Seasonal variation of the protozooplanktonic community in a tropical oligotrophic environment (Ilha Solteira reservoir, Brazil)

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(With 5 figures)

Abstract

The seasonal variation of the protozooplanktonic community (ciliates and testate amoebae) was studied in a tropical oligotrophic reservoir in Brazil, which was under the influence of two contrasting climatic seasons (rainy/warm and dry/cold). The aim of this study was to evaluate the effect of these climatic changes on physical, chemical and biological variables in the dynamic of this community. The highest mean density of total protozoans occurred in the rainy/warm season (5683.2 ind L^{-1}), while the lowest was in the dry/cold (2016.0 ind L^{-1}). Considering the seasonal variations, the protozoan groups that are truly planktonic, such as the oligotrichs (Spirotrichea), predominated in the dry season, whereas during the rainy season, due to the material input and resuspension of sediment, sessile protozoans of the Peritrichia group were the most important ones. The dominant protozoans were *Urotricha globosa*, *Cothurnia annulata*, *Pseudodifflugia* sp. and *Halteria grandinella*. The highest densities of *H. grandinella* were associated with more oxygenated and transparent water conditions, while the highest densities of *C. annulata* occurred in sites with high turbidity, pH and trophic state index (TSI). The study demonstrated that density and composition of protozooplanktonic species and groups of the reservoir suffered seasonal variation due to the environmental variables (mainly temperature, turbidity, water transparency, dissolved oxygen and TSI) and the biological variables (*e.g.* morphological characteristics, eating habits and escape strategies from predation of the species).

Keywords: protozoans, freshwater, ciliates, testate amoebae.

Variação sazonal da comunidade protozooplanctônica em um ambiente oligotrófico tropical (reservatório de Ilha Solteira, Brasil)

Resumo

A variação sazonal da comunidade protozooplanctônica (ciliados e amebas testáceas) foi estudada em um reservatório oligotrófico tropical no Brasil, que estava sob a influência de dois períodos climáticos contrastantes (chuvoso/quente e seco/frio). O objetivo deste estudo foi avaliar os efeitos destas mudanças climáticas sobre as variáveis físicas, químicas e biológicas na dinâmica desta comunidade. A maior densidade média de protozoários total ocorreu no período chuvoso e quente (5683,2 ind L^{-1}), enquanto a menor foi no período seco e frio (2016,0 ind L^{-1}). Considerando-se as variações sazonais, os grupos de protozoários que são verdadeiramente planctônicos, como os oligotrichs (Spirotrichea), predominaram no período seco, enquanto que, no período chuvoso, em razão da entrada de material e da ressuspensão do sedimento, os protozoários sésseis do grupo Peritrichia foram os mais importantes. Os protozoários dominantes foram *Urotricha globosa*, *Cothurnia annulata*, *Pseudodifflugia* sp. e *Halteria grandinella.* As maiores densidades de *H. grandinella* foram associadas com condições de águas mais oxigenadas e transparentes, enquanto que as maiores densidades de *C. annulata* ocorreram em locais com alta turbidez, pH e índice de estado trófico (IET). O estudo demonstrou que a densidade e a composição de espécies, e os grupos protozooplanctônicos do reservatório sofreram variação sazonal por causa das variáveis ambientais – principalmente temperatura, além de turbidez, transparência da água, oxigênio dissolvido e IET – e das variáveis biológicas, como, por exemplos, características morfológicas, hábitos alimentares e estratégias de escape à predação das espécies.

Palavras-chave: protozoários, águas doces, ciliados, amebas testáceas.

1. Introduction

Since limnologists started to include protozooplankton in their studies (e.g. Pace and Orcutt, 1981), protozoans are seen as a significant portion of the microzooplankton community (Beaver and Crisman, 1990) and an important link in the food chain, performing a key role in energy flow and acting as important mineralizing agents of limiting essential nutrients such as phosphorus and nitrogen (Azam et al., 1983). More recently, studies have shown their importance as consumers and controllers of the bacterial community, causing direct impacts on their production, biomass, structure, morphology, physiology, taxonomy and diversity (e.g. Pernthaler, 2005; Corno et al., 2008; Bell et al., 2010). Furthermore, due to the fact that they respond to low organic pollution levels and other physical, chemical and biotic alterations, they may be used as indicators of ecological changes in aquatic ecosystems (Foissner, 1988; Paerl et al., 2003).

The trophic state of aquatic environments is essential in determining patterns of spatial and temporal variation of planktonic protozoans (Velho et al., 2005). It is known, for example, that recycling of carbon and nutrients through the microbial food chain is very important in oligotrophic environments, where trophic interactions are tightly coupled (Tremaine and Mills, 1991). Despite the potential importance of protozoans in oligotrophic systems, they have received less attention than in eutrophic and mesotrophic ones (Quevedo et al., 2003). According to Laybourn-Parry and Walton (1998), they are neglected because the techniques are more difficult to apply in this kind of water, where the organisms are scarce and often stressed.

