/10.1023/A:1003969217686

HENRY, R. 2003. Os ecótonos nas interfaces dos ecossistemas aquáticos: conceitos, tipos, processos e importância. Estudo de aplicação em lagoas marginais ao rio Paranapanema na zona de sua desembocadura na Represa de Jurumirim. In HENRY, R., org. *Ecótonos nas interfaces dos ecossistemas aquáticos*. São Carlos: Rima. p. 1-28.

HENRY, R. 2005. The conectivity of the Paranapanema River with two lateral lakes in its mouth zone into the Jurumirim Reservoir. *Acta Limnologica Brasiliensia*, vol. 17, no. 1, p. 57-69.

HENRY, R. and SANTOS, CM. 2008. Importance of excretion by *Chironomus* larvae to internal loads of nitrogen and phosphorus in a small eutrophic urban reservoir. *Brazilian Journal of Biology*, vol. 68, n. 2, p. 349-358. http://dx.doi.org/10.1590/S1519-69842008000200016

HEPP, LU. 2002. *Ocorrência e distribuição de macroinvertebrados bentônicos no Rio Suzana, Erechim, RS*. Erechim: Universidade Regional Integrada. 79 p. [Monografia de Especialização em Ciências Ambientais].

HIGUTI, J. and TAKEDA, AM. 2002. Spatial and temporal variation of Chironomid larval (Diptera) in two ponds and two tributaries of the upper Paraná river floodplain, Brazil. *Brazilian Journal of Biology*, vol. 62, no. 4, p. 807-818.

HIRABAYASHI, K. and HAYASHI, H. 1994. Horizontal distribution of benthic macroinvertebrates in Lake Kizaki, Tokyo. *Japanese Jounal of Limnology*, vol. 55, no. 2, p. 105-114. http://dx.doi.org/10.3739/rikusui.55.105

JONASSON, PM. 1996. Limits for life in the lake ecosystem. *Verhandlungen des Internationalen Verein Limnologie*, vol. 26, p. 1-33.

KOWNACKI, A., GALAS, J., DUMINICKA, E. and MIELEWCZYK, S. 2000. Invertebrate communities in permanent and temporary high mountain lakes (Tatra Mts). *Annales de Limnologie*, vol. 36, no. 3, p.181-188. http://dx.doi.org/10.1051/limn/2000016

LEAL, JJF., ENRICH-PRAST, A., ESTEVES, FA. and FARJALLA, VF. 2003. Effect of *Campsurus notatus* on NH4, DOC fluxes, O2 uptake and bacterioplankton production in experimental microcosms with sediment-water interface of an Amazonian lake impacted by bauxite tailings. *International Review of Hydrobiology*, vol. 88, no. 2, p. 167-178. http://dx.doi.org/10.1002/iroh.200390012

LEECH, DM. and JOHNSEN, S. 2009. Light, Biological Receptors. In LIKENS, GE., ed. *Encyclopedia of Inland Waters*. Oxford: Elsevier. vol. 2, p. 671-681.

MARTINS, GM. and HENRY, R. 2004. Composição e abundância do zooplâncton em três lagoas laterais ao rio Paranapanema na zona de sua desembocadura na represa de Jurumirim (São Paulo). In CHELLAPPA, NT., CHELLAPPA, S. and PASSAVANTE, JZO., eds. *Ecologia Aquática Tropical*. Natal. p. 53-72.

MERRIT, RW. and CUMMINS, KW. 1996. *An introduction to the aquatic insects of North America*. Dubuque: Kendall/Hunt. 862 p.

MUGNAI, R., NESSIMIAN, JL. and BAPTISTA, DF. 2010. *Manual de identificação de macroinvertebrados aquáticos do Estado do Rio de Janeiro*. Rio de Janeiro: Technical Books, 176 p.

PAMPLIN, PAZ., ALMEIDA, TCM. and ROCHA, O. 2006. Composition and distribuition of benthic macroinvertebrates in Americana Reservoir (SP, Brazil). *Acta Limnologica Brasiliensia*, vol. 18, no. 2, p. 121-132.

ROQUE, FO., CORREIA, LCS., TRIVINHO-STRIXINO, S. and STRIXINO, G. 2004. A review of Chironomidae studies in lentic systems in the State of São Paulo, Brazil. *Biota Neotropica*, vol. 4, no. 2, p. 1-19.

SANSEVERINO, AM., NESSIMIAN, JL. and OLIVEIRA, AHA. 1998. A fauna de Chironomidae (Diptera) em diferentes biótipos aquáticos na serra do Subaio (Teresópolis, RJ). In NESSIMIAN, JL. and CARVALHO, AL., eds. *Ecologia de insetos aquáticos*. Rio de Janeiro: PPGE-UFRJ. p. 253-263. Série Oecologia brasiliensis.

SANTOS, CM. and HENRY, R. 2001. Composição, distribuição e abundância de Chironomidae (Diptera, Insecta) na Represa de Jurumirim (rio Paranapanema, SP). *Acta Limnologica Brasiliensia*, vol. 13, n. 2, p. 99-115.

STATSOFT, Inc. 2002. Statistica (data analysis software system), version 6.0 www.statsoft.com

STENERT, C., SANTOS, EM. and MALTCHIK, L. 2004. Levantamento da diversidade de macroinvertebrados em áreas úmidas do Rio Grande do Sul (Brasil). *Acta Biologica Leopoldensia*, vol. 26, no. 2, p. 225-240.

STRIXINO, G. and TRIVINHO-STRIXINO, S. 1980. Macroinvertebrados do fundo da Represa do Lobo (Estado de São Paulo – Brasil). *Tropical Ecology,* São Carlos, vol. 21, no.1, p. 16-23.

SUGUIO, K. 1973. *Introdução a sedimentologia*. São Paulo: Edgard Blücher, 317p.

TRIVINHO-STRIXINO, S. and STRIXINO, G. 1995. *Larvas de Chironomidae (Diptera) do Estado de São Paulo:* guia de identificação e diagnose dos gêneros. São Carlos: PPGERN/ UFSCar. 229 p.

WALKER, I. 1998. Population dymanics of Chironomidae (Diptera) in the central Amazon blackwater river Tarumã-Mirim (Amazonas, Brazil). In NESSIMIAN, JL. and CARVALHO, AL., eds. *Ecologia de insetos aquáticos*. Rio de Janeiro: PPGE-UFRJ. Série Oecologia brasiliensis.

Received: 11 February 2011
Accepted: 09 December 2011