

Influence of depth and rainfall on testate amoebae (Protozoa-Rhizopoda) composition from two streams in northwestern São Paulo state

Influência da profundidade e pluviosidade na composição de amebas testáceas
(Protozoa-Rhizopoda) de dois córregos do noroeste paulista

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Abstract: The present survey investigated the influence of depth and rainfall on testate amoebae species richness in plankton samples from two streams with different depths. Monthly samplings were performed from April 2002 to March 2003. Using a conical plankton net (65 μ m mesh), samples were obtained through horizontal hauls at the subsurface in the pelagic region for 5 minutes. Twenty-one species were sampled (20 in Talhado Stream and 14 in Talhadinho Stream). Moreover, Talhado Stream presented species richness values statistically higher than Talhadinho Stream over the 12 months. The Spearman correlation coefficient between the pluviometric data and the two streams showed a concordant increase in species richness and the amount of rainfall in the sampling period. β -2 diversity values obtained for Talhado (4.9%) and Talhadinho (6.8%) streams were low, showing a reduced alteration in species turnover over the 12 sampling months. Our results suggest that alterations in current flow, determined by variations in pluviometric indexes, as well as the interaction between the water column and the benthonic and littoral compartments, intensified in shallower environments, are determinants in testate amoebae species richness variations in lotic environments.

Keywords: lotic environment, testate amoebae, streams, rainfall, potamoplankton.

Resumo: O presente estudo teve como objetivos investigar a influência da profundidade e da pluviosidade sobre a riqueza de espécies de amebas testáceas no plâncton de dois córregos com diferentes profundidades. Foram realizadas amostragens mensais de abril de 2002 a março de 2003. As amostras foram obtidas por meio de arrasto horizontal, à subsuperfície, na região pelágica por um tempo fixo de 5 minutos, utilizando-se rede cônica de plâncton com 65 μ m de abertura de malha. Foram registrados 21 táxons de protozoários testáceos nos dois córregos, sendo 20 para o córrego Talhado e 14 para o córrego Talhadinho. O córrego Talhado apresentou valores de riqueza de espécies estatisticamente maiores do que o córrego Talhadinho ao longo de doze meses de coleta. Além disso, o coeficiente de correlação de Spearman entre os dados pluviométricos e os resultados de ocorrência das espécies nos dois córregos evidenciou um aumento concordante da riqueza de espécies e a quantidade de chuva no período amostrado. Os valores de diversidade β -2 obtidos para os córregos Talhado (4,9%) e Talhadinho (6,8%) foram baixos, evidenciando uma reduzida alteração, na composição de espécies ao longo dos 12 meses de amostragem. Os resultados sugerem que alterações na velocidade de corrente, determinadas pelas variações dos índices pluviométricos, bem como a interação entre a coluna de água e os compartimentos bentônico e litorâneo, intensificada em ambientes mais rasos, são determinantes nas variações dos valores de riqueza de espécies de amebas testáceas de ambientes lóticos.

Palavras-chave: ambientes lóticos, tecameba, córregos, pluviosidade, potamoplâncton.

1. Introduction

Surveys of planktonic communities in freshwater environments have mainly dealt with lakes and reservoirs, while plankton from lotic environments has been, as a rule, little researched. In addition, most studies of these environments, at least in South America, are restricted to large rivers, while plankton from streams has been systematically neglected.

Planktonic communities from rivers have a large amount of components dragged from the sediment to the water column, or coming from dammed areas connected to the river. The few organisms considered true potamoplankton are continuously dragged by the water while their populations develop (Margalef, 1983).

Obviously, the presence of planktonic organisms is much more probable in large rivers (3rd order or greater). In such environments, stretches with low current flow and a great distance between banks permit a greater light incidence and productivity, providing biotic and abiotic features more favorable to plankton establishment than low order rivers (less than 3rd order).

However, since the establishment of these microorganisms depends on whether or not their reproductive rates exceed the displacement caused by the current flow (Margalef, 1983; Marzolf, 1990; Reynolds, 2000), r-strategist species (e.g. testate amoebae and rotifers), presenting short life cycles, are favored in smaller rivers, while the establishment of other zooplankton groups (e.g. cladocerans and copepods) is limited in such conditions.

In such lotic systems, the structure of microorganism communities is strongly influenced by current flow (Viroux, 1997) and, according to Reynolds (2000), variations in river flow exert a central role in the development of these communities.

