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Structure and dynamics of the periphytic algae community of Iraí reservoir, Paraná State, Brazil

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ABSTRACT. In order to analyze the structure and dynamics of the periphytic community in Iraí reservoir, an eutrophic environment, samples were taken in two seasons: summer (April) and winter (September) of 2002, in littoral areas from three regions of the reservoir (upper, intermediary and lower). Rooted aquatic vegetation were used as sampling substrates, because they were found in all sampling sites. A total of 297 species was recorded (225 in April, 73 exclusive taxa; and 224 in September, with 72 exclusive taxa). Bacillariophyceae predominated in all regions in both seasons, in species number, as well in density. There were differences in richness among zones; intermediary and lower regions were more similar, mainly in September. The periphytic algae density differed significantly between seasons ($p = 0.002$; $F = 16.48$), with lower values in the summer. No significant difference in density was recorded among zones.

Key words: reservoir, periphyton, richness, abundance.

RESUMO. Estrutura e dinâmica da comunidade de algas perifíticas no reservatório de Iraí, Estado do Paraná, Brasil. Para analisar a estrutura e a dinâmica da comunidade de algas perifíticas no reservatório de Iraí, um ambiente eutrofizado, foram feitas coletas em duas estações: verão (abril) e inverno (setembro) de 2002, sempre na zona litorânea de cada uma das três regiões do reservatório (superior, intermediária e inferior). O substrato utilizado foi vegetação aquática, por estar presente em todos os pontos de amostragem. Foram registradas 297 espécies, das quais 225 foram constatadas no verão, sendo 73 exclusivas desta estação e 224 no inverno, das quais 72 foram encontradas apenas nesta estação. Observou-se predomínio de Bacillariophyceae em todas as regiões e em ambas as estações do ano, tanto para o número de táxons, quanto para a densidade. Com relação à riqueza, a distinção entre as zonas e as regiões intermediária e inferior foram mais similares quando comparadas à região superior, principalmente no inverno. No que diz respeito à densidade das algas perifíticas foi observada diferença significativa entre as estações ($p = 0{,}002$; $F = 16{,}48$), com os menores valores no verão e maiores no inverno. Não houve diferença significativa entre as regiões do reservatório.

Palavras-chave: reservatório, perifiton, riqueza, abundância.

Introduction

One of the main objectives of reservoir construction is to provide water storage for human consumption (TUNDISI et al., 2002a). These environments are known as intermediate systems between rivers and lakes; they show a longitudinal gradient of three distinct zones with physical, chemical and biological differences (THORNTON, 1990). Due the large need for drinking water, the construction of the reservoirs frequently comprises regions with high population density, which favors the eutrophization process (TUNDISI et al., 2002b; PAGIORO et al., 2005). The quality of the water that drains the reservoirs depends on: soil type, vegetation, human activities, climate and precipitation (STRAŠKRABA; TUNDISI, 2000).

The consequences of eutrophization can be critical to aquatic environments, as the increase in nutrient concentration results in high productivity (ESTEVES, 1988; TUNDISI et al., 2002b), which modifies the structure of all aquatic communities (MEHNER; BENNDORF, 1995). While massive investments are allocated to construction of reservoirs, very little is invested in basic knowledge generation in Brazil, such as the natural composition of primary producers of these aquatic environments (TUNDISI et al., 2002b). The use of sessile biological organisms as indicators has advantages because they respond to the instantaneous effects of environmental factors, and represent a previous effect (JÚLIO JÚNIOR et al., 2005).

Periphyton can be found in almost all types of environments (AZIM; ASAEDA, 2005). It is defined as a microorganism community (fungus, algae, bacteria, animals) and organic and inorganic particles, which are adhered or associated with a submerged substratum (WETZEL, 1983). It is an excellent indicator of changes that occur in the aquatic environment, because it shows high species diversity in a small space (AZIM et al., 2005) with short life cycle and fast answers to environmental alterations (LOWE; PAN, 1996).

The taxonomic diversity and periphyton abundance depend on several factors, such as substratum type (BURKHOLDER, 1996), nutrient availability (STELZER; LAMBERTI, 2001), light intensity (VERMAAT, 2005), temperature variations (RODRIGUES; BICUDO, 2004; MURAKAMI; RODRIGUES, 2009), and system hydrodynamics (MOSCHINI-CARLOS et al., 2000).