Studies on protozoan seasonal variations, mainly in oligotrophic environments, are essential to: 1) interpret the factors that mediate the patterns of abundance and species succession and 2) provide data for incorporation in models that describe the dynamic in the plankton, especially in tropical regions, where data about these organisms are scarce. Thus, in this study we investigated possible seasonal patterns in protozooplankton (ciliates and testate amoebae) in a Brazilian oligotrophic aquatic environment situated in a tropical region (Ilha Solteira reservoir). The main objective was to investigate possible influences of the physical, chemical and biological environmental characteristics over the distribution of the protozoans, in rainy/warm and dry/cold seasons that characterize the climate of the region where the reservoir is situated.

2. Material and Methods

2.1. Study area and sampling

The studied system was Ilha Solteira reservoir, which lies in the states of São Paulo, Mato Grosso do Sul, Goias and Minas Gerais and has as its main affluent rivers the Paranaiba and Grande. The length of the reservoir is about 70 km, with a maximum volume of 210.6×10^8 m^3 and a mean depth of 17 m. The region has a tropical climate – Aw (Köppen´s classification), which is characterized by a rainy summer and dry winter, with an annual mean temperature of 23.7 °C and annual rainfall of 1,300 mm.

Taking into consideration mainly the morphology of the system, six sampling points were selected along the reservoir (see Figure 1) where four samplings were conducted in 2007: January and March in the rainy/warm period and May and August in the dry/cold period. Water samples were collected from the surface of the sampling points, using a Van Dorn bottle (2 L) and were used for protozooplankton counts and limnological analyses. Samples filtered in a plankton net (10 µm pore diameter) were used for protozooplankton qualitative analyses.

2.2. Limnological analyses and trophic state index

In the field, the water pH, dissolved oxygen (DO) and temperature were measured using a multiparameter probe (YSI 6820). The water transparency was measured by the Secchi disk and the turbidity by a turbidimeter (HACH Model AN2100). After the water was sampled, the total phosphorus was determined according to Valderrama (1981), the total dissolved phosphorus as Golterman et al. (1978) and the biochemical oxygen demand (BOD_5) using the modified Winkler method (APHA, 1995). To determine the concentration of chlorophyll *a*, samples were filtered in GF/C (Whatman®) filter and the extraction was made with ethanol 80% heated to 75 °C (Nusch, 1980).

The reservoir was classified in accordance with the trophic state index (TSI) from Carlson (1977) modified by Toledo et al. (1983) that uses water transparency, total phosphorus, total dissolved phosphorus and chlorophyll *a* data.

2.3. Analysis of protozooplankton (ciliates and testate amoebae)

For protozoan identification, water samples were filtered using a plankton net (10 µm) and stored in plastic flasks. In the laboratory, the protozoan were analyzed *in vivo*, within a maximum period of 6 hours after the sampling, using an optical microscope, based mainly on the work of Edmondson (1959), Foissner and Berger (1996), Foissner et al. (1999) and Lee et al. (1985). The identified ciliates were classified according to Lynn (2008) and the testate amoebae were classified according to the Systema Naturae 2000 (Brands, 1989-2005).

For protozoan counts, water samples (400 mL) were placed in snap-cap flasks and fixed in the field with mercuric chloride and stained with bromophenol blue at 0.04%, according to Pace and Orcutt (1981). In the laboratory, the samples were left undisturbed for the sedimentation of organisms and particulate matter. The supernatant liquid was discarded and the remaining concentrated material was counted in Sedgwick-Rafter chambers in an optical microscope. Protozoan taxonomic features were also analyzed in counts from fixed samples.

2.4. Statistical analyses

The Student's t-test was used to observe possible differences between the climatic seasons (rainy and dry). The Pearson correlation test was performed to determine