According to Junk et al. (1989), contrary to what is observed in large rivers, where the hydrological regime follows a more or less predictable pattern; the hydrological regime in streams reflects the climate of the watershed area, and brings about an irregular flooding pattern, with several peaks, since it is strongly influenced by local precipitation.

Since flow performance is a selective factor, stream organisms must adapt to attach, support the displacement and use layers where this effect is reduced, and at same time be able to obtain food from water flow (Lampert and Sommer, 1997).

However, according to Viroux (1997), water flow is not homogeneous through a transversal section of a lotic environment. In addition, the sinuosity and the presence of natural vegetation along the banks may furnish potential shelter for organisms, thus hindering the quick displacement downstream.

Margalef (1983) argued that the most important adaptations for living in lotic environments are morphological. In this sense, Velho et al. (2003) verified a relationship between

shell shape of testate amoebae and the most favorable environment type for the establishment of their populations. Species with hemispheric and spherical shells present optimum development in lentic environments, while species with elongated shells and, mainly, flattened ones present maximum abundances in lotic environments.

In spite of some studies emphasizing the great contribution of testate amoebae to the species richness and total density of plankton from lotic environments, ecological and taxonomic researches focusing on these protozoans are rare. Although there is an increase in the number of studies in this area, those related to the occurrence and geographic distribution of these organisms in Brazil are scarce, and, according to Lansac-Tôha et al. (2000) and Velho et al. (2000), they tend to cover few geographical regions.

Testate amoebae play an important role in terrestrial and aquatic environments, due to their abundance, biomass and energetic storage renewal (Arndt, 1993). With the displacement of individuals from other compartments (e.g. sediment and littoral vegetation), they become important components in the species richness and total density of plankton from lotic environments, despite being preferably associated with these biotopes.

Therefore, due to the scarcity of information about potamoplankton from small-sized environments, and considering the importance of current flow on the structure of testate amoebae assemblages, this study aims to i) compare testate amoebae species richness between two streams with different depths, presupposing that in lotic and shallow environments, the influence of current flow on the assemblage of microorganisms is greater than in deeper environments; ii) measure the degree of temporal replacement of species in both streams; and iii) compare the species composition between these streams.

2. Material and Methods

The studied environments are located in the district of Talhado (20° 42' S and 49° 18' W) in the municipality of São José do Rio Preto, northwestern São Paulo State.

Talhado Stream, together with its tributary Talhadinho, is a right bank tributary of the Preto River, which constitutes one of the main rivers of the Turvo/Grande sub-basin, and has great urban and rural importance for the district of Talhado (Figure 1). There is domestic sewage inflow in both streams. In addition, riparian vegetation has been greatly altered by human intervention and, due to its absence in some places, grass (mainly *Setaria* sp.) development has been observed. The most conspicuous difference between the streams is depth, since the Talhado Stream sampling stations presented a mean depth of 0.45 m, while Talhadinho Stream had a mean depth of 1.40 m.

2.1. Data collection

Monthly samplings were carried out in two sampling stations in each stream from April 2002 to March 2003. Two sampling stations were chosen in each stream to decrease possible sampling errors due to the heterogeneous distribution of the plankton in the water column. The sampling stations between the streams are about 2 km apart, while the stations within each stream are about 20 m from each other.

Samples were obtained through horizontal hauls at the subsurface in the pelagic region for 5 minutes, using a conical plankton net (20 cm diameter; 65 μm mesh). Samples were maintained in glass flasks and preserved in a 4% formaldehyde solution buffered with calcium carbonate.

Organisms were identified using a Sedgwick-Rafter chamber, common slides, an optical microscope and a specialized bibliography (Deflandre, 1928, 1929; Gauthier-Liévre and Thomas, 1958, 1960; Chardez, 1967; Vucetich, 1973; Ogden and Hedley, 1980; Velho et al., 1996 and Velho and Lansac-Tóha, 1996). Voucher specimens are deposited in the collection of the Nupélia zooplankton laboratory.

2.2. Data analysis

Rainfall data (mm) from the study area (April 2002 to March 2003) were provided by the Secretaria de Agricultura e Abastecimento do Estado de São Paulo.

Monthly data obtained in both sampling points of each stream were combined ($n = 12$ for each stream). We used the Spearman Correlation Coefficient to measure the correlation between the testate amoebae assemblages and the monthly pluviometric level in Talhado and Talhadinho streams. A positive significant correlation indicates that the presence of testate amoebae in plankton from lotic environments can be explained, in part, by organism displacement from sediment or fauna associated with littoral vegetation.