In some aquatic ecosystems, periphyton can contribute with a large share of total productivity and perform relevant functions in the dynamics of these ecosystems (LOWE; PAN, 1996; AZIM et al., 2005).

The aim of this study was to analyze the structure and dynamics of periphytic algae community of Iraí reservoir along its zones (upper, intermediate and lower) and between seasons (summer and winter) in 2002. It is believed that periphytic algae communities respond to physical, chemical and biological differences along reservoir zones. The seasons, due to hydrologic cycle variations, contribute with floristic and dynamics modifications in this community.

Material and methods

Study area – Iraí reservoir is located in the upper Iguaçu River watershed and was constructed to supply the Curitiba metropolitan area with water; it accounts for about 40% of the treated water for consumption (CARNEIRO et al., 2005) (Figure 1).

Iraí is characterized as an eutrophic reservoir (JÚLIO JÚNIOR et al., 2005) and is located next to urban, agriculture, pasture and mining areas. The susceptibility to eutrophication is also favored by characteristics such as shallow average depth and high retention time (CARNEIRO et al., 2005). Iraí reservoir was inaugurated in 2000; it has 15 km^2 of flooded area, average depth of 5 m and residence time from 8 to 13 months. Tributaries such as Cercado, Curralinho, Timbú and Canguiri streams drain the reservoir.