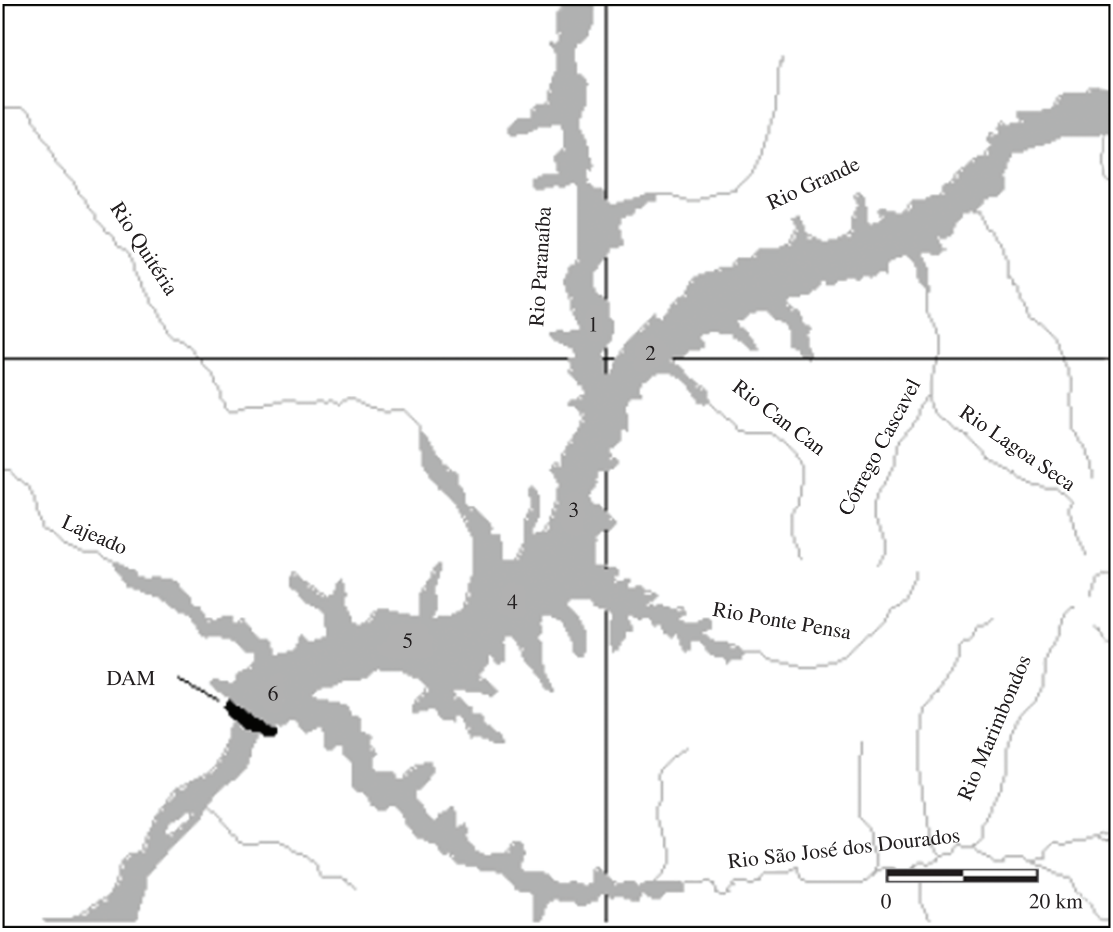

Figure 1. Localization of the sampling points in Ilha Solteira reservoir, Brazil.

the relationships among the different studied variables. The Principal Component Analysis (PCA) was used as a method of ordination of the correlations among physical, chemical and biological water variables. The Canonical Correspondence Analysis (CCA) was used to detect a pattern of variation in the species composition, and the main relationships among species and environmental variables. All the statistical analysis was performed using the XLSTAT Pro 2008 software.

3. Results

The trophic state index (TSI) calculated for the sampled points during the studied period ($TSI_{P1} = 26.4$; $TSI_{P2} = 31.2$; $TSI_{P3} = 30.3$; $TSI_{P4} = 29.8$; $TSI_{P5} = 28.7$; $TSI_{P6} = 30.2$) reveals that all of them were classified as oligotrophic. Student's t-tests showed that the physical, chemical and biological variables were significantly different between the rainy and dry seasons revealing a well-defined seasonal pattern. Thus, the general descriptive statistics of all variables analyzed in the reservoir for the two seasons are shown in Table 1. In Figure 2, a clear distinction between the sampled months can be observed from the principal component analysis (PCA), also defining a seasonal pattern with the rainy (January and March) and dry (May and August) periods. The rainy season was marked by higher values of temperature, turbidity, chlorophyll *a*, pH and trophic state index (TSI). The dry season (mainly in August) was marked by higher values of oxygen concentrations and water transparency. Points P5 and P6, in March, differed from all the others by having high concentrations of chlorophyll *a*.

Table 2 shows the relative proportions (%) of the protozoan taxa identified in the reservoir and the mean values for their annual densities and for their densities in the rainy and dry seasons. The six dominant taxa that contributed with 71.2% of the total protozoan density in the reservoir were, respectively, *Urotricha globosa*, *Cothurnia annulata*, *Pseudodifflugia* sp., *Halteria grandinella*, *Ctedoctema acanthocryptum* and *Vorticella aquadulcis-complex* (see Figure 3). From the 31 protozoan taxa observed in the reservoir, 6 were testate amoebae and 25 were ciliates (see Table 2). The highest species richness was observed in January (24 taxa) and the lowest in August (15 taxa).

In terms of density, there was a predominance of bacterivorous/algivores, followed by bacterivorous protozoans in the system. The highest ciliate and testate amoebae densities occurred in the rainy/warm season (January and March) and the lowest in the dry/cold season (May and

Table 1. Descriptive statistics of variables analyzed in Ilha Solteira reservoir in the dry season (January and March 2007) and in the dry season (May and August 2007).

Variable	Rainy season				Dry season			
	mean	min	max	SD	mean	min	max	SD
Chlorophyll *a* (μg L^{-1})	2.3	0.0	10.4	2.8	0.8	0.0	1.7	0.5
pH	7.6	7.4	8.1	0.2	6.9	6.2	7.6	0.5
DO (mg L^{-1})	6.1	4.8	6.7	0.5	7.0	6.0	7.8	0.7
BOD (mg L^{-1})	0.6	0.2	1.0	0.3	0.3	0.0	0.6	0.2
Temperature (°C)	28.3	27.0	30.0	1.0	24.2	23.0	25.0	0.8
Transparency (m)	1.2	0.5	1.7	0.4	5.0	2.5	7.5	1.7
Turbidity (NTU)	17.8	7.2	35.3	7.3	2.5	0.8	5.5	1.7
Trophic state index	36.9	21.6	43.7	6.3	26.8	13.3	35.8	6.2
Ciliate density (ind L^{-1})	4795.2	2850.0	6919.0	1052.1	1783.7	980.5	2588.5	497.6
Testate amoebae density (ind L^{-1})	888.0	128.0	1655.8	534.8	232.3	71.8	492.5	125.6
Total protozoan density (ind L^{-1})	5683.2	4016.3	7275.1	896.2	2016.0	1219.0	2839.0	469.2

