Benthic macroinvertebrate dynamics in a shallow floodplain lake in the South of Brazil.

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ABSTRACT: Benthic macroinvertebrate dynamics in a shallow floodplain lake in the South of Brazil. The objective of this study was to analyze the effects of the floods on the macroinvertebrate richness, density and composition in a shallow lake associated to a floodplain system over one year (from May 2001 to April 2002) in the South of Brazil. A total of 1,292 macroinvertebrates representing 25 morphotypes distributed in 20 families and one class (Oligochaeta) was obtained. The majority of the morphotypes was aquatic insects (76.2%). From the total of the organisms found, 53.6% belonged to Leptoceridae, which dominated over the period with floods, and 31.3% belonged to Oligochaeta, which dominated over the period without floods. The richness and density of macroinvertebrates varied during the studied year and they were greater in the period without floods than the period with floods. Floods of brief duration were enough to diminish the richness and density of macroinvertebrates. The macroinvertebrate richness, density and composition were not influenced by the water depth and temperature and lake area. These results showed that flood events, even of brief duration, influence the macroinvertebrate dynamics in river-floodplain systems of the Neotropical region.
Key-words: macroinvertebrates, river-floodplain system, flood pulse, Neotropical Region.

RESUMO: Dinâmica de macroinvertebrados bentônicos em uma lagoa rasa associada a uma planície de inundação no Sul do Brasil. O objetivo desse estudo foi analisar os efeitos das inundações na riqueza, densidade e composição de macroinvertebrados em uma lagoa rasa associada a uma planície de inundação ao longo de um ano (de maio de 2001 a abril de 2002) no Sul do Brasil. Um total de 1.292 macroinvertebrados representando 25 morfotipos distribuídos em 20 famílias e uma classe (Oligochaeta) foi coletado. A maioria dos morfotipos foi de insetos aquáticos (76,2%). Do total de organismos coletados, 53,6% foram representados pela família Leptoceridae, que dominou ao longo do período com inundações e 31,3% foram representados pela classe Oligochaeta, que dominou ao longo do período sem inundações. A riqueza e densidade de macroinvertebrados variaram ao longo do ano estudado e foram maiores no período sem inundações que no período com inundações. As inundações de breve duração foram suficientes para diminuir a riqueza e densidade de macroinvertebrados. A riqueza, densidade e composição de macroinvertebrados não foram influenciadas pela profundidade e temperatura da água e área da lagoa. Esses resultados demonstraram que eventos de inundação, inclusive as de breve duração, influenciam a dinâmica de macroinvertebrados em sistemas rio-planície de inundação da região Neotropical.
Palavras-chave: macroinvertebrado, sistema rio-planície de inundação, pulso de inundação, região Neotropical.

Introduction

Disturbance has received substantial attention by ecologists mainly because it is a major organizer in many aquatic ecosystems (Sousa, 1984; Grimm & Fisher,

1989). The concept of disturbance in aquatic ecosystems may be defined in terms of the physical event, e.g. intensity, frequency, duration and predictability (Lake, 1990; Poff, 1992) or in terms of the biotic response (White & Pickett, 1985). In this sense, the definition of perturbation proposed by Bender et al. (1984) and Glasby & Underwood (1996) is useful because it describes the combination of cause (disturbance) and effects (response).

The concept of disturbance in aquatic ecosystems is controversial (Benke et al., 1999). While in streams, the floods may be seen as catastrophic events (Resh et al., 1988), in lower courses of the rivers, the flood pulse is regarded as the major environmental parameter influencing the existence, productivity and interactions of biota (Junk, 1980; Junk et al., 1989; Van den Brink et al., 1994). During the flood events, the exchange of water, nutrients and aquatic organisms occur between the river channel and its associated floodplain lakes (Amoros & Roux, 1988; Chauvet & Décamps, 1989).

The floods provide a temporary habitat for aquatic organisms several times greater than the area of the river channel (Ross & Baker, 1983; Welcomme, 1985), included for the macroinvertebrate community (Castella et al., 1984; Junk et al., 1989; Van den Brink & Van der Velde, 1991; Bournaud et al., 1992). The community of macroinvertebrates plays an important role in the trophic dynamics of the lakes associated to floodplain systems, through nutrient cycling and providing food for higher trophic levels, like fishes and birds (Van den Brink et al., 1994). The composition of macroinvertebrate in floodplain systems is influenced by the duration, frequency, intensity of flooding and connectivity with the main river channel (Neckles et al., 1990; De Szalay et al., 1999).

