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Species richness of testate amoebae in different environments from the upper Paraná river floodplain (PR/MS)

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ABSTRACT. This study evaluated the species richness of testate amoebae in the plankton from different environments of the upper Paraná river floodplain. Samplings were performed at subsurface of pelagic region from twelve environments using motorized pump and plankton net (68 μm), during four hydrological periods. We identified 67 taxa, distributed in seven families and Arcellidae, Difflugiidae and Centropyxidae were the most representative families. Higher values of species richness were observed in the lakes (connected and isolated) during the flood pulses. *Centropyxis aculeata, Difflugia gramem* and *D. pseudogramem* were frequent throughout the study period. Seasonal variability of species in the channels and isolated lakes was evidenced by beta diversity. Besides that, in the rivers, extreme changes in species composition were verified during the high-water period. Our results highlight the importance of the present study to improve the knowledge about the diversity and geographic distribution of these organisms in Brazil and emphasize the importance of current flow in the displacement of testate amoebae from their preferred habitats, marginal vegetation and sediment.

Keywords: protozoa, plankton, diversity, species composition.

RESUMO. Riqueza de amebas testáceas em diferentes ambientes da planície de inundação do alto rio Paraná (PR/MS). Este estudo objetivou avaliar a riqueza de táxons de amebas testáceas no plâncton de diferentes ambientes da planície de inundação do alto rio Paraná. Foram amostrados 12 pontos da região pelágica em diferentes ambientes (rios, canais e lagoas) e em quatro períodos hidrológicos. Foram identificados 67 táxons, distribuídos em sete famílias. Arcellidae, Difflugiidae e Centropyxidae foram as famílias mais especiosas. Nas lagoas (abertas e fechadas), durante os pulsos de inundação, foram observados os maiores valores para a riqueza de espécies. *Centropyxis aculeata, Difflugia gramem* e *D. pseudogramem* foram frequentes durante todo o período estudado. Os dados obtidos pela diversidade beta evidenciaram a variabilidade sazonal das espécies nos canais e lagoas fechadas. Nos rios, as alterações ocorreram com maior intensidade no período de cheia. Os resultados ressaltam a importância desse estudo para o acréscimo do conhecimento sobre a diversidade e distribuição geográfica desses organismos no Brasil e ratifica a importância do fluxo de corrente no carreamento de amebas testáceas de seus hábitats preferenciais, vegetação marginal e sedimento.

Palavras-chave: protozoa, plâncton, diversidade, composição.

Introduction

The ecology of testate amoebae has been intensely focused in Brazil, from the 90's decade in different aquatic environments, as rivers, reservoirs and lakes (DABÉS, 1995; VELHO et al., 1996, 2003, 2004; LANSAC-TÔHA et al., 2004, 2008, 2009; FULONE et al., 2005; ALVES et al., 2008, among others). Despite this advance, the researches about the fauna of testate amoebae in Brazil are still scarce to furnish a genuine idea of species richness in the country, considering that these studies are limited to few areas, basically restricted to South, Southeast and Center-West regions (LANSAC-TÔHA et al., 2007).

Most of testate amoebae species (about 80% of the species) inhabit aquatic environments associated to marginal vegetation and sediment (BONNET, 1974). Currently, these organisms have been frequently recorded in samples of plankton from rivers and lakes, with high abundance (ARNDT, 1993; GREEN, 1975, 1994; VELHO et al., 1996, 2003; LANSAC-TÔHA et al., 2004, 2009).

Lansac-Tôha et al. (2007) indicated that planktonic compartment contains the highest species richness of these organisms (282 infrageneric taxa), followed by aquatic macrophytes (80 taxa) and sediment (72 taxa). This significant representativeness of testate amoebae in plankton may be related to the presence of gas vacuoles for floating (STEPANÉK; JIRÍ, 1958), and shells with low density (SCHÖNBORN, 1962), which according to Velho et al. (1999), may permit the access of these organisms to planktonic compartment.