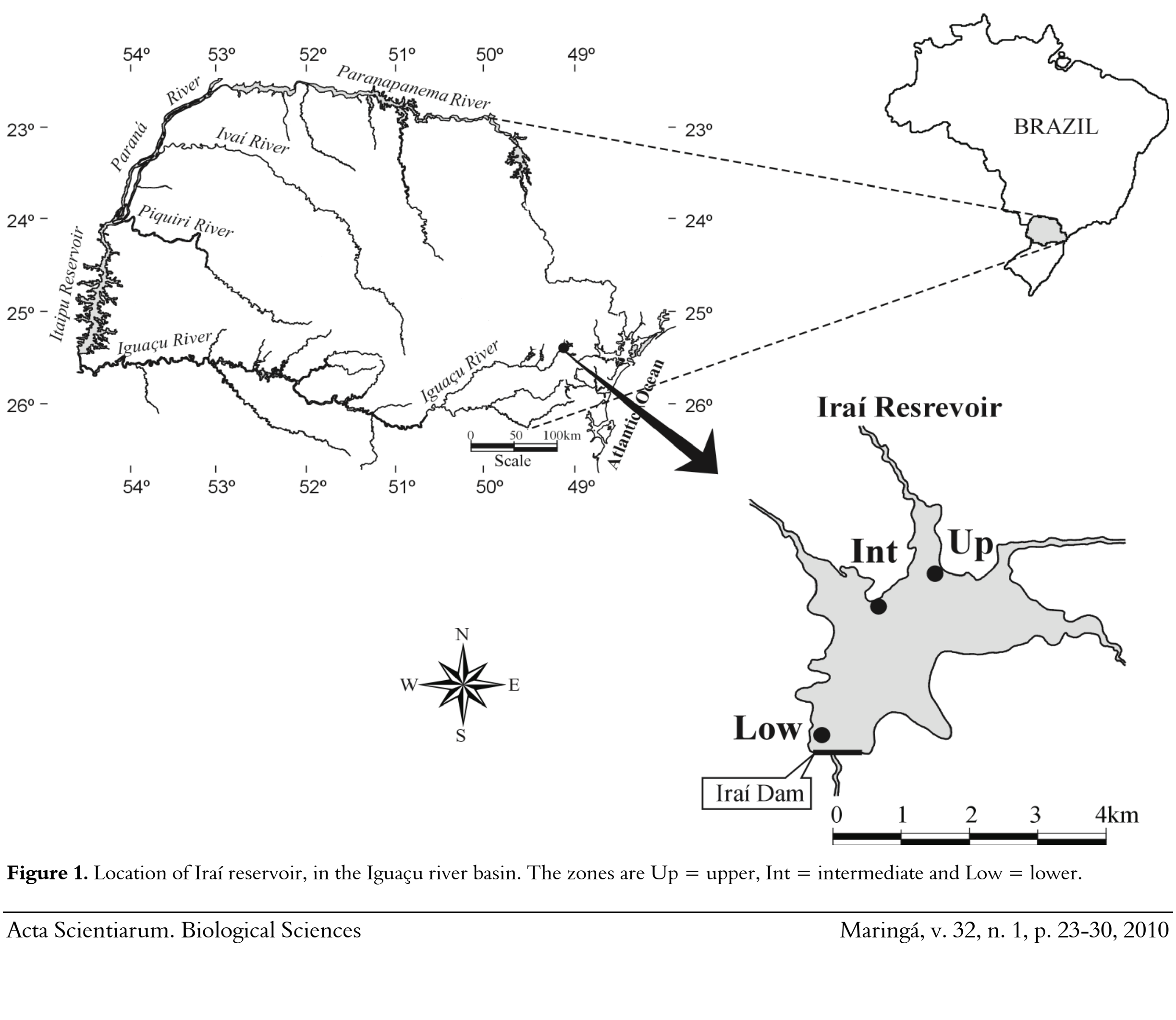

Figure 1. Location of Iraí reservoir, in the Iguaçu river basin. The zones are Up = upper, Int = intermediate and Low = lower.

Sampling method – Periphyton samples were taken in two seasons: summer (April) and winter (September) of 2002, always in the littoral zone of each one of the three zones of the reservoir (upper, intermediate and lower), amounting to six qualitative and twelve quantitative samples. The substratum established for sampling was rooted aquatic vegetation, because it occurs over all sampling stations. After the scraping area was defined, the periphytic material was shaved with a splinter, washed with distilled water, and transferred to 150 mL glass bottles. The samples were preserved with Transeau solution for qualitative analyses and with Lugol 5% for quantitative analyses.

For qualitative analysis, semi permanent slides were prepared, on average 20 slides for sample, or until no new taxa were further registered. The slide analyses were carried out on a binocular microscope, connected to ocular micrometric and objective lenses of 40 and 100X. The identification of the periphytic algae was based on classic, specific and regional literatures.

The counting of the periphytic algae community was carried out through inverted microscope according to Uthermöhl (1958) using random fields, as recommended by Bicudo (1990). The sedimentation of biological material was done on 2.8 mL chambers. The equation for density calculation followed Ros (1979), adapted for substratum area, the results were reported per unit of area. The counting limit was established according to the species rarefaction curve and up to reach at least 100 individual of the most abundant species (BICUDO, 1990).

Abiotic variables, recorded simultaneously to collection of biological data, were: water temperature (digital thermister YSI); transparency (Secchi disk); pH and conductivity (digital potentiometer Digimed); dissolved oxygen (digital oximeter YSI), dissolved organic carbon (Schimadzu carbon analyzer); total nitrogen, N-nitrite and N-nitrate (GUINÉ et al., 1980); N-ammoniac, total phosphorus and total dissolved phosphorus (MACKERETH et al., 1978). For the analysis of the dissolved fraction of nutrients, the samples were immediately filtered in Whatman GF/C filters. The values of these variables were provided by the Limnology laboratory of Nupelia (Research Nucleus in Limnology, Ichthyology and Aquaculture) of the State University of Maringá.

Precipitation and outflow data were supplied by ANA (National Water Agency) and Copel (Paraná State Electric Company). The rain precipitation corresponded to the average of ten previous days to sampling dates. The outflow data were provided by Copel and corresponded to the average of twenty previous days to sampling dates.

The similarity of the periphytic algae community among zones (upper, intermediate and lower) of the reservoir and between the periods was assessed through cluster analysis. The similarity measure was the presence and absence Jaccard index, and the clustering method was the unweighed pair group method with arithmetic mean (UPGMA); the analysis was computed on the NTSYS software version 1.5 (ROHLF, 1989). To test significant differences in density between seasons and zones (upper, intermediate and lower) of Iraí reservoir, a factorial Anova was computed using the software Statistica 7.1.