The floodplains are important wetlands systems in the South of Brazil. However, studies that analyze the effects of a series of flood pulses on macroinvertebrate communities in shallow lakes associated with floodplain systems are still scarce (Stenert et al., 2003; Santos et al., 2003; Takeda et al., 2004). The objective of this study was to analyze the effects of the flood events on the macroinvertebrate richness, density and composition in a shallow lake associated to a floodplain system over one year (2001-2002) in the South of Brazil.

Study area

This study was conducted in a shallow lake associated to a floodplain system in the lower course of the Sinos River in the south of Brazil (Rio Grande do Sul - RS) (Fig. 1). The Sinos River is a seventh order permanent river (Strahler, 1952) of Jacuí/Guaiba catchment. It is 190 km long from its origin, at 900 m above sea level, to its confluence with Jacuí River at an elevation of 10 m. The annual precipitation in the Sinos River basin (~ 4.000 km^2) ranges from 1,200 to 2,000 mm and is well distributed along the year. The increase in the discharge due to high precipitation originates a series of flood events resulting in the temporary inundation of the floodplain.

The studied floodplain was approximately 30 ha, and presents several permanent and intermittent shallow lakes, scattered within two different types of vegetation: native woodland and grasslands. During the flood events, the water penetrates into the floodplain system along the different stream reaches. The surface water velocity in the floodplain systems during the flood period is very low. The discharge of Sinos River near the studied floodplain varies between 2.9 and 71 m^3/s (COMITESINOS, 2000).

The studied lake is permanent, irregular and it is fed by water from precipitation, runoff and flood events from the Sinos River. It has an inundation area of approximately 4,141 m^2 and is approximately 300 m from the main channel of the Sinos River. The mean water depth is 22 cm and the maximum water depth is 64.8 cm. During the flooding events, the water depth may reach approximately 200 cm in the studied

floodplain system. The substratum of the studied lake consists of silt and organic debris. The permanent presence of surface water in the studied shallow lake contributes to the development of aquatic macrophytes, represented mainly by the species Ludwigia peploides, Myriophyllum aquaticum and Polygonum hidropiperoides.