Besides these aspects, the great species richness of testate amoebae in plankton may be associated to the fact that the water column may function as a collector of information about the fauna present in the whole system, not only from the plankton but also from littoral region, attached to the vegetation and sediment, as stated by Lansac-Tôha et al. (2007). Furthermore, most of those environments with high species richness in plankton are shallow and/or with great development of littoral vegetation, intensifying the fauna exchange among the different compartments.

Other important factor influencing the high species richness of testate amoebae in the plankton from Brazilian aquatic environments is that these environments have been the most studied, from marginal lakes and small channels and tributaries, until large rivers, as Paraná River (VELHO et al., 1999, 2003; LANSAC-TÔHA et al., 2004).

The upper Paraná river floodplain is formed by a great number of aquatic environments, such as secondary channels, backwaters, tributaries with semi-lotic traits, temporary and permanent lakes. These last environments are essential for the floodplain functioning since they maintain a water layer even during low water periods, composing shelter for several aquatic species. These environments present a considerable variability in relation to limnological characteristics, which is associated to connectivity (or isolation) degree with the rivers, depth and mostly the hydrological regime of Paraná river (THOMAZ et al., 2004).

The present study evaluated the species richness of testate amoebae in plankton from different environments of the upper Paraná river floodplain (PR/MS), including rivers, channels, connected and isolated lakes, located within the main three subsystems of the floodplain: Baía, Paraná and Ivinheima, during different hydrological periods.

Material and methods

Study area

This study was performed in the upper Paraná river floodplain (22°40' - 22°50'S and 53°10'-53°40'W), which is inserted in the Environmental Protection Area of Islands and 'Várzeas' of the Paraná river (Figure 1).

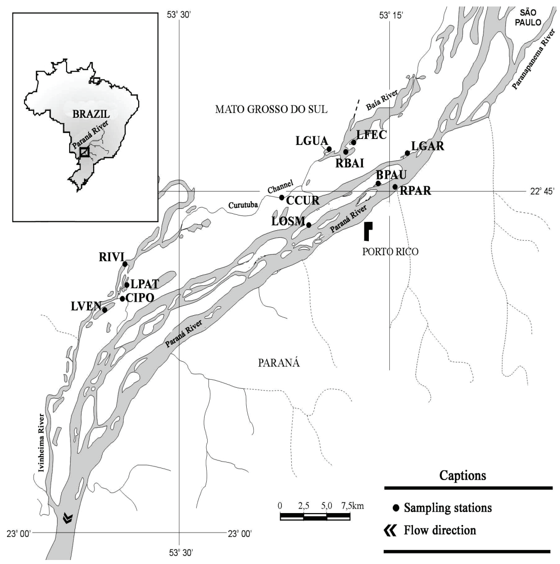

Figure 1. Study area map and location of sampling stations (RPAR: Paraná river; RBAI: Baía river; RIVI: Ivinheima river; CIPO: Ipoitã channel; CCUR: Curutuba channel; BPAU: Pau Véio backwater; LGAR: Garças lake; LPAT: Patos lake; LFEC: Fechada lake; LGUA: Guaraná lake; LVEN: Ventura lake; and LOSM: Osmar lake).

Paraná system is formed by Paraná river and associated floodplain lakes, islands and 'várzeas'. The studied stretch of this river (22°45'S – 53°15'W) presents mean depth of 4.0 m, but may reach 15.0 m of maximum depth, varied width, and presence of extensive islands and bars (THOMAZ et al., 1992).

Baía system is comprised by Baía river (22°43'S – 53°17'W) and a great number of associated lakes along the river course. This river is connected to the Paraná river through a channel at the inferior stretch, and presents varied width with mean depth of 3.2 m. It is a meandering river, considered as a semilotic environment, directly influenced by hydrological regime of Paraná river.

Ivinheima system is composed by floodplain lakes associated to Ivinheima river (22°47'S – 53°32'W) and the own river. This is the one of the main tributaries in the right bank of the Paraná river, with mean depth of 3.9 m. It is connected to the Baía river through Curutuba channel, and to the Paraná river through Ipoitã channel and other two channels (THOMAZ et al., 1992).