A t -test for dependent samples was used to test the equality hypothesis of the species richness between the two streams.

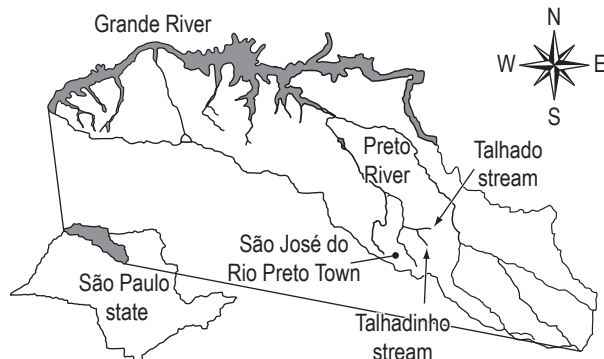


Figure 1. Localization of the Talhado and Talhadinho streams in Turvo/Grande sub basin.

Species composition was compared between the two environments (Talhado and Talhadinho streams) using a Detrended Correspondence Analysis (DCA) (Hill and Gauch, 1980) and an analysis of similarity (ANOSIM) (Clarke, 1993).

To quantify the temporal change in species composition (turnover) in both streams, the Beta diversity index (β -2) (Harrison et al., 1992) was calculated. This index can be used to measure how species composition changes along a spatial or temporal gradient. The β -2 was calculated using the following equation:

$$\beta\text{-2} = \{[(S / \alpha_{\max}) - 1] / (N-1)\} \times 100 \quad (1)$$

where S is regional diversity (species number recorded in each stream) and α_{\max} the maximum value of alpha diversity found in N sampling units.

3. Results

Twenty-one species were sampled. Talhado presented 20 species and Talhadinho 14 (Table 1). We observed two well-defined pluviometric periods during the study period: dry (April to October 2002) and rainy (November 2002 to March 2003) (Figure 2).

Table 1. Testate amoebae taxa sampled in Talhado and Talhadinho streams during 12 studied months.

Taxa	Talhado	Talhadinho
TESTACEA		
ARCELLIDAE		
<i>Arcella dentata</i> Ehrenberg, 1838	+	+
<i>Arcella discoides</i> Ehrenberg, 1843	+	+
<i>Arcella hemisphaerica</i> Perty, 1852	-	+
<i>Arcella megastoma</i> Pénard, 1902	+	+
<i>Arcella vulgaris</i> Ehrenberg, 1830	+	+
CENTROPYXIDAE		
<i>Centropyxis aculeata</i> (Ehrenberg, 1838)	+	+
<i>Centropyxis discoides</i> (Pénard, 1890)	+	+
<i>Centropyxis ecomis</i> (Ehrenberg, 1841)	+	+
<i>Centropyxis marsupiformis</i> (Wallich, 1864)	+	-
TRIGONOPYXIDAE		
<i>Cyclopyxis impressa</i> (Daday, 1905)	+	+
<i>Cyclopyxis kahli</i> (Deflandre, 1929)	+	-
DIFFLUGIIDAE		
<i>Diffugia corona</i> Wallich, 1864	+	+
<i>Diffugia corona</i> var. <i>tuberculata</i> Vucetich, 1973	+	+
<i>Diffugia corona</i> var. <i>ecomis</i> GL. and Th., 1958	+	+
<i>Diffugia lobostoma</i> Leidy, 1879	+	+
<i>Diffugia lobostoma</i> var. <i>cornuta</i> GL. and Th., 1958	+	-
<i>Diffugia muriformis</i> GL. and Th., 1958	+	-
<i>Diffugia urceolata</i> Carter, 1864	+	+
<i>Protocucurbitella coroniformis</i> GL. and Th., 1960	+	-
<i>Cucurbitella madagascarensis</i> GL. and 1960	+	-
LESQUEREUSIIDAE		
<i>Lesquereusia spiralis</i> (Ehrenberg 1840)	+	-

The Spearman Correlation Coefficient between the pluviometric data and the two streams shows a concordant increase in species richness and amount of rainfall in the sampled period (n = 12 and 12; r = 0.60 and 0.67; P = 0.038 and 0.016 for Talhado and Talhadinho streams, respectively) (Figure 3).