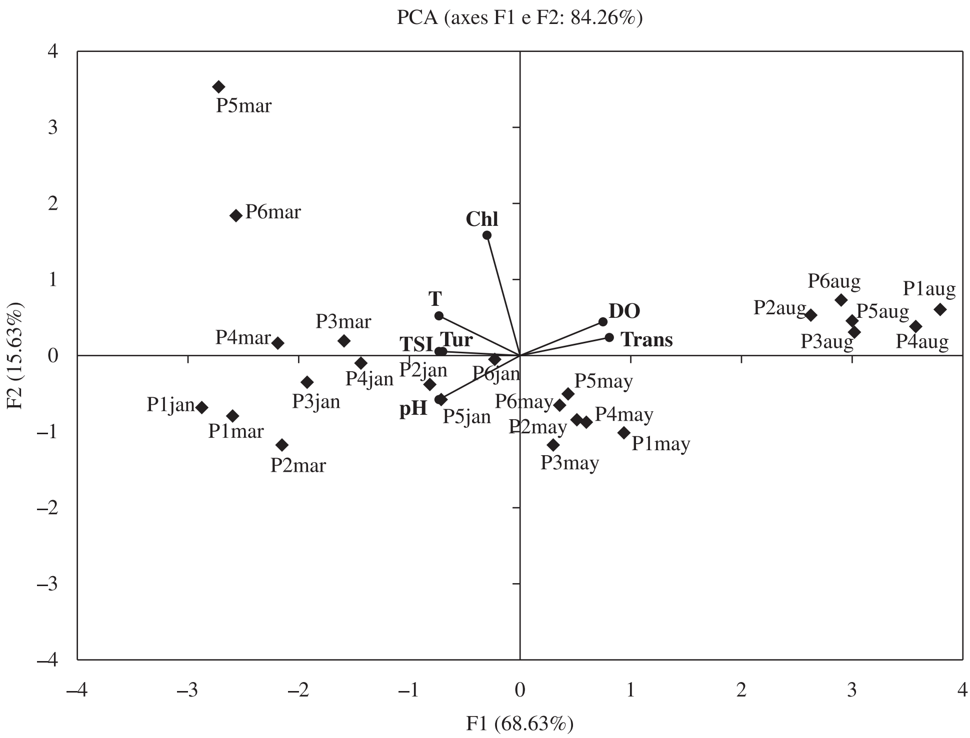

Figure 2. Ordination diagram of PCA with the limnological variables registered in the collection points during the studied period. P1jan to P6jan (Point 1 to Point 6 in January); P1mar to P6mar (Point 1 to Point 6 in March); P1may to P6may (Point 1 to Point 6 in May); P1aug to P6aug (Point 1 to Point 6 in August), DO (dissolved oxygen), Trans (water transparency), Chl (chlorophyll *a*), T (temperature), Tur (turbidity), TSI (trophic state index).

August) (see Table 1). The total protozoan density (see Table 3) correlated significantly (positive and negative ones) with all the physical and chemical variables (except for chlorophyll *a*). However, the highest positive correlations were with temperature ($r = 0.84$, $p < 0.05$) and turbidity ($r = 0.74$, $p < 0.05$) and the highest negative correlation was found with water transparency ($r = -0.76$, $p < 0.05$).

The canonical correspondence analysis (CCA) between species and limnological variables (see Figure 4) showed evidence that the sampled points in the dry season tended to stay close in the diagram, indicating that they have a similar protozoan species composition. Among the species, *H. grandinella* was the predominant in all sampled stations (except in the P2D). However, the sampled points in the

Table 2. Relative proportion (%) and annual mean density of the taxa identified in Ilha Solteira reservoir during the studied period and their mean values in the rainy and dry seasons. * = observed only *in vivo*.