In order to accomplish this study, 12 sampling stations were established, including three rivers (Paraná, Baía and Ivinheima), three lakes with permanent connection to the main river (connected lakes), three lakes without direct connection to the main river, associated to it through the groundwater (isolated lakes), two channels and one backwater (lentic environment formed by the settlement of sediment along the river bank) (Figure 1; Table 1).

Table 1. Studied environments from the upper Paraná river floodplain, categories (river = R, channel = C, connected lakes = CL and isolated lakes = IL), area and mean depth.

Environments	Categories	System	Area (ha)	Mean depth (m)
		Rivers		
Paraná	R	Paraná	-	4
Ivinheima	R	Ivinheima	-	3.9
Baía	R	Baía	-	3.2
		Channels		
Ipoitã	C	Ivinheima	-	3.2
Curutuba	C	Baía	-	2.7
		Backwater		
Pau Véio	CL	Paraná	3	1.8
		Connected lakes		
Garças	CL	Paraná	14.1	2
Patos	CL	Ivinheima	113.8	3.5
Guaraná	CL	Baía	4.2	2.1
		Isolated lakes		
Osmar	IL	Paraná	0.006	1.1
Ventura	IL	Ivinheima	89.8	2.16
Fechada	IL	Baía	7.5	2.46

Field sampling

The testate amoebae were sampled at subsurface of pelagic region from each environment, during the periods of low-water period (September, 2007), flooding (November, 2007), high-water period (February, 2008) and ebbing (June, 2008). Samples were taken using motorized pump and plankton net (68 μm) to filter 600 liters of water per sample. The collected material was kept in polyethylene flasks, properly labeled, and preserved with formaldehyde solution (4%) buffered with calcium carbonate.

Taxa identification was carried out using glass slides under optical microscope. Species identification was made using the following references: Deflandre (1928, 1929), Gauthier-Lièvre and Thomas (1958, 1960), Vucetich (1973), Ogden and Hedley (1980), Velho and Lansac-Tôha (1996), Velho et al. (1996, 2000, 2001), Alves et al. (2007), Gomes e Souza (2008) and Lansac-Tôha et al. (2008).

Data analysis

The species composition of testate amoebae assemblages, in each environment and hydrological period, was analyzed from the faunistic survey performed for the entire study area.

Changes in assemblages composition was evaluated from the β-2 diversity index (WHITTAKER, 1960) that quantifies the change in species composition considering the environment categories and hydrological periods. This index is estimated from the equation:

$$\beta\text{-}2 = [(R/\alpha_{max})-1]/[n-1]$$

where:

α_{max} = maximum value of species richness in the set of n considered samples; R = total number of taxa recorded for the n compared samples.

The frequency of taxa was examined from their occurrences in the samples, i.e., frequent taxa are those occurring in more than 50% of the samples, constant, between 25% and 50% of the samples, and rare, in less than 25% of the samples.

Results

During the study period, the Paraná river did not show clearly differentiated flooding periods. The September month had the lowest level. Highest values of river level prevailed in February with 24 days higher than 3.0 meters. On the other hand, only 2 days in November with flood levels, which coincided with sampling days, with most of the period with levels below 3 meters (Figure 2).

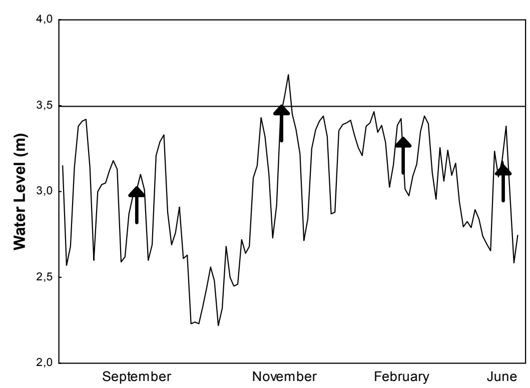

Figure 2. Paraná river level measured daily at Porto São José. Arrows indicate sampling days. The horizontal line indicates the overflow level.