Results

Physical and chemical variables – In Iraí reservoir, water temperature was higher in summer. Dissolved phosphorus, particulate phosphorus, N-nitrate, precipitation and water transparency were higher in September. Particulate phosphorus and N-ammoniac were higher in intermediate zone in summer and in upper and lower zones in winter. Conductivity was higher in intermediate and lower zones in summer and in upper zone in winter. The suspension material and N-nitrite recorded the highest values in the upper zone in summer and the lowest values in the lower and intermediate zones in winter (Table 1). A detailed analysis of the abiotic data can be found in Pagioro et al. (2005).

Table 1. Physical and chemical data from Iraí reservoir during summer and winter of 2002. Up = upper; Int = intermediate; Low = lower. Rain (average of ten days prior to the sampling dates).

	Summer			Winter		
	Up	Int	Low	Up	Int	Low
Secchi disc (m)	0.35	0.4	0.55	Total	0.8	0.8
Conductivity (μS cm^{-1})	54.2	47.2	48.6	56.8	46.6	45.1
pH	6.1	6.86	7.41	6.66	7.31	6.49
Turbidity	2.4	4.78	5.28	4.1	6.62	5.24
Dissolved Oxygen (mg L^{-1})	6.9	8.92	9.1	9.21	9.48	7.62
Water Temperature (ºC)	25.2	25.4	26	13.5	17.3	16.7
Alkalinity (μEq L^{-1})	322.9	307.5	465.4	354.6	275.0	281.2
Suspension Material (mg L^{-1})	2.4	1.0	1.2	1.9	2.1	2.3
Total Nitrogen (μg L^{-1})	480.6	797.3	789.2	600.1	657.5	431.5
N-Nitrate (μg L^{-1})	205.5	10.6	16.5	231.3	106.8	76.2
N-Ammoniac (μg L^{-1})	80.8	10.0	11.7	95.5	4.7	12.3
N-Nitrite (μg L^{-1})	12.1	0.5	1.2	4.5	3.2	2.3
Total phosphorus (μg L^{-1})	31.5	37.0	39.2	42.7	39.2	48.5
Dissolved total phosphorus (μg L^{-1})	17.1	10.3	12.2	18.3	17.0	15.9
Rain precipitation (mm)	0.74	0.74	0.74	1.4	1.4	1.4
Outflow m^3 s^{-1}	13.48	13.48	13.48	1.92	1.92	1.92

Richness of algal classes and cluster analysis - In Iraí reservoir, 297 species were found, distributed in the groups Bacillariophyceae (33.67%), Zygnemaphyceae (21.55%), Chlorophyceae (14.81%), Oedogoniophyceae (1.35%), Xanthophyceae (1.01%), Chrysophyceae (2.02%), Rhodophyceae (0.34%), Dinophyceae (0.34%), Euglenophyceae (7.41%) Craspedomonadophyceae (0.67%), and Cyanophyceae

(16.84%). Among these species, 225 were recorded in summer (73 exclusive to that season) and 224 were recorded in winter (72 exclusive to that season) (Table 2).

Table 2. Total number of taxa by group of periphytic algae recorded in summer and winter, in Up = upper, Int = intermediate and Low = lower zones of Iraí reservoir in 2002.

	Summer			Winter			Total
	Up	Int	Low	Up	Int	Low	
Bacillariophyceae	50	37	39	67	55	39	100
Zygnemaphyceae	28	28	23	35	31	21	64
Chlorophyceae	24	31	19	15	18	16	44
Oedogoniophyceae	4	3	4	2	3	3	4
Xanthophyceae	2	2	3	3	3	0	3
Chrysophyceae	1	2	1	4	5	2	6
Rhodophyceae	0	1	0	0	0	0	1
Dinophyceae	1	1	1	1	1	0	1
Euglenophyceae	3	9	4	12	6	3	22
Craspedomonadophyceae	1	0	0	1	0	1	2
Cyanophyceae	19	27	22	15	22	13	50
Total	133	141	116	155	144	98	297

Bacillariophyceae dominance was observed for all regions (upper, intermediate and lower) and for both periods, although stronger in winter. For Zygnemaphyceae, the largest taxa number was registered in winter, with the exception of the lower zone, which had the largest species number in summer. Chlorophyceae and Cyanophyceae were more representative in summer for all zones; Euglenophyceae had the largest taxa number in summer, with the exception of the upper zone, which had more taxa in winter (Table 2).