	Group	Mean density (ind L^{-1})		Annual mean density (ind L^{-1})	Relative proportion (%)
		rainy	dry		
Testate amoebae					
Arcella discoides Ehrenberg	Tubulinea	0.0	2.2	1.1	<1
Arcella sp.	Tubulinea	*	*	*	*
Arcella vulgaris Ehrenberg	Tubulinea	*	*	*	*
Difflugia sp.	Tubulinea	*	*	*	*
Euglypha acanthophora Ehrenberg	Imbricatea	*	*	*	*
Pseudodifflugia sp.	Thecofilosea	888.0	230.1	559.0	14.5
Ciliates					
Campanella umbellaria (Linnaeus) Goldfuss	Peritrichia	9.7	0.0	4.9	<1
Cinetochilum margaritaceum (Ehrenberg) Perty	Scuticociliatia	53.6	64.3	58.9	1.5
Coleps hirtus (Müller) Nitzsch	Prostomatea	76.9	4.3	40.6	1.1
Cothurnia annulata Stokes	Peritrichia	1087.1	79.8	583.4	15.2
Ctedoctema acanthocryptum Stokes	Scuticociliatia	350.8	120.3	235.5	6.1
Cyclidium sp.	Scuticociliatia	270.5	85.1	177.8	4.6
Enchelys gasterosteus Kahl	Haptoria	189.2	42.5	115.9	3.0
Epistylis pygmaeum Ehrenberg	Peritrichia	*	*	*	*
Halteria chlorelligera Kahl	Spirotrichea	102.3	54.7	78.5	2.0
Halteria grandinella (Müller) Dujardin	Spirotrichea	521.5	547.8	534.7	13.9
Lacrymaria olor (Müller) Bory de Saint-Vincent	Haptoria	0.0	5.3	2.7	<1
Lagynophrya acuminata Kahl	Haptoria	0.0	15.6	7.8	<1
Limnostrombidium viride (Stein) Krainer	Spirotrichea	80.5	10.8	45.6	1.2
Mesodinium pulex (Claparède & Lachmann) Stein	Haptoria	269.0	155.4	212.2	5.5
Metopus sp.	Armophorea	0.0	5.0	2.5	<1
Paradileptus elephantinus (Švec) Kahl	Haptoria	10.6	0.0	5.3	<1
Pelagostrombidium mirabile (Penard) Krainer	Spirotrichea	174.1	73.2	123.6	3.2
*Pleurotricha grandis*Stein	Spirotrichea	*	*	*	*
Rimostrombidium humile (Penard) Petz & Foissner	Spirotrichea	173.6	47.5	110.6	2.9
Tintinnidium pusillum Entz	Spirotrichea	34.9	0.0	17.5	<1
*Trichodina domerguei*Wallengreen	Peritrichia	*	*	*	*
Uronema sp.	Scuticociliatia	105.7	94.3	100.0	2.6
Urotricha globosa Schewiakoff	Prostomatea	916.2	288.7	602.5	15.6
Vorticella aquadulcis-complex	Peritrichia	365.7	89.1	227.4	5.9
Vorticella campanula Ehrenberg	Peritrichia	3.2	0.0	1.6	<1

rainy season remained scattered in the diagram, and these were differentiated by limnological variables (mainly turbidity and chlorophyll *a*) and species dominance. In point 3, in the rainy season (P3R) a high density of *C. annulata* was associated to high turbidity. In point 5, in the rainy season (P5R), a high density of *V. aquadulcis-complex* associated with increased concentrations of chlorophyll *a* was observed. In the diagram, higher densities of *H. grandinella* were observed in oxygenated environments with high transparency, while for *C. annulata* this occurred in sites with high turbidity, pH and TSI.

The predominant protozoan groups in the reservoir were Spirotrichea and Peritrichia, followed by Prostomatea, Scuticociliatia and Thecofilosea. Considering the seasonal variations during the studied period, Peritrichia was more important in the rainy season and Spirotrichea in the dry season (see Figure 5).

Table 3 shows the significant Pearson correlations among the variables analyzed in the Ilha Solteira reservoir. Most protozoan groups and species were positively correlated with temperature and turbidity and negatively with water transparency. *H. grandinella* showed a significant positive correlation with the DO ($r = 0.46$, $p < 0.05$) and negative