Testate amoebae were represented by 67 infrageneric taxa, distributed in seven families, and Difflugiidae and Arcellidae were the most species-rich, with 29 taxa and 15 taxa, respectively (Table 2).

Spatially, in general, higher values of species richness were observed in the lakes during the different periods, especially during the high-water period (February, 2008). Moreover, there was a similar pattern for channel and rivers. Considering the lakes, there was low variation in species richness among the studied months. On the other hand, for the different studied months, the mean values of species richness were always lower during the low-water period (September, 2007) in relation to the high-water period (February, 2008) (Figure 3).

Table 2. Faunistic survey of testate amoebae recorded in 12 environments from the upper Paraná river floodplain, from september 2007 to June 2008.

Protozoa	
Arcellidae	
Arcella arenaria Greeff, 1866	*A. hemisphaerica* f.*undulata* Deflandre, 1929
A. catinus Pénard, 1890	*A. megastoma* Pénard, 1902
A. conica (Playfair, 1917)	*A. mitrata* Leidy, 1879
A. costata Ehrenberg, 1847	*A. mitrata* var. *spectabilis* Deflandre, 1928
A. dentata Ehrenberg, 1830	*A. vulgaris* Ehrenberg, 1830
A. discoides Ehrenberg, 1843	*A. vulgaris* f. *elegans* Deflandre, 1928
A. gibbosa Pénard, 1890	*A. vulgaris* f. *undulata* Deflandre, 1928
A. hemisphaerica Perty, 1852	
Centropyxidae	
Centropyxis aculeata (Ehrenberg, 1838)	*C. gibba* Deflandre, 1929
C. aerophila Deflandre, 1929	*C. hirsuta* Deflandre, 1929
C. cassis (Wallich, 1864)	*C. marsupiformis* (Wallich, 1864)
C. constricta Ehrenberg, 1841	*C. platystoma* Pénard, 1902
C. discoides (Pénard, 1890)	*C. spinosa* (Cash, 1905)
C. ecornis (Ehrenberg, 1841)	
Diffllugiidae	
Cucurbitella crateriformis G.L. & T., 1960	*D. lobostoma* Leidy, 1879
C. dentata f. *crucilobata* G.L. & Th., 1958	*D. lobostoma* var. *cornuta* G.L. & Th., 1958
C. dentata f. *quinquelobata* G.L. & T., 1960	*D. lobostoma* f. *multilobata* G.L. & Th., 1958
C. dentata f. *trilobata* G.L. & Th., 1958	*D. lobostoma* var. *tuberosa* G.L. & Th., 1958
C. madagascariensis G.L. & Th., 1960	*D. microclaviformis* Kourov, 1925
C. mespiliformis Pénard, 1902	*D. muriculata* G.L. & Th., 1958
Difflugia acuminata Ehremberg, 1838	*D. muriformis* G.L. & Th., 1958
D. amphoralis var. *cornuta* Hopkinson, 1909	*D. muriformis* f. *crucilobata* G.L. & Th., 1958
D. amphoralis globosa G.L. & Th., 1958	*D. oblonga* Ehrenberg, 1838
D. corona Wallich, 1864	*D. parva* Thomas, 1954
D. curvicaulis Pénard, 1989	*D. pseudogramen* G.L. & Th., 1960
D. globularis Wallich, 1864	*D. stellastoma* Vucetich, 1989
D. gramen Pénard, 1902	*D. urceolata* Carter, 1864
D. limnetica Levander, 1900	*D. ventricosa* Deflandre, 1926
D. lithophila Pénard, 1902	
Hyalospheniidae	
Lesquereusia mimetica Pénard, 1902	*L. spiralis* var. *caudata* Playfair, 1917
L. modesta Rhumbler, 1896	*Neztelia oviformis* (Cash, 1909)
L. modesa. var.*caudata* Thomas, 1959	*N. tuberculata* (Wallich, 1864)
*L. spiralis (*Ehrenberg, 1840)	*N. wailesi* (Wailes, 1912)
Trigonopyxidae	
Cyclopyxis impressa Daday, 1905	*C. kahli* Deflandre, 1929
Euglyphidae	
Euglypha acantophora Ehrenberg 1841	
Plagiopyxidae	
Plagiopyxis callida Pénard, 1910	