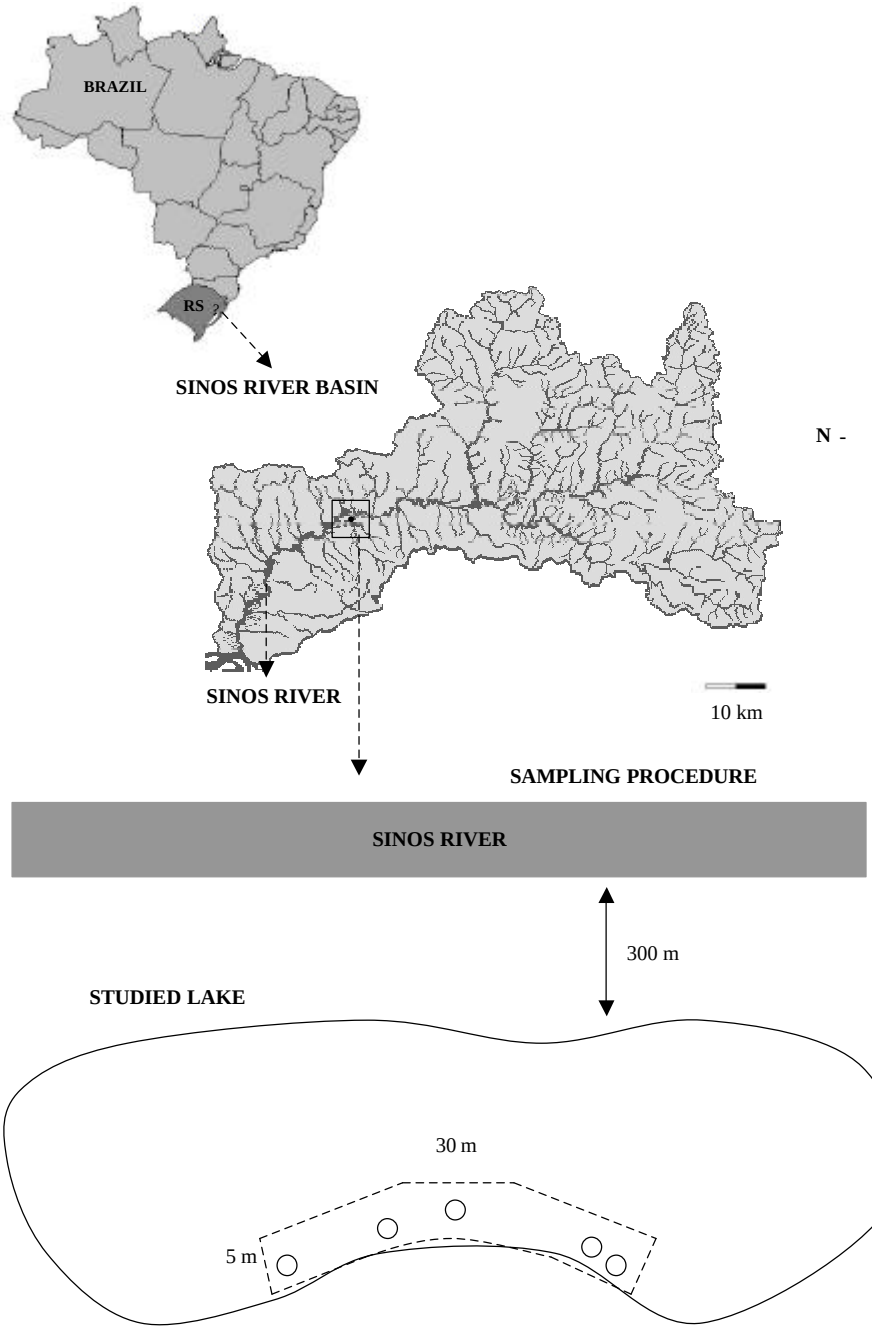

Figure 1: Position of studied floodplain system in the Sinos River basin (Rio Grande do Sul, Brazil) showing the sampling procedure.

Material and methods

Sixteen macroinvertebrate collections were carried out during one year (from May 2001 to April 2002) in a shallow lake, distributed in two hydrological periods: nine collections during the period with floods (from May 17 to October 18) and seven collections during the period without floods (from October 25 to April 12). In each collection, five macroinvertebrates samples were collected at random along a transect (30 m length per 5 m width) located in one of the lake's margins (Fig. 1). The samples were collected using a corer (7.5 cm diameter) inserted 10 cm into the substratum, preserved in 10 % formaldehyde and taken to the laboratory, where they were elutriated through 0.42 mm mesh to remove mud and vegetal remains. The used mesh size was small enough to retain most macroinvertebrates (Resh & McElravy, 1993; Batzer et al., 2001; Rosenberg et al., 1997). For the sorting and classification of the macroinvertebrates specimens in the laboratory was used 40X magnification through a stereomicroscope, and after, the organisms were kept in small tubes with 70 % alcohol. Water temperature was measured in situ using digital equipment (Water test – model 90). The water depth was measured with a PVC tube graduated in centimeters. The wetland area was measured with a tape measure of 50 m.

The duration of flooding was measured in days and classified as long (between 7-30 days) and brief duration (2 to 7 days) (Tiner, 1999). Following Tiner's classification (Tiner, 1999), the flood events in the Sinos basin are frequent (more than fifty floods along 100 years). The macroinvertebrates were classified in family taxonomic level, excepting Oligochaeta that remained in the class taxonomic level. The families that presented organisms morphologically distinguishable were divided in distinct morphotypes (e.g., Chironomidae 1, Chironomidae 2). Each taxon (family or class) was represented by one or more morphotypes. The macroinvertebrate families were classified according to Merritt & Cummins (1996), Lopretto & Tell (1995), Usinger (1963) and Fernández & Domínguez (2001). The mean richness and density per collection were the average number of morphotypes and individuals per m^2 observed in the samples (n=5, mean ± standard error), respectively.

