Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v36i2.19560

Community structure of periphytic algae in a floodplain lake: a long-term study

Luciana Carapunarla[1,2*], Dirceu Baumgartner[3] and Liliana Rodrigues[1,2]

*[1]Laboratório de Ecologia de Perifíton, Núcleo de Pesquisa em Limnologia, Ictiologia e Aquicultura, Universidade Estadual de Maringá, Av. Colombo, 5790, 87020-900, Maringá, Paraná, Brazil. [2]Programa de Pós-graduação em Ecologia de Ambientes Aquáticos Continentais, Departamento de Biologia, Universidade Estadual de Maringá, Maringá, Paraná, Brazil. [3]Departamento de Engenharia de Pesca, Universidade Estadual do Oeste do Paraná, Toledo, Paraná, Brazil. *Author for correspondence. E-mail: lcarapunarla@gmail.com*

ABSTRACT. This is a study with temporal approach on the community of periphytic algae in the upper Paraná river floodplain, inserted in the Long-Term Ecological Research/CNPq, site 6. We sought to evaluate the community structure of periphytic algae, analyze the influence of abiotic factors on this structuring, and determine a model for the density of the phycoperiphyton community in 11 years of study. Samples were taken in two periods of the year (February/March and August/September) at Patos Lake, lentic environment between 1999 and 2009, using as substrate the petiole of *Eichhornia azurea* Kunth. The highest density was found in February 2002, after a long dry period. The lowest density was observed in March 2005, period with the highest richness in the study (165 taxa), when the water level of the Paraná river reached its highest value. During the study, the community density has responded to local environmental variables and the model generated has summarized 45% of the first NMDS axis, indicating the structure of the community by the intensity of flood pulse or even by the absence in determinate years.

Keywords: periphyton, flood pulse, temporal scale.

Estrutura da comunidade de algas perifíticas em ambiente lêntico de planície de inundação: um estudo de longa duração

RESUMO. Este é um estudo com abordagem temporal sobre a comunidade de algas perifíticas na planície de inundação do alto rio Paraná, inserido no projeto de Pesquisas Ecológicas de Longa Duração/CNPq, sítio 6. Neste trabalho buscou-se avaliar a estrutura da comunidade de algas perifíticas, analisar a influência dos fatores abióticos sobre essa estruturação e encontrar um modelo que possibilite o seu entendimento ao longo dos 11 anos de estudo. O perifíton foi coletado em dois períodos anuais (meses fevereiro/março e agosto/setembro), no lago dos Patos, ambiente lêntico, entre os anos de 1999 e 2009, o substrato utilizado foi pecíolo de *Eichhornia azurea* Kunth. A maior densidade foi encontrada no mês de fevereiro de 2002, logo após um longo período de seca. A menor densidade também foi constatada em março, no ano 2005, período que apresentou maior riqueza no estudo (165 táxons) e quando o nível do rio Paraná atingiu seu maior valor. Durante o estudo a densidade da comunidade perifítica respondeu às variáveis ambientais locais e o modelo gerado resumiu 45% do primeiro eixo da NMDS, indicando que a variação temporal da comunidade foi regida principalmente pela intensidade do pulso de inundação ou até mesmo pela ausência em determinados anos.

Palavras-chave: perifíton, pulso de inundação, escala temporal.

Introduction

The excessive development of macrophytes, along with other types of surfaces, such as particulate detritus and sediment, favors the profuse development of periphyton in wetlands (RODRIGUES et al., 2003). Periphytic algae present a remarkable spatial and temporal heterogeneity, including variations in the composition, density, biomass and productivity. Besides that, given the small size and short life cycle, algae can rapidly adjust to environmental changes (JUNK, 2005; STEVENSON, 1997).

There is a pattern of interaction between ecological factors, which affect the functioning and structure of this community, and can be classified according to the way these factors operate, either directly or indirectly. The relative importance of local variables reflects environmental characteristics at a greater extent, considered regional variables (RODRIGUES et al., 2009).