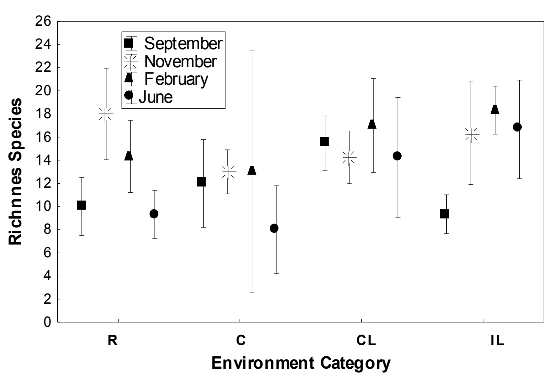

Figure 3. Species richness of testate amoebae recorded in different studied environments (R= river, C = channel, CL= connected lakes and IL = isolated lakes) during the studied months.

Analyzing the frequency of occurrence of testate amoebae, we verified a higher number of frequent taxa in November (13 taxa), and during February and June, a higher number of rare taxa (25 and 24 taxa, respectively). Arcellidae, Difflugiidae and Centropyxidae presented taxa more constant during the four sampling months. Only *Centropyxis aculeata, Difflugia gramem* and *D. pseudogramem* were identified as frequent throughout study period (Table 3).

Regarding the species composition, in different environments and periods, the beta diversity analysis pointed a higher change among the rivers in February (high-water period). For these environments, the lowest change in species composition were registered in September (low-water period). In relation to lakes, in general, isolated lakes presented higher changes in species composition during the distinct periods (Figure 4).

Beta diversity values indicated that the channels and isolated lakes presented greater changes in species composition of testate amoebae among the studied periods. Otherwise, lower changes in this attribute were observed in connected lakes and rivers (Figure 5).

Table 3. Frequency of testate amoebae taxa during different sampling periods (■ Frequent (> 50%); ▓ Constant (25% - 50%); ░ Rare (< 25%) and — absent).