The differentiation of the taxonomic composition in periphytic algae community in the zones of reservoir and different seasons (summer and winter) is observed in the similarity dendrogram (Figure 2).

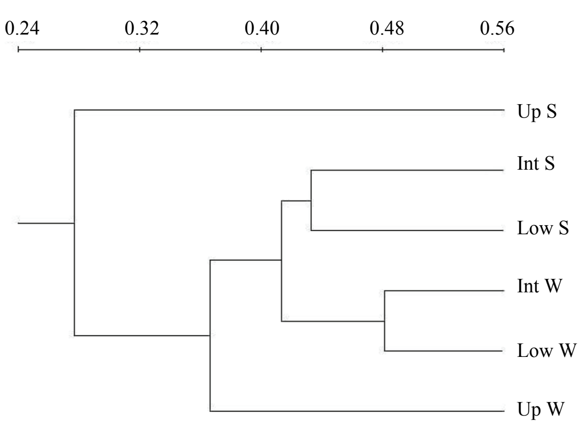

Figure 2. Dendrogram based on the Jaccard similarity index for the taxa recorded in Iraí Reservoir (r = 0.90). Zones: Up = upper, Int = intermediate and Low = lower. Seasons: S = summer and W = winter of 2002.

The periphytic community in upper zone during the summer was separated by other zones for both seasons. In other group, the upper zone of winter was separated of the rest. The intermediate and lower zones were similar in summer, and in winter, when the similarity was stronger. The composition the periphytic algae community was mainly characterized through the zones the reservoir and the season.

Density – The periphytic algae community density, for all regions, was the lowest during the summer (April) and the largest during the winter (September) (Figure 3).

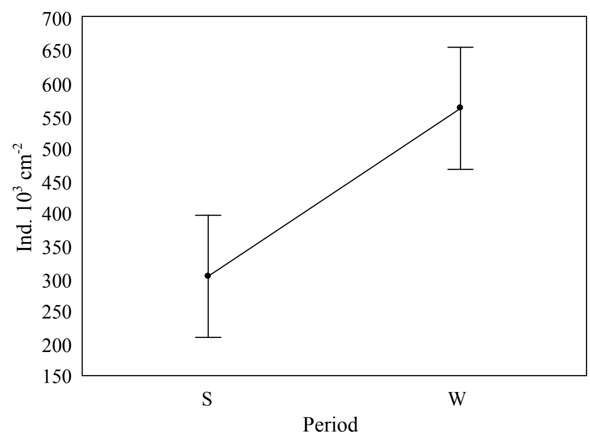

Figure 3. Results of the analysis of variance (Anova) for periphytic algae density data (ind. 10^3 cm^{-2}), of Iraí reservoir, during summer and winter of 2002.

No significant difference in periphytic algae density among regions (upper, intermediate and lower) was detected by Anova, whereas significant differences between seasons (summer and winter) were found ($p = 0.002$; $F = 16.48$).

The fluctuation the total periphytic algae community density was determined by variation trend of Bacillariophyceae abundance for all regions and during both seasons (Figure 4). The contribution the other algae group was larger in upper/lower regions in summer and in lower region in winter (Figure 5).

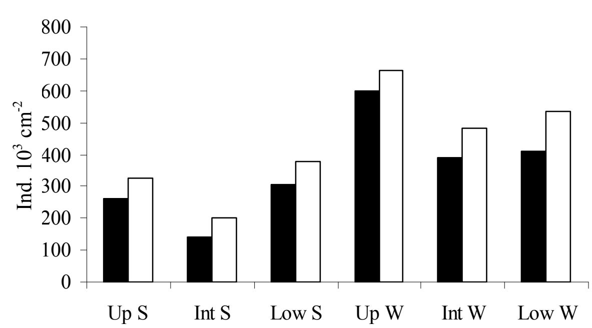

Figure 4. Periphytic algae community density (ind. 10^3 cm^{-2}) of Iraí Reservoir (in white total –density and in black – Bacillariophyceae), zones Up = upper, Int = intermediate and Low = lower, seasons S = summer and W = winter of 2002.