In Talhado Stream, species richness changed between 2 and 13 species and showed a mean value of approximately 8 species. In Talhadinho Stream, the mean value was 5 species, ranging from 2 to 8 species (Figure 4). The results of the t-test for dependent samples showed that species richness in Talhado Stream was significantly higher

than in Talhadinho Stream over the 12 sampling months ($t = 2.67$; $df = 11$; $P = 0.022$).

Detrended Correspondence Analysis results showed a difference in species composition between the two streams (Figure 5). Talhado Stream presented 7 exclusive species among the 21 sampled species, and all species sampled in Talhadinho Stream were present in Talhado Stream. Through an ANOSIM, concomitant with a DCA, we verified a significant difference in species composition between the sampled environments ($R = 0.287$; $P = 0.0211$; 1000 randomizations).

β -2 diversity values obtained for Talhado (4.9%) and Talhadinho (6.8%) streams were low, showing a reduced alteration in species turnover over the 12 sampling months.

4. Discussion

In accordance with the assumption that in shallower environments the interaction between the plankton compartment and the sediment is more pronounced, we expected to find a larger number of species in Talhado Stream. In fact, Talhado Stream presented higher values of testate amoebae species richness than Talhadinho Stream, corroborating the hypoth-

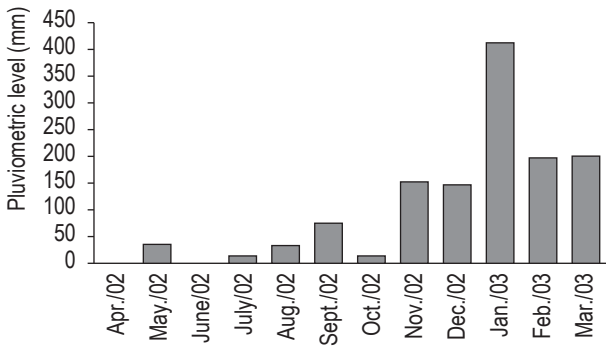


Figure 2. Monthly pluviometric level (mm) from April 2002 to March 2003 in study area.

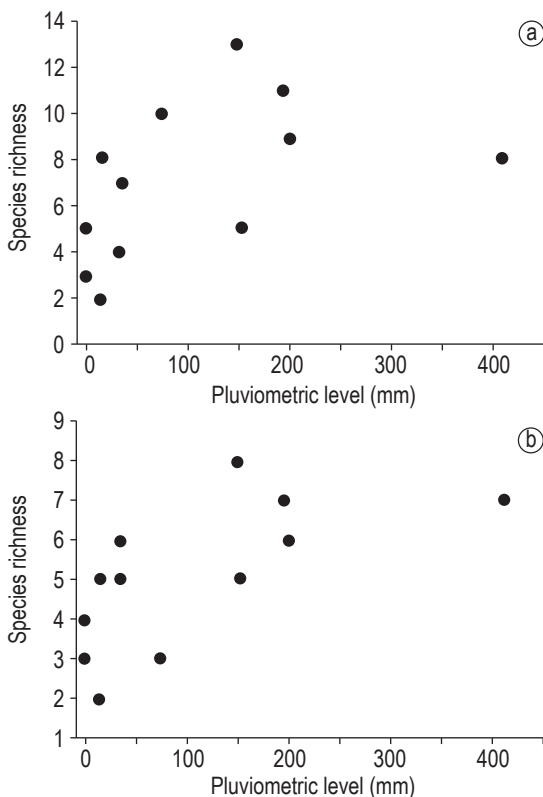


Figure 3. Relationship between pluviometric level (mm) and species richness sampled in a) Talhado, and b) Talhadinho streams.

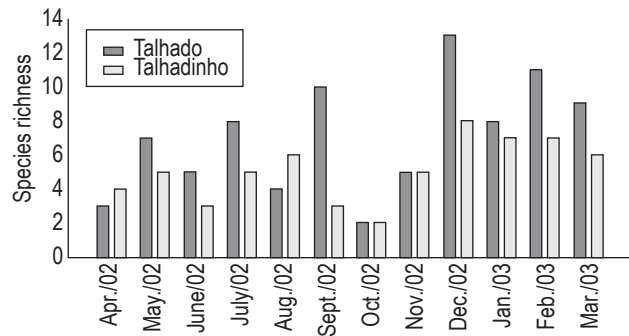


Figure 4. Temporal variation of testate amoebae species richness (April 2002 to March 2003) in Talhado and Talhadinho streams.