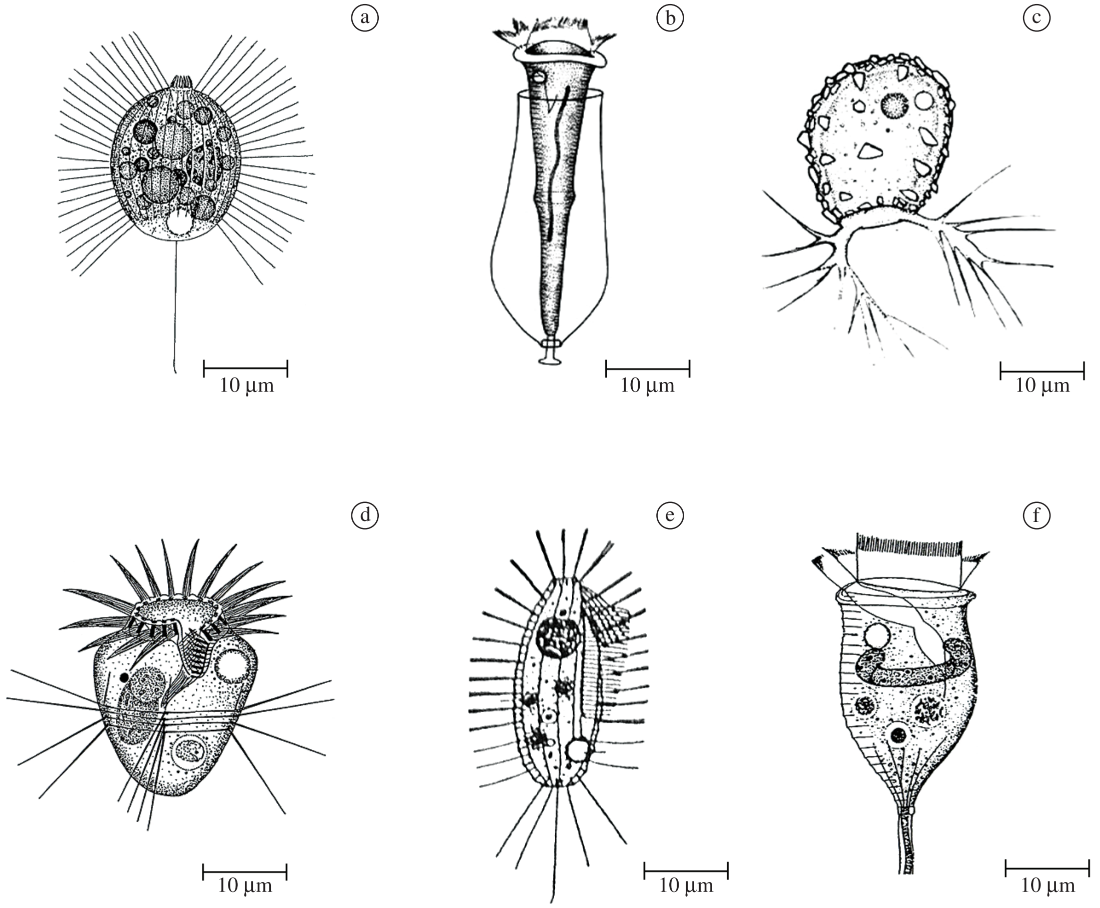

Figure 3. The dominant protozoan in the reservoir Ilha Solteira: a) *Urotricha globosa*; b) *Cothurnia annulata*; c) *Pseudodifflugia* sp.; d) *Halteria grandinella*; e) *Ctedoctema acanthocryptum* and f) *Vorticella aquadulcis-complex*. Figure a, d-f were modified from Foissner et al. (1999) and Figure b, c were modified from Shen and Zhang (1990).

Table 3. Pearson correlation coefficients among the densities of different groups and protozooplanktonic species with other studied variables in Ilha Solteira reservoir. Chl (chlorophyll *a*), DO (dissolved oxygen), BOD (biochemical oxygen demand), T (temperature), Trans (water transparency), Tur (turbidity), TSI (trophic state index), - non significant correlation; $p < 0.05$.

Variables	Chl	pH	DO	BOD	T	Trans	Tur	TSI
Total protozoan density	-	0.57	–0.51	0.52	0.84	–0.76	0.74	0.53
Spirotrichea	-	-	-	0.46	-	-	-	-
Peritrichia	0.49	0.51	-	-	0.66	–0.65	0.68	0.58
Prostomatea	-	-	-	-	0.57	–0.45	-	-
Scuticociliatia		0.66	–0.52	0.45	0.60	–0.68	0.75	0.61
Thecofilosea	0.53	0.45	–0.63	-	0.75	–0.59	0.54	0.54
Haptoria	-	-	-	0.55	0.56	–0.53	0.50	-
Cothurnia annulata	-	0.48	-	-	0.46	–0.57	0.64	0.44
Urotricha globosa	-	-	-	-	0.51	–0.42	-	-
Pseudodifflugia sp.	0.53	0.45	–0.63	-	0.75	–0.59	0.54	0.54
Halteria grandinella	-	-	0.46	-	-	-	-	–0.63
Vorticella aquadulcis-complex	0.92	-		-	0.42	-	-	-
Ctedoctema acanthocryptum	-	0.57	–0.54	-	0.55	–0.62	0.57	0.64

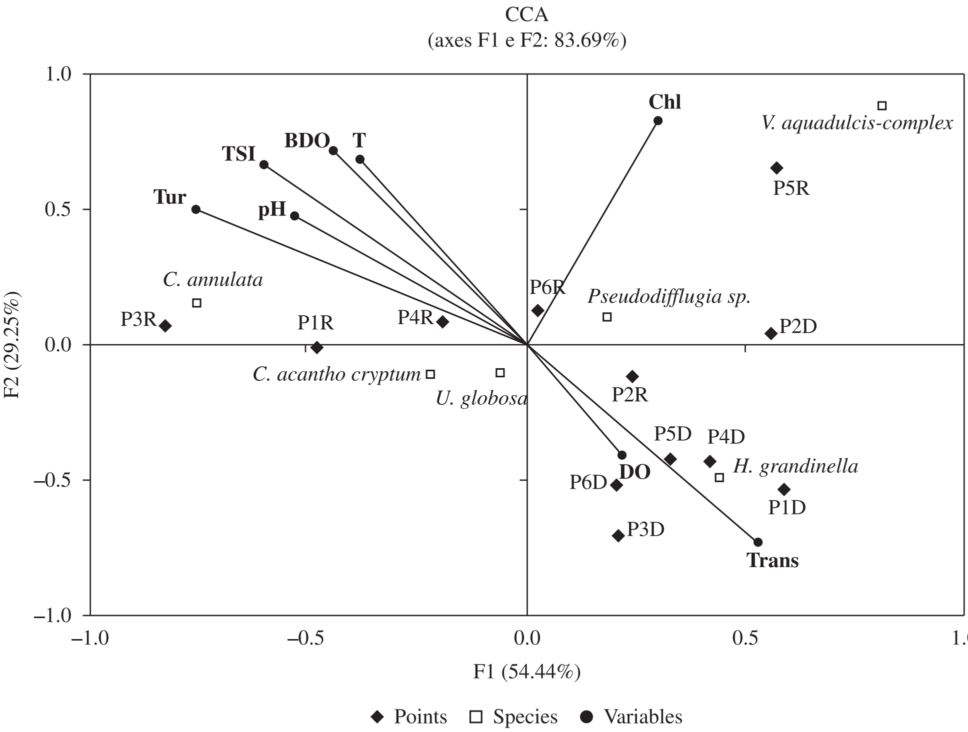

Figure 4. Ordination diagram of CCA with the main species and limnological variables registered during the studied period. P1R to P6R (Point 1 to Point 6 in rainy season); P1D to P6D (Point 1 to Point 6 in dry season), DO (dissolved oxygen), BOD (biochemical oxygen demand), Trans (water transparency); Chl (chlorophyll *a*), T (temperature), Tur (turbidity), TSI (trophic state index).