	% of taxa Sep/07	Frequency of taxa Sep/07	% of taxa Nov/07	Frequency of taxa Nov/07	% of taxa Feb/08	Frequency of taxa Feb/08	% of taxa Jun/08	Frequency of taxa Jun/08
				Arcellidae				
Arcella arenaria	0	—	0	—	25	░	8	░
A. catinus	0	—	0	—	17	░	50	▓
A. conica	33	▓	67	■	67	■	25	▓
A. costata	50	▓	58	■	58	■	17	░
A. dentata	8	░	0	—	0	—	0	—
A. discoides	67	■	83	■	67	■	50	▓
A. gibbosa	50	▓	75	■	58	■	50	▓
A. hemisphaerica	50	▓	58	■	58	■	17	░
A. hemisphaerica f. *undulata*	0	—	0	—	25	▓	0	—
A. megastoma	8	░	25	▓	8	░	8	░
A. mitrata	17	░	33	▓	33	▓	42	▓
A. mitrata var. *spectabilis*	8	░	8	░	8	░	0	—
A. vulgaris	17	░	42	▓	50	▓	25	▓
A. vulgaris f. *elegans*	0	—	0	—	8	░	0	—
A. vulgaris undulata	17	░	8	▓	17	░	8	░
				Centropyxidae				
Centropyxis aculeata	75	■	100	■	83	■	92	■
C. aerophila	0	—	25	▓	17	░	0	—
C. cassis	8	░	0	—	0	—	0	—
C. constricta	8	░	33	▓	25	▓	25	▓
C. discoides	42	▓	50	▓	17	░	42	▓
C. ecornis	33	▓	58	■	42	▓	17	░
C. gibba	0	—	0	—	8	░	0	—
C. hirsuta	25	▓	75	■	25	▓	25	▓
C.marsupiformis	0	—	0	—	17	░	33	▓
C. platystoma	0	—	8	░	8	░	8	░
C. spinosa	42	▓	58	■	58	■	25	▓
				Trigonopyxidae				
Cyclopyxis impressa	0	—	0	—	8	░	17	░
C. kahli	33	▓	8	░	33	▓	0	—
				Difflugiidae				
Cucurbitella crateriformis	0	—	8	░	0	—	0	—
C. dentata f. *crucilobata*	17	░	8	░	8	░	67	■
C. dentata f. *quinquelobata*	42	▓	58	■	83	■	50	▓
C. dentata f. *trilobata*	67	■	58	■	50	▓	50	▓
C. madagascariensis	8	░	0	—	8	░	0	
C. mespiliformis	17	░	33	▓	25	▓	8	░
Difflugia acuminata	0	—	0	—	17	░	8	░
D. amphoralis var. *cornuta*	0	—	0		8	░	0	—
D. amphoralis var *globosa*	0	—	0	—	0	—	8	░
D. corona	25	▓	42	▓	42	▓	25	▓
D. curvicaulis	0	—	0	—	8	░	0	—
D. globularis	25	▓	8	░	8	░	8	░
D. gramen	83	■	92	■	100	■	58	■
D. limnetica	25	▓	17	░	33	▓	17	░
D. lithophila	25	▓	8	░	0	—	25	▓
D. lobostoma	8	░	50	▓	33	▓	17	░
D. lobostoma var. *cornuta*	8	░	8	░	0	—	0	—
D. lobostoma f. *multilobata*	8	░	0	—	0	—	0	—
D. lobostoma var *tuberosa*	0	—	0	—	0	—	33	▓
D. microclaviformis	8	░	8	░	25	▓	8	░
D. muriculata	0	—	0	—	0	—	8	░
D. muriformis	8	░	33	▓	42	▓	33	▓
D. muriformis f. *crucilobata*	0	—	0	—	8	░	0	—
D. oblonga	25	▓	25	▓	0	—	25	▓
D. parva	0	—	8	░	0	—	0	—
D. pseudogramem	75	■	75	■	58	■	58	■
D. stellastoma	33	▓	25	▓	58	■	33	▓
D. urceolata	8	░	8	░	0	—	0	—
D. ventricosa	8	░	0	—	17	░	8	░
				Lesquereusiidae				
Lesquereusia mimetica	0	—	8	░	17	░	17	░
L. modesta	25	▓	25	▓	8	░	17	░
L. modesta var. *caudata*	0	—	0	—	0	—	17	░
L. spiralis	8	░	33	▓	42	■	33	▓
L. spiralis var. *caudata*	0	—	0	—	8	░	0	—
Netzelia oviformis	0	—	0	—	8	░	8	░
N. tuberculata	33	▓	0	—	0	—	0	—
N. wailesi	0	—	0	—	8	░	8	░
				Plagiopyxidae				
Plagiopyxis callida	0	—	0	—	0	—	8	░
				Euglyphidae				
Euglypha acanthophora	17	░	42	▓	33	▓	17	░

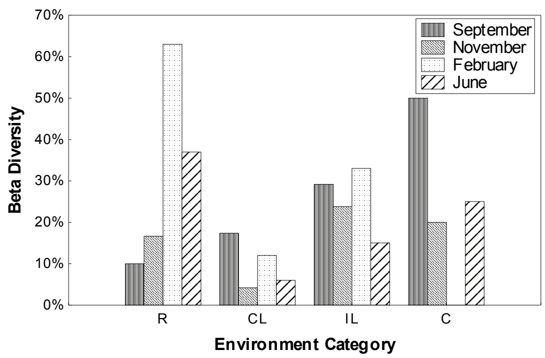

Figure 4. Beta diversity of testate amoebae community in different months among each environment types (R = river, C = channel, CL = connected lakes and IL = isolated lakes).