Floodplains are environments that present a high heterogeneity of habitats and high biodiversity and are controlled by flood pulses, the major driving force of these environments (NEIFF, 1990; WANTZEN et al., 2008a). In the upper Paraná river floodplain, upstream reservoirs caused a redistribution of flood pulses, especially after the closure of Porto Primavera Dam, the nearest to the study site (AGOSTINHO et al., 2004) influencing the natural conditions of environments associated.

During the flood pulse, the influence of the river on lacustrine environments is greater, altering limnological variables, by resuspending the sediment, until changing the lake morphology (THOMAZ et al., 2004; WANTZEN et al., 2008b). According to Thomaz et al. (2007), in the high water period, the system is homogenized, approximating the physical, chemical and biological characteristics of environments in a floodplain.

Models formulated by long-term studies assist in understanding irregular fluctuations and recurrent events, and are necessary for the development of framework for future monitoring (BOVO-SCOMPARIM; TRAIN, 2008; HOFMANN et al., 2008). Studies developed in the upper Paraná river floodplain show that the hydrological regime is an important structuring factor of the periphytic algal community, but most involves only a short time scale. Only one study comprises about seven years (ALGARTE et al., 2009).

For better understanding possible patterns in the abundance of periphytic algal species in a time scale including 11 years in the upper Paraná river floodplain, we initially examined variations in the density of periphytic algae in a connected lake within the Ivinheima river State Park, Brazil. Then we evaluated the influence of the hydrological regime and limnological variables. We hypothesized that the community structure of periphytic algae in the upper Paraná river floodplain is governed by the flood pulse of each year (temporal scale), and its abundance at group and taxa levels is defined by the availability of nutrients, particularly nitrogen and phosphorus.

Material and methods

This study was conducted at Patos Lake (Figure 1), a lentic environment connected to the Ivinhema river through a channel of about 10 m length. This lake is asymmetrical-shaped with several multispecific stands of macrophytes. Samplings were held between 1999 and 2009, in two year periods, February/March (period A) with greater rainfall, and commonly called as flood, and September/October (period B), also known as drought, during the researches of the PELD project - Long-Term Ecological Research.