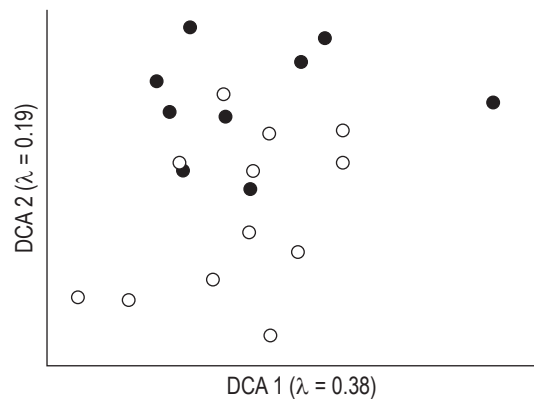


Figure 5. Scores derived from DCA comparing the composition of testate amoebae assemblages between Talhado (filled circles) and Talhadinho (open circles) streams.

esis that in shallower environments current flow promotes a greater organism input from other compartments to the plankton compartment. In a recent study focusing on testate amoebae abundance in plankton from reservoirs located in Paraná State, Velho et al. (2004) observed a strong influence of reservoir depth and other morphometric dimensions on the composition and abundance of these protozoans. Testate amoebae were recorded in 23 out of 30 sampled reservoirs, and higher densities were found in those with hydrodynamic features similar to lotic environments (high current flow, in addition to reduced depth and dimensions). In the same study, comparing the results seasonally, higher densities were recorded in the dry period in most of the reservoirs. The authors suggested that this result could be related to the fact that these environments present a clear reduction in their dimensions (depth and area) during the dry period, leading to a greater influence of the benthonic compartment in the water column.

Some studies such as Green (1963), Bonecker et al. (1996) and Lansac-Tôha et al. (1999) emphasize the importance of current flow as one of the main intervenient factors in patterns of composition, diversity and abundance of the zooplankton community in lotic environments (organism displacement from the sediment and littoral vegetation to the plankton compartment). Corroborating these researches, the pluviometric level during the study period was correlated with testate amoebae species richness in both streams (Talhado and Talhadinho).

According to Lampert and Sommer (1997), water fluctuation is a strong selective force in streams, because extreme floods can mechanically disturb the stream bottom and damage populations in this compartment, quickly altering the sediment structure and destroying organism habitats. Thus, the positive significant relationship between the pluviometric level and species richness values can be explained by the increase in the testate amoebae displacement from the benthonic compartment, as well as the littoral vegetation, to the water column due to the increase in water flow caused by rainfall.

β -2 diversity results obtained in Talhado and Talhadinho streams were relatively low, showing that, although conspicuous changes in pluviometric level had been recorded, remarkable changes in testate amoebae species composition over the 12 studied months were not observed.

At first, this result seems contradictory. If the presence of testate amoebae in stream plankton is mainly due to the displacement of organisms associated with littoral vegetation and sediment, we had expected to find a greater alteration in species composition during the study period, considering the stochastic nature of these displacements.

A factor that could explain the obtained result for β -2 diversity is the eutrophication affecting the biota from the studied streams (Fulone et al., 2005), reducing their diversity and making the establishment of new species difficult, bring-

ing on low temporal alteration in species composition. Moreover, diversity is rarely high in strongly selective environments (Reynolds et al., 1993). In the case of the studied streams, this is mainly due to the limit imposed by the interference of the physical environment. Succession can only occur when the environment is stable. In the case of a variable environment, the ecosystem is composed of species with a high reproductive rate and few special requirements (Margalef, 1963).

Green (1963, 1975), Walker (1982) and Velho et al. (1999) emphasized the influence of water flow on sediment and littoral vegetation, carrying organisms from these compartments to the plankton compartment. In this way, the water column acts as a collector of faunistic information from all compartments in such environments, mainly when the environments are shallow and small, intensifying the fauna exchange among compartments (Lansac-Tôha et al., 2004).

Thus, the variations found in the testate amoebae assemblages are, mainly, driven by losses of individuals from assemblages in the streambed and littoral vegetation due to displacements. These processes act to a greater or lesser degree over months, and during the dry period (April to October 2002) the main determining factor of these displacements was depth. In this way, the shallower environment (Talhado) presented higher species richness values than the deeper stream (Talhadinho). This also explains the difference in species composition found between the streams through the DCA. As regards the period with higher pluviometric values (November 2002 to March 2003), the displacement was greater in both environments due to the increase in water flow caused by rainfall.

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