To examine resistance to floods, we compared displacements of macroinvertebrate richness and density before and after floods. Resistance of macroinvertebrate community was estimated for each sequence by comparing mean richness and density before and after each flood using a t test. If these differences were not significant ($P>0.1$) we considered the macroinvertebrate community resistant to floods (Grimm & Fisher, 1989). The variation of the richness and density of macroinvertebrates over the studied period and between the periods with and without floods were quantified through analyses of variance (Repeated Measures ANOVA and One-Way ANOVA, respectively). A multiple regression (General Linear Model – GLM) was used, with stepwise selection, to determine any relationships between macroinvertebrate richness and density with the environmental variables (area, water depth and temperature). To remove the heteroscedasticity, we log transformed the environmental and biological data.

Ordination was performed using PC-ORD Version 4.2 (McCune & Mefford, 1999). A multivariate analytical approach (canonical correspondence analysis - CCA) was used to examine the relationships between the measured environmental variables and the macroinvertebrate composition and abundance. The environmental variables used in CCA ordination were: lake area, water depth and temperature, and flood duration. The biological variables were the morphotypes represented by 10 or more individuals founded over the studied period. Statistical significance of the contribution of each variable to each CCA axis was tested using Monte-Carlo simulation (1,000 iterations) (Ter Braak & Smilauer, 1998).

Results

During the studied period, four floods of different duration occurred. One flood was characterized as long duration (14 days), and three were characterized as brief duration (three to five days) (Tab. I). All four floods inundated all the floodplain

Table I: Physical characteristics and occurrence and duration of flood events in the studied shallow lake in the South of Brazil (Rio Grande do Sul) over one year (2001-2002).

	Period with floods												Period without floods						
	May 17	May 31	June 14	June 25*	June 28	July 12*	July 19	Aug. 3	Aug. 24	Sept. 25*	Sept. 28	Sept. 30*	Oct. 18	Oct. 25	Nov. 16	Dec. 13	Jan. 15	Feb. 28	Mar. 22	Apr. 12
Days after flood	-	-	-		3		7	22	43		3		18	25	47	74	107	151	173	184
Flood duration (d)				3		5				3		14								
Water temperature (°C)	16.9	24.6	22.5		14.8		18.2	22.6	16		21		22	25.4	22	34	26	29	26	25
Water depth (cm)	12	21.66	28.33	180	43.2	180	64.8	25	11.83	180	43.33	180	22.66	21.66	17.5	18	4.66	3.33	3.33	26.25
Area (m^2)	3,901	3,901	3,901		6,800		7,000	6,000	5,500		6,800		7,000	3,000	3,000	3,000	1,000	500	500	4,000

* flood events

Discussion

In floodplain systems, the macroinvertebrate community is predominantly represented by aquatic insects, mainly by the Odonata, Ephemeroptera, Hemiptera, Coleoptera, Diptera and Trichoptera (Davis & Christidis, 1997; De Szalay & Resh, 1996). In the studied lake, the aquatic insects group was the most representative,

Table II: Number of individuals per morphotype in the studied shallow lake in the South of Brazil (Rio Grande do Sul) over one year (2001-2002).

	Period with floods									Period without floods							
	May 17	May 31	June 14	June 28	July 19	Aug. 03	Aug. 24	Sep. 28	Oct. 18	Oct. 25	Nov. 16	Dec. 03	Jan. 15	Feb. 28	Mar. 22	Apr. 12	Total
Leptoceridae*	29	25	52	6	12	26	39	66	127	51	47	17	53	50	54	38	692
Oligochaeta	18	0	46	10	5	0	0	0	0	59	89	49	7	38	15	68	404
Sphaeriidae	1	0	28	0	0	0	0	0	0	0	0	0	0	1	1	3	34
Glossiphoniidae 1	3	0	3	1	0	0	0	0	0	8	11	2	1	1	1	2	33
Glossiphoniidae 2	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	3
Chironomidae 1*	2	0	10	1	0	0	0	0	1	0	0	0	0	0	1	9	24
Chironomidae 2*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Ceratopogonidae*	0	0	6	0	0	0	0	0	0	0	1	0	0	8	2	1	18
Chaoboridae*	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Dolichopodidae*	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	3
Dytiscidae*	0	0	0	0	0	0	0	0	0	0	0	6	1	0	1	2	10
Hydrophilidae 1*	3	1	8	1	1	0	0	0	0	4	1	1	7	2	5	0	34
Hydrophilidae 2*	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Noteridae*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Caenidae*	2	0	2	0	0	1	0	0	0	0	1	0	0	0	1	1	8
Baetidae*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2
Corixidae*	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	5
Planorbidae 1	2	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	4
Planorbidae 2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Libellulidae*	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	4
Coenagrionidae*	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3
Lestidae*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Aeshnidae*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Hydroptilidae*	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Ampullaridae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Total	63	26	160	19	18	29	39	66	129	127	151	75	73	107	83	127	1292

with 66.7 % of the total of morphotypes observed.