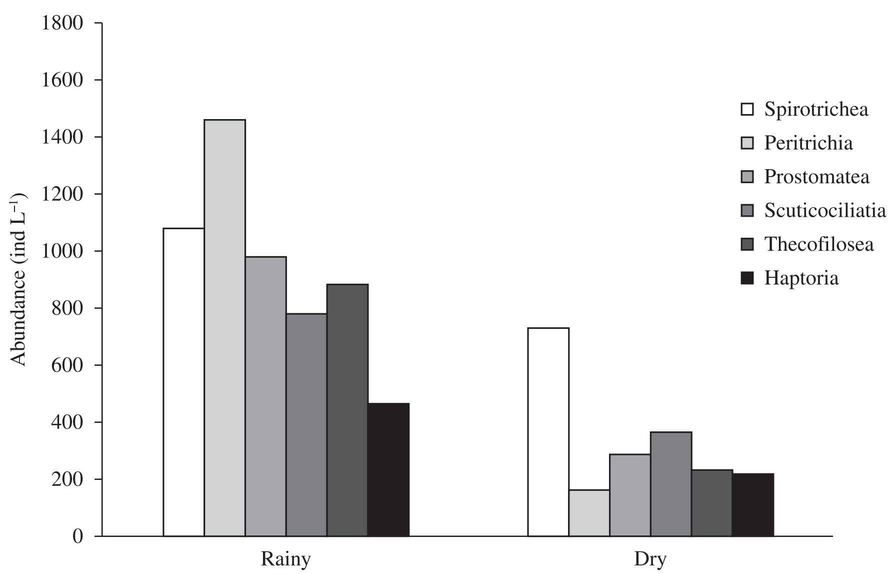

Figure 5. Abundance (ind L^{-1}) of the main protozoan groups in the rainy and dry seasons in Ilha Solteira reservoir.

with the TSI ($r = -0.63$, $p < 0.05$) and *V. aquadulcis-complex* correlated positively with chlorophyll *a* ($r = 0.92$, $p < 0.05$). *C. annulata* and *Pseudodifflugia* sp. correlated positively with turbidity ($r = 0.64$ e $r = 0.54$, $p < 0.05$, respectively) and negatively with water transparency ($r = -0.57$ e $r = -0.59$, $p < 0.05$, respectively).

4. Discussion

Statistical analysis (PCA and Student's t-tests) of the studied variables (mainly temperature, dissolved oxygen, turbidity and water transparency) confirmed, for the studied period, the climatological pattern typical of the region (rainy/warm and dry/cold). During the year, precipitation in the summer probably produced inputs of nutrients and suspended solids in the system and the winds in the winter increased water turbulence, causing an enhancement of dissolved oxygen (DO) concentration and homogenization of the water column. Moreover, the concentration of DO in the winter is probably also related to the higher solubility of oxygen as a consequence of the lower water temperatures.

The protozooplankton community showed seasonal variations with higher densities and species diversity in the rainy season in comparison with the dry season. In other Brazilian reservoirs from tropical and subtropical regions, which have the same regime of dry and rainfall, similar protozoan seasonality patterns were found (e.g. Gomes and Godinho, 2003; Araújo and Costa, 2007). These higher values in the rainy season were probably due to the precipitation that may have caused: 1) sediment resuspension carrying some benthic protozoans to the water column; 2) the entrance of soil protozoa coming from the drainage basin along with protozoans originated from rivers whose water volume increases at this season. Protozoan density could also be affected by temperature, a fact confirmed by the high positive correlation between these variables. The increasing protozoan density with temperature could be related to the enhancement of their: 1) reproductive rates due to the higher metabolic rates; and 2) prey and predator populations that normally are also positively affected by temperature. However, neither the prey, nor the predator populations were evaluated in this study.

The mean protozoan density obtained in the reservoir, whose trophic state index pointed to the oligotrophic, was low compared to eutrophic environments (e.g. Velho et al., 2005; Araújo and Costa, 2007; Chróst et al., 2009; Kiss et al., 2009; Xu and Cronberg, 2010) and within the range of those found in other oligotrophic systems (e.g. Quevedo et al., 2003; Pirlot et al., 2005; Macek et al., 2006; De Wever et al., 2007; Claessens et al., 2010). This pattern is expected because, according to Laybourn-Parry (1992), the protozoan densities increase with the trophic level of the ecosystems.

Concerning the dominant protozoan in the system, organisms such as *Halteria grandinella*, *Urotricha* sp. and *Vorticella* spp. are frequently reported in Brazilian aquatic environments (e.g. Barbieri and Godinho, 1989; Pauleto et al., 2009), and have widespread geographic distribution (Foissner et al., 1999; Šimek et al., 2000). One of the reasons for the prevalence of *U. globosa* and *H. grandinella* might be the jumping ability of these species which is an effective strategy for escaping from predation by cladocerans and rotifers (Gilbert, 1994). The *H. grandinella* also has a broad diet (bacteria, autotrophic and heterotrophic nanoprotists, detritus), which can be a selective advantage compared with specialized bacterivorous or algivores ciliates, resulting usually in a numerical dominance of this species in freshwater plankton (Jürgens and Šimek, 2000). The dominance of the *Vorticella* may also be due to its ability to escape predators due to the myonema contraction in the peduncle.