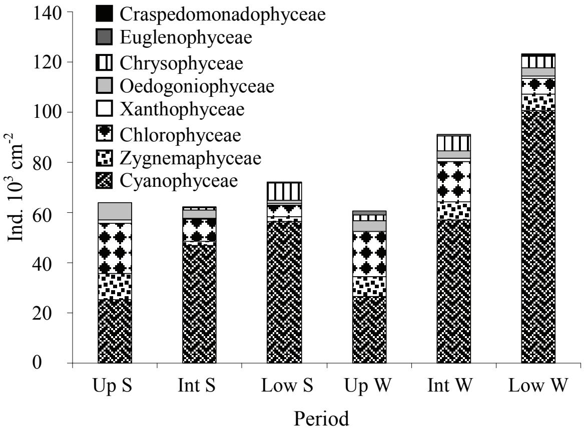

Figure 5. Density of the algae groups, excepting Bacillariophyceae, in Iraí reservoir, zones: Up = upper, Int = intermediate and Low = lower, in A = April and S = September, of 2002.

In summer, the algae group that had higher densities in upper zone was Bacillariophyceae (80.61%), Cyanophyceae (7.70%) and Chlorophyceae (6.15%). The other groups added to 5.54% of total density of the periphytic algae community. In intermediate zone, the groups with higher densities were Bacillariophyceae (69.16%), Cyanophyceae (23.39%), and Chlorophyceae (4.48%). The rest added to 3.07%. For lower zone 81.00% were Bacillariophyceae and 14.78% were Cyanophyceae, the other groups added to 4.22% (Figures 4 and 5).

In winter, the most abundant periphytic algae groups were, in upper zone, Bacillariophyceae (90.79%) and Cyanophyceae (4.08%), the other groups added 5.13% of total density. In intermediate zone, Bacillariophyceae were the most abundant group (81.12%), followed by Cyanophyceae (11.83%); the other groups added to 7.05%. For lower zone, Bacillariophyceae were the most abundant group (76.82%), followed by Cyanophyceae (18.88%); the other algae groups added to 4.3% of total periphytic algae density (Figures 4 and 5).

Discussion

The taxa number of periphytic algae registered in Iraí reservoir (299), in 2002, is comparable to those found in other Paraná reservoirs, for the same period. Felisberto and Rodrigues (2005) recorded 269 species in Salto do Vau reservoir during four seasons, 318 in Mourão reservoir and 405 in Rosana reservoir. Cetto et al. (2004), while studying the lower region of Iraí reservoir in 2001, recorded 130 taxa.

The dendrogram highlighted a differentiation of reservoir regions and seasons based on the similarity of periphytic algae taxa. The discrimination of upper zone from the rest and the similarity between the intermediate and lower zone for both seasons became clear. The upper region had 28 and 29 exclusive species, during summer and winter, respectively. It also showed differences in abiotic parameters, with higher conductivity, N-nitrate, N-nitrite and total dissolved phosphorus values and lower turbidity and water temperature values than the rest. According to Wetzel (1990) and Kimmel et al. (1990), this zone frequently functions as a river, with high turbulence, sediment load, nutrients and flow. However, the extent of the horizontal zonation varies for each individual reservoir, because it depends on the morphometry, retention time, thermal stratification, season and geographic position of the reservoir (STRAŠKRABA, 1999).

Although the effect of upper region may disappear with changes in basin width and depth along the axis of the reservoir, riverine influences may persist for considerable distances in some reservoirs (KENNEDY; WALKER, 1990). In reservoirs with retention time more than 200 days, like Iraí reservoir, the upper zone is small and most of reservoir has lacustrine characteristics (STRAŠKRABA, 1999; STRAŠKRABA; TUNDISI, 2000), which may be the reason for the similarity on taxonomic composition of the intermediate and lower zones for both seasons, especially during winter, when the outflow was the lowest and rain was the biggest. Also, some limnological variables were similar in intermediate and lower zones and different for the upper zone, such as the conductivity, the N-nitrate, N-ammonium and the N-nitrite.