The duration of the floods is an important attribute when evaluating the patterns of community responses to flood disturbance (Romme et al., 1998). Van den Brink et al. (1994) found a negative relationship between duration of flood and the variation of the macroinvertebrate density in lakes associated with floodplain systems. In this

Table III: Canonical Correspondence Analysis: summary of results for the first three ordination axes.

	CCA axis		
	1	2	3
CCA: data set (16 collections)			
Eigenvalue	0.133	0.040	0.016
Cumulative % variance of taxa data	21.8	28.4	30.9
Taxa-environmental correlations (Pearson)	0.670	0.649	0.533
Monte Carlo test (p)	0.521	0.209	0.265

study, the relationships between duration of flood and variation of the richness and density of macroinvertebrates were not analyzed due to the low number of events over the studied period. However, it is imports to highlight, that the floods of brief

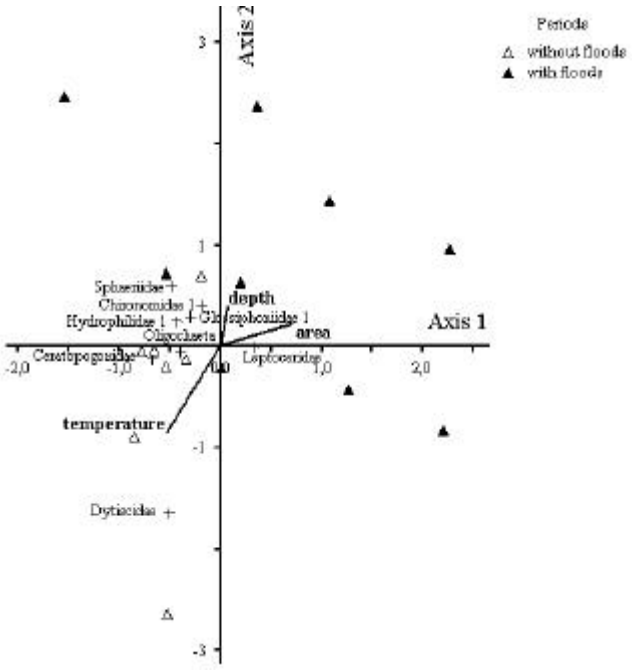

Figure 2: CCA ordination biplot with macroinvertebrate composition (+), collections (") and environmental variables.

duration were enough to diminish the macroinvertebrate richness and density. The increase in the macroinvertebrate density after the flood of long duration may be consequence of the input of organisms from the river channel during the floods. Williams (1997) regarded that the water movement between floodplain systems and the river channel during the flooding period facilitate the exchange of macroinvertebrates between both systems. This result corroborates previous researches carried out in the studied floodplain system (Stenert et al., 2003; Santos

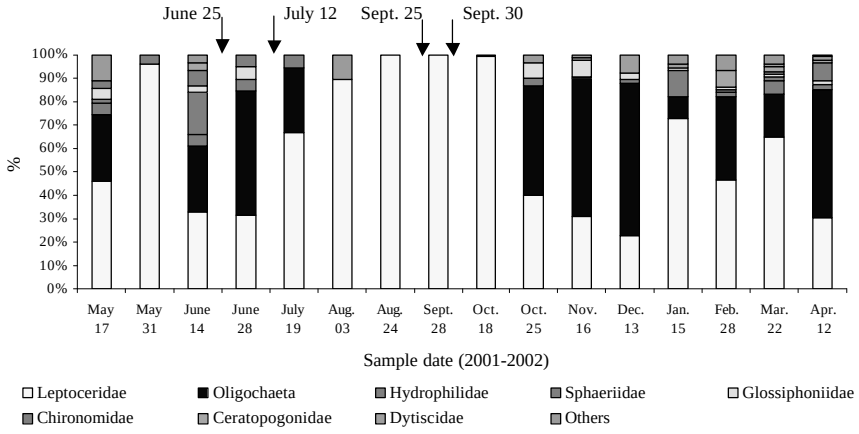

Figure 3: Composition of macroinvertebrate community (morphotypes) in the studied shallow lake in the South of Brazil (Rio Grande do Sul) over one year (2001-2002). Arrow = flood occurrence.