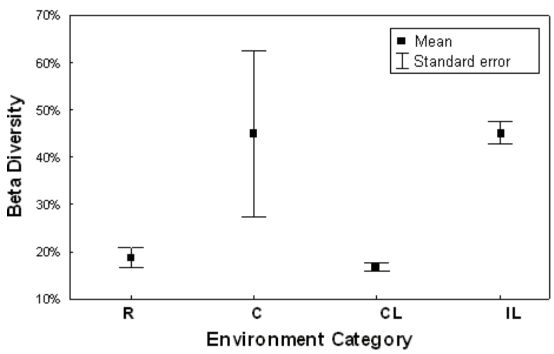

Figure 5. Beta diversity of testate amoebae community in each environment types among the different sampling months (R = river, C = channel, CL = connected lakes and IL = isolated lakes).

Discussion

The most representative families of testate amoebae recorded in the present study, Difflugiidae, Arcellidae and Centropyxidae, have been highlighted for the great diversity in other studies performed in freshwater plankton (GREEN, 1975; DABÉS, 1995; LANDA; MOURGUÉS-SCHURTER, 2000; LANSAC-TÔHA et al., 2008), as well as in other studies in this same floodplain (LANSAC-TÔHA et al., 2004, 2007, 2009; VELHO et al., 2000, 2001; ALVES et al., 2007).

Regarding the temporal variation of species richness, the highest value was recorded in February (high-water period). This result may be related to the raise of hydrometric level and the increase in current flow observed during this period that allow the input of organisms coming from other habitats, mainly littoral vegetation, as verified in other studies accomplished in aquatic environments (GREEN, 1975; WALKER, 1982; VELHO et al., 1999, 2003; LANSAC-TÔHA et al., 2004, 2009).

Spatially, in general, higher values of species richness were registered in the lakes. These environments present high habitat heterogeneity associated to extensive stands of aquatic macrophytes in littoral region. Together with this feature, the low depth intensifies the fauna exchange among the different compartments, as stated by Lansac-Tôha et al. (2007).

The interrelation among the compartments may also be registered through the analysis of species occurrence frequency in distinct environments. *Centropyxis aculeata, Difflugia gramem* and *D. pseudogramem*, frequent taxa during the entire study period, were also classified as frequent, both in plankton and associated to aquatic macrophytes, in studies performed in other Brazilian regions (VELHO et al., 2000; LANSAC-TÔHA et al., 2001, 2007).

Beta diversity results indicated higher changes in species composition in lotic environments. Some studies emphasized the occurrence of great alterations in zooplankton communities in this type of environment (GREEN, 1975; BONECKER et al., 1996; LANSAC-TÔHA et al., 1999; VELHO et al., 2004). In the present study, the intermediary values observed for beta diversity in the channels were predictable. The importance of flow rate for the increase in species number was evidenced by Lansac-Tôha et al. (2003).

Alves et al. (2005), studying cladocerans in lakes from this same floodplain, detected a lower temporal variation of beta diversity in lakes with high connectivity degree. The authors verified that in lakes without connectivity, changes in the structure of cladoceran assemblages occurred concurrently to high water level of the rivers. The same pattern was identified in the present study, in which the connected lakes did not present great changes in species composition among studied periods, as well as the rivers.

Nevertheless, the channels and isolated lakes presented high values of temporal beta diversity. This result suggests the importance of connectivity for the permanence of testate amoebae species in environments with some type of connection. In relation to the channels, the high change in species composition may be associated to the connectivity to different rivers, influencing the testate amoebae composition in these environments.

Conclusion

The obtained results emphasize the importance of the present study to improve the knowledge about the diversity and geographical distribution of testate amoebae in Brazil. Besides that, temporally, higher values of diversity in each environment were recorded during the high-water period, evidencing the relevance of current flow for the displacement of testate amoebae from their preferred habitats, marginal vegetation and sediment. Additionally, the increase in available niche in this period when there is great input of organic matter in planktonic compartment favor the amoebae with decomposer feeding habit.

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