Iraí reservoir is located very near urban, agriculture, pasture and mining areas (CARNEIRO et al., 2005). For Straškraba and Tundisi (2000) the reservoir itself is a collector of inputs and existing effects in hydrographic basins. Among these effects there are physical, chemical and biological processes and their consequences inside the reservoir. According to these authors, the hydrographic basin, including elements such as climate, precipitation, vegetation and human activities, determines the characteristics of waters that flow into reservoir, its temporal distribution and its effect on water quality.

The highest periphytic algae densities registered during winter may be explained by high nutrient concentrations found during this season. During winter the rain amount was a little higher than during summer, which probably carried external inputs with high nutrient contents to reservoir.

According to Tundisi (1990) and Tundisi et al. (1999), rain brings terrestrial downloads to the water body. Esteves (1988) assumes that in periods of rise of water level the concentration of dissolved and particulate organic substance increases, due to entrance of superficial water from tributaries and to sediment re-suspension. Silva and Esteves (1995) reported high concentrations of phosphorus and nitrogen forms in Acurizal and Porto de Fora bays (Pantanal do Mato Grosso), which are derived from extensive loads of organic material from the flood. In Mato Lagoon, located in Mogi-Guaçú river, Camargo and Esteves (1995) reported that during the rainy season there is an increase of nitrogen and phosphorus forms, and they attributed it, among others, to entrance of rain water in lagoon.

The outflow was low during winter, which suggests that flow speed was low during this season. For systems with reduced flow, the development of periphytic algae community is not limited by current, thus communities loosely adhered can develop (AZIM; ASAEDA, 2005).

The diatoms, a group that had high species number and density, are very good competitors for nutrients, specially phosphorus (SOMMER, 1988) and, frequently, dominate the periphytics algae communities (VERMAAT, 2005). They are considered efficient and fast colonizers, because many species have specialized structures to attach to substratum, such as mucilaginous stalks, production of mucilaginous matrices and formation of base fixed colonies (ROUND, 1991). In Paraná, diatoms dominance was found for periphytic algae community, in 2002, in Salto do Vau, Mourão and Rosana reservoirs (FELISBERTO; RODRIGUES, 2005) in 2001, in Iraí reservoir (CETTO et al., 2004), and in 2006, in Corvo and Guairacá rivers, both tributaries of Rosana reservoir (FONSECA et al., 2008) Also, in the Upper Paraná River floodplain, Rodrigues and Bicudo (2001) reported that the Bacillariophyceae is the richest and most dense class.

During winter, Bacillariophyceae dominance was recorded, but density of other groups, such as Cyanophyceae, Chlorophyceae and Zygnemaphyceae, was, in general, higher than densities registered during summer, mainly in intermediate and lower zones. For Vermaat (2005), green algae become abundant when nitrogen and phosphorus concentrations are high and there is wide light availability. These algae have short life cycles and are opportunistic, reaching fast growth rates when nutrient availability is adjusted (HAPPEY-WOOD, 1988), generally related to the eutrophication process (BIGGS, 1996). Sheath and Wher (2003) noticed that filamentous green algae develop preferentially in lentic and shallow environments. In lentic systems, the density of loosely adhered forms of Zygnemaphyceae and Chlorophyceae increase gradually (AZIM; ASAEDA, 2005); Zygnemaphyceae tend to be more common in metaphyton (HAPPEY-WOOD, 1988). Euglenophyceae are generally found in waters enriched with organic substances (ROUND, 1974).

Cyanophyceae are favored in nitrogen enriched environments (CROSSETTI; BICUDO, 2005). They also have competitive advantages in low phosphorus environments (PAERL, 1988), because they have the capacity to store this element internally (MUR et al., 1999). Additionally, they occur in high density in low flow environments (AZIM; ASAEDA, 2005). Therefore, the highest nitrogen concentrations, the lowest phosphorus concentrations and the reduced flow may have contributed to the largest Cyanophyceae density in winter.

Although the temperature was low during winter, the highest periphytic algae densities were detected in this season. Algae frequently require more nutrients when the temperature is lower than the growth optimum (VERMAAT, 2005), however the temperature is not a limiting factor when other factors are favorable (RODRIGUES; BICUDO, 2004).

Conclusion

The taxonomic composition of periphytic algae community in Iraí reservoir is different between zones and it has moderate variations between seasons. The density fails to verify differences among zones during a season, but it is markedly different between summer and winter.

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