Interestingly, the higher densities of *V. aquadulcis-complex* were associated to the increase of phytoplankton (high positive correlation between this species and chlorophyll *a*) in the rainy season (mainly in March). A concomitant density increase of this species and *Microcystis* spp. was also observed, which usually remains suspended in the water column, and it is used as a fixation substract by this protozoan. The association between these two species has been frequently reported in the literature (e.g. Pratt and Rosen, 1983).

Among the prevalent protozoans in the system, *C. annulata* was especially important during the rainy season, probably due to a higher amount of suspended particles (positive correlation with turbidity) when compared to the dry season (negative correlation with the water transparency). Since this is a sessile species, the suspended material should be important for use as a fixation substrate.

Pseudodifflugia sp. was the most important testate amoebae in the system, having the highest densities during the rainy season, when the reservoir showed a high turbidity and high amount of suspended solids (observed by the low value of water transparency). Probably such predominance in this period was due to the influence of the sediment in the water column, because it is known that the sediment is one of the places of origin of these organisms (Lansac-Tôha et al., 2000).

Considering the protozoan trophic function in the reservoir, the numerical predominance of the bacterivorous/algivores protozoan types was noted. The dominance of this type of feeding can be explained by the easiness of the adaptation to fluctuations on food availability, a desirable characteristic for the organisms, especially in oligotrophic environments such as this. The most common protozoans in the system with this feeding preference were Spirotrichea and Prostomatea ciliates, which also have small dimensions that determine rapid growth rates.

In Ilha Solteira reservoir, the Spirotrichea, Prostomatea and Scuticociliatia were the dominant ciliate groups which are made up of small sized organisms. The dominance of small protozoan species is not the usual for oligotrophic waters. Studies have shown the dominance of small protozoan species (<30μm), mainly oligotrichs (Spirotrichea) and prostomatids (Prostomatea) in mesotrophic and eutrophic temperate lakes (e.g. Macek et al., 1996), while species from Scuticociliatia, Haptoria and Peritrichia are usually less numerous (Šimek et al., 2000). On the other side, according to Beaver and Crisman (1989) and Modenutti and Pérez (2001) the Oligotrichida (Spirotrichea) dominate numerically in oligotrophic lakes, while Scuticociliatia and Haptoria predominate in environments with higher trophic level (Beaver and Crisman, 1989).

Seasonally in the reservoir, Peritrichia was more important in the rainy season and Spirotrichea in the dry season. This pattern reflects the effect of precipitation in determining the protozooplankton composition of the environment. During the dry season the protozoans groups that are truly planktonic, such as oligotrichs (Spirotrichea), were predominant, whereas in the rainy season a greater input of allochthonous particulate and biological material by the rivers probably occurred, as well as the sediment resuspension (verified by the high turbidity and low water transparency), which enriched the local biota with the entry of protozoan that tend to live on particulate surfaces, such as sessile protozoans from the Peritrichia group.

When the Pearson correlation was applied to total protozoan densities and chlorophyll, the result was not significant, whereas the chlorophyll concentration was low throughout the year (mean 1.6 mg L^{-1}) and showed small fluctuations (except for P5 and P6 in March). This fact was already expected because in nutrient-poor environments, such as oligotrophic ones, the abundance of the phytoplankton community is generally low and reveals small seasonal variations. According to Sanders et al. (1992), the bottom-up control is more important in oligotrophic systems, while the top-down control is more important in eutrophic environments. Thus, as the studied reservoir is poor in nutrients and algae (low chlorophyll concentration) probably the protozoan community was controlled by resources (bottom-up control). However, this does not imply that in all the months of the year, the control in the reservoir was by resources, and that this is the main control for all the protozoan groups, due to the diversity of feeding strategies and predation escape of themselves.

The results of this work showed evidence of the importance of limnological studies with protozoan, as well as the analysis of the results considering the species or at least the taxonomic and/or functional groups. Due to the great diversity of species and life strategies, especially nutritive and to avoid predation, the roles of protozoan in the systems are multiple. When an analysis of protozoan is made regarding them as a single and homogeneous group, the interpretations of their importance in the studied environment might be totally distorted. The study demonstrated that the protozooplankton community of the Ilha Solteira reservoir experienced seasonal variation in relation to the density and composition of species and groups due to the environmental variables, mainly temperature, turbidity and water transparency related to the influence of the rainfall, DO and TSI. Moreover, biological variables, such as morphological characteristics (small cell, mostly <30μm), places of origin (*Pseudodifflugia* sp. resuspended from sediment), eating habits (broad diet of *H. grandinella*) and strategies of escaping from predators (jumping ability of *U. globosa* and *H. grandinella*) of the species, also influenced seasonal variation of this community. However, more studies must be conducted about the patterns and responses of the protozooplankton to the seasonal variations of environmental and biotic conditions, looking for relationships that contribute to the understanding of the protozoan ecology in aquatic systems of different trophic levels and climates to which they are exposed to.

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