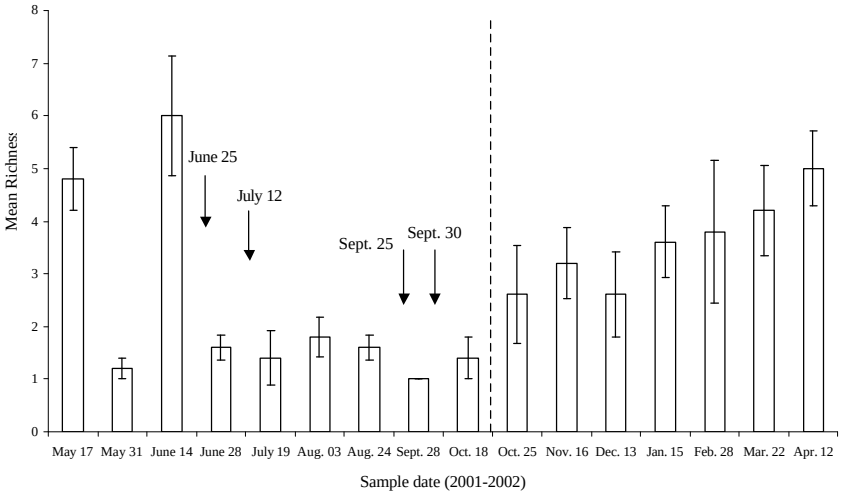

Figure 4: Richness of macroinvertebrate community (n = 5; mean ± standard error) in the studied shallow lake in the South of Brazil (Rio Grande do Sul) over one year (2001-2002). Arrow = flood occurrence.

Table IV: Resistance (as percent change in richness and density) of macroinvertebrate community in the studied shallow lake in the South of Brazil (Rio Grande do Sul) over one year (2001-2002).

Date	Flood duration (days)	Richness change (%)	Density change (%)
June 25	3	-73.33 (p=0.005)	-88.88 (p=0.09)
July 12	5	-12.5 (p=0.38)	+5.2 (p=0.44)
September 25	3	-37.5 (p=0.035)	+57.14 (p=0.23)
September 30	14	+40.0 (p=0.18)	+ 95.45 (p=0.07)

et al., 2003).

The flood frequency is another important attribute of floods that influence the community stability. Continuous floods may reduce invertebrates density overall in seasonal wetland systems (Boulton & Jenkins, 1998). In this study, the floods were concentrated on the first half of the studied period. In spite of some isolated floods did not influence the richness and density of macroinvertebrate, those attributes were lower during the period with floods. Vogl (1980) regarded that continuous perturbations may have more impact than isolated events. This result showed the importance of the frequency of the floods in the macroinvertebrate dynamics.

The composition of macroinvertebrate communities in floodplain wetlands is influenced by the regime of flooding (Boulton & Jenkins, 1998). Santos et al. (2003) and Stenert et al. (2003) regarded that the floods did not impede the establishment of dominant macroinvertebrate taxa. Over the studied period, Oligochaeta and Leptoceridae were dominant in 75% of the collections in the studied shallow lake. This high dominance contrast with previously studies developed in the same floodplain system, where Chironomidae was dominant (Stenert et al., 2003).

Menge & Sutherland (1987) assumed that the abiotic process become more important than the biotic process (competition and predation) in the dynamics of the communities in disturbed aquatic systems. In this study, the flood events influenced the macroinvertebrate community. The macroinvertebrate richness and density were lower in the period with floods than the period without floods, with no variation of those community parameters during the period without floods. However, biotic characteristics of the macroinvertebrate community not addressed in this paper as e.g., colonization, dispersal, predation and reproduction, may also have influenced

the macroinvertebrate richness and density. These results showed that flood events, even of brief duration, influence the macroinvertebrate dynamics in river-floodplain systems of the Neotropical region.

Acknowledgements

This research was supported by funds from UNISINOS (02.00.023/00-0) and CNPq (52370695.2). Dr. Leonardo Maltchik holds Brazilian Research Council – CNPq Research Productivity grant (302536/2004-3).

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