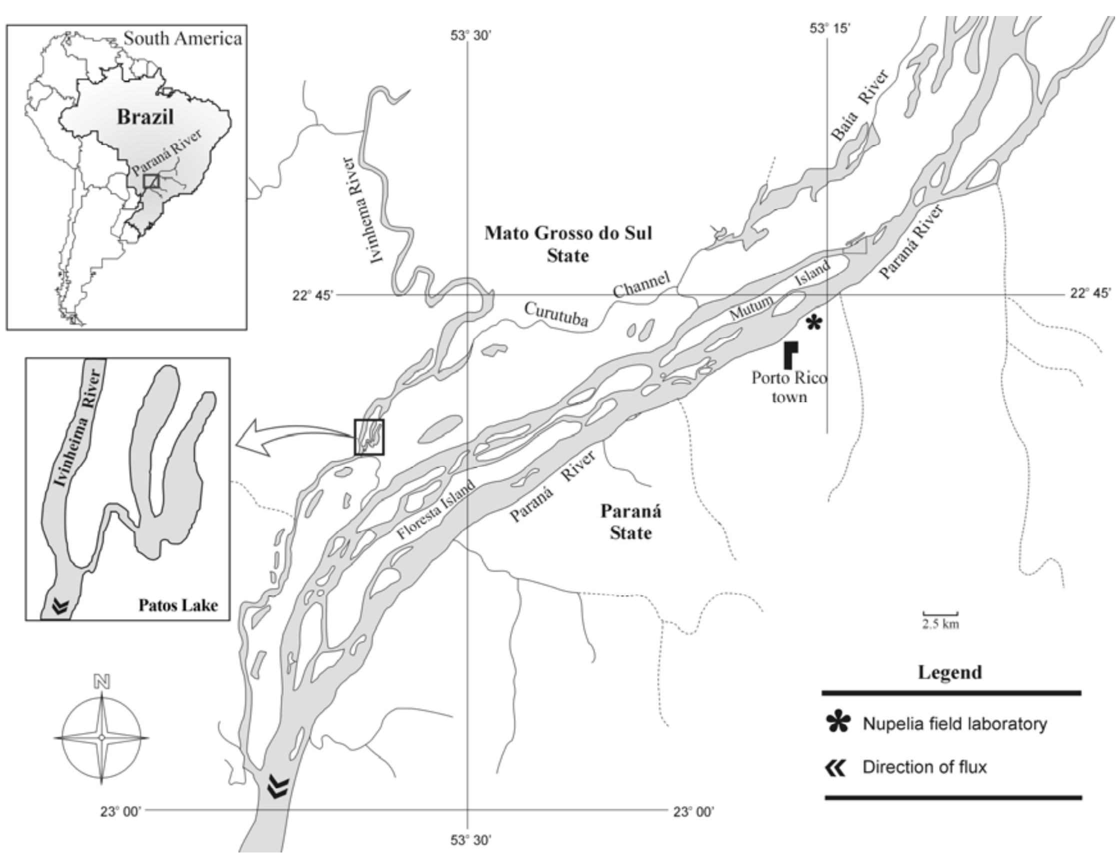

Figure 1. Location of the Patos Lake in the upper Paraná river floodplain, Mato Grosso do Sul State, Brazil (22º49'33.66"S; 53º33'9.9"W).

The substrate always collected in triplicate was the petiole of *Eichhornia azurea* Kunth at adult stage, as recommended by Schwarzbold (1990). The periphytic material was removed from the substrate, fixed with acetic lugol (5%) and stored in dark vials. The algal density was calculated and values were expressed per unit area (cm^2). Qualitative analyses were carried out through quantitative analyses.

Simultaneously to biotic data collection, the following abiotic variables were measured: water temperature (YSI portable oximeter, model 55), total nitrogen (TN) and nitrate (NO_{3-}) (flow injection analysis - FIA), ammonium (NH_{4+}), total phosphorus (TP) and orthophosphate (PO_4^{3-}), suspended matter (organic and inorganic). Data of water level variation of the Paraná river were provided by ANA (Brazilian National Water Agency).

A non-metric multidimensional scaling (NMDS) was run to ordinate periphyton samples. To identify which abiotic factors had influence on the community structure of periphytic algae, a multiple regression analysis was performed with independent variables (abiotic factors) on the dependent variable (1st NMDS axis) that summarized the information of the assemblage structure. The regression was run by the procedure of including all available factors (independent variables) and progressively excluding those non-significant ($p > 0.05$), seeking the simplest model with the most representative variables (*Backward stepwise procedure*).

After setting the complete model (*Least Squares Regression method-Backward Stepwise*), variables without a significant relationship ($p > 0.05$) were removed from the model until achieving a model with only statistically significant parameters. The assumptions of the models were checked according to Hair et al. (2005) and Kéry and Hatfield (2003).

Results

The Ivinhema river is influenced by the Paraná river when its level exceeds 4.5 m and inundates the floodplain. This connection occurred markedly in 2005, 2007 and 2009, when the systems remained connected for 29, 54 and 28 days, respectively. The highest level of the Paraná river was observed in January 2005, when reached 6.27 meters and the lowest level was in July 2001, with 1.10 meters (Figure 2).

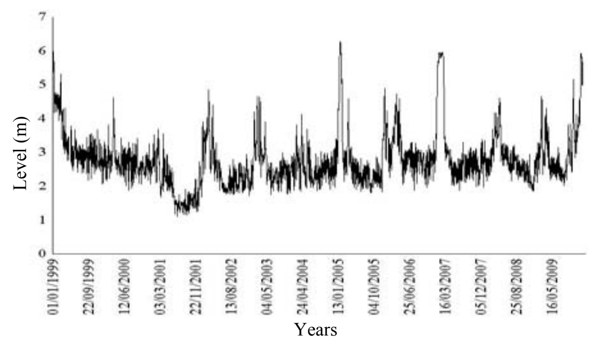

Figure 2. Water level of the Paraná river (1999-2009), according to data provided by ANA (Brazilian National Water Agency) and by Nupélia - *Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura* (2000-2009).

In general, higher values of temperature and lower values of dissolved oxygen were observed in February/March. Values of suspended matter, organic and inorganic, were higher in August/September. There was a trend of TN:TP values closer to ideal (approximately 16) in February/March (Table 1).

Table 1. Main abiotic parameters analyzed in February/March (A) and August/September (B) from 1999 to 2009, at Patos Lake, upper Paraná river floodplain, Mato Grosso do Sul, State. MSI (suspended inorganic matter); MSO (suspended organic matter); NT:PT (total nitrogen: total phosphorus ratio); NO_3 (nitrate); NH_4 (ammonium); PO_4 (phosphate).

	Temp.	pH	Cond.	Turb.	MSI	MSO	Alc.	NO3	NH4	PO4	NT/PT
A 1999	31.1	6.56	40.0	4.61	0.74	0.54	285.0	28.86	13.19	9.73	16.62
B 1999	24.0	6.74	27.0	23.60	2.05	0.71	239.6	29.38	14.00	8.81	16.06
A 2000	26.4	6.44	34.0	100.9	2.04	0.63	290.2	37.0	33.7	11.5	12.58
B 2000	17.7	6.43	37.4	13.5	1.00	1.00	260.9	0.0	15.6	0.9	26.43
A 2001	29.5	6.26	46.8	7.3	0.15	0.39	350.2	18.3	9.1	7.6	27.07
B 2001	21.4	6.15	26.2	46.7	1.55	0.60	181.2	53.2	11.4	7.0	20.34
A 2002	27.8	8.54	36.4	3.6	0.85	1.30	262.7	46.0	2.9	4.3	23.50
B 2002	19.6	6.69	28.3	21.0	8.75	1.75	262.4	86.6	5.3	2.1	24.78
A 2003	29.4	6.11	40.4	3.3	0.15	0.49	178.8	35.7	5.6	11.8	28.30
B 2003	20.7	7.32	32.9	8.0	1.28	1.12	244.3	2.6	4.5	15.2	8.28
A 2004	27.8	6.83	34.5	65.5	2.01	0.49	258.6	32.0	30.3	10.5	10.37
B 2004	24.4	6.08	34.8	36.1	0.80	0.28	195.7	14.9	9.3	13.0	16.32
A 2005	29.4	6.79	46.5	5.7	0.16	0.26	379.4	0.0	15.2	3.7	31.24
B 2005	17.3	6.80	27.1	126.1	3.03	0.54	190.2	95.6	32.3	8.3	30.55
A 2006	28.6	6.20	46.5	5.7	0.32	0.42	360.5	0.0	8.0	14.7	16.34
B 2006	24.2	6.88	33.4	57.2	1.53	0.43	240.7	41.0	14.9	18.8	31.35
A 2007	29.9	6.83	53.0	12,5	0.44	0.88	392.3	53.2	6.0	4.5	52.98
B 2007	24.8	7.66	39.6	30.6	1.35	0.63	367.0	0.0	9.1	8.2	27.88
A 2008	28.5	6.65	53.2	58.5	1.16	0.31	312.8	66.3	14.2	16.6	16.67
B 2008	20.3	7.46	37.1	14.5	1.23	0.67	301.7	0.0	2.2	4.1	31.87
A 2009	28.2	6.03	37.1	7.6	0.14	0.26	244.5	0.0	7.0	12.0	37.39
B 2009	22.7	6.05	60.0	11.0	0.06	0.08	362.3	0.0	35.5	10.4	43.77

In this study, we identified 639 taxa distributed into 11 classes: Cyanophyceae (200), Chlorophyceae (124), Bacillariophyceae (116), Zygnemaphyceae (104), Euglenophyceae (24), Chrysophyceae (20), Oedogoniophyceae (20), Xanthophyceae (17), Cryptophyceae (11), Rhodophyceae (2) and Dinophyceae (1).

During the eleven years of study, a higher total density of periphytic algae was verified in the low water period for eight years. Between 2002 and 2004, this pattern was reversed, that is, higher density values were registered in the high water period (Figure 3).

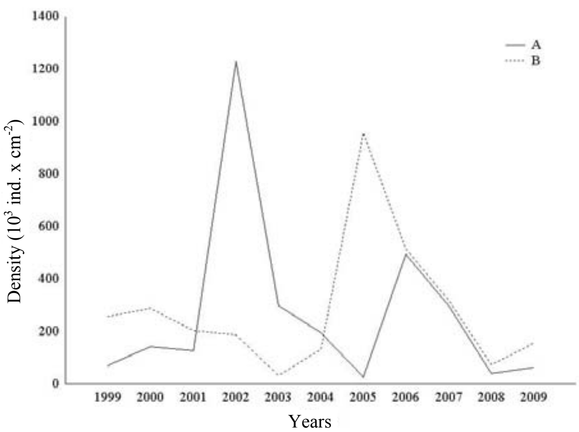

Figure 3. Total density of the periphytic algal community in 11 years (1999-2009) at Patos Lake, upper Paraná river floodplain, in February/March (A) and August/September (B).

The highest density was found in February 2002, after a long dry period. In turn, the lowest was observed in February/March 2005, period with the highest richness of the study (165 taxa). This year, among all, had the highest numerical representativeness of periphytic algae, in August/September. The years between 2006 and 2008 were characterized by density values similar between periods, with higher numerical representativeness always in the months of February/March, besides the downward trend in algal density. Between 1999 and 2003, in the period of August/September, it was verified a decreasing trend of total density of periphytic algae.

The fluctuation pattern of the total density along the 11 years was determined by the variation trend in the density of diatoms (class Bacillariophyceae), regardless of the period (Table 2). The class presented mean values of 174.10^3 individuals per cm^2, followed by Cyanophyceae with mean of 73.10^3 individuals per cm^2. This latter class had two density peaks in February/March (2002 and 2006), and one in August/September 2005 (Table 2).

Oedogoniophyceae, with mean of 16.10^3 individuals per cm^2, in general had its higher values in August/September (Table 2). In 2000, 2002 and 2006, its values were also high in February/March. Zygnemaphyceae has contributed more significantly in February/March (Table 2), especially in 2002, 2003 and 2007, whilst Chlorophyceae had higher densities in 2000, 2004 and 2005, in August/September and in February/March 2007 (Table 2).

Table 2. Density of periphytic algal classes ($.10^3$ ind. cm^2) in the study period (1999 - 2009) in February/March (A) and August/September (B), at Patos Lake, upper Paraná river floodplain, Mato Grosso do Sul State. (Bacill. = Bacillariophyceae; Zygne. = Zygnemaphyceae; Cyano. = Cyanophyceae; Oedogo. = Oedogoniophyceae; Chloro. = Chlorophyceae; Xanth. = Xanthophyceae; Eugle. = Euglenophyceae; Chryso. = Chrysophyceae; Crypto. = Cryptophyceae; Rodo. = Rodophyceae; Dino. = Dinophyceae).

	Bacill.	Zygne.	Cyano.	Oedogo.	Chloro.	Xanth.	Eugle.	Chryso.	Crypto.	Rodo.	Dino.
A1999	24.30158	6.294965	32.90874	3.25325	3.21413	0.854478	0.164622	0.039198	0	0	0
B1999	173.8187	2.963188	59.2188	16.84065	3.286383	0	0	0	0.161597	0	0
A2000	41.10586	0.143529	62.65107	32.31578	6.105929	0	0	0.624946	0	0.143529	0
B2000	207.4637	1.126296	48.65598	13.96607	13.06503	1.126296	0	1.576814	0.450518	0	0
A2001	23.87595	3.080636	74.39544	12.65334	6.805172	0.435619	0.328075	0.21917	6.553336	0	0
B2001	118.366	0.220599	56.63076	22.96746	2.492215	1.34547	0	0.441199	0	0	0
A2002	1051.805	22.54383	106.6277	37.93207	7.599221	0.638033	1.276066	0.797351	0.212678	0	0
B2002	137.0249	0.554566	32.73614	12.51795	4.596653	0	0.079188	0	0	0	0
A2003	62.57076	16.25743	190.4586	8.708433	10.01438	0.842495	1.987586	1.788508	5.796328	0	0.089983
B2003	9.733818	0	17.52087	0.081115	1.297842	0	0	3.163491	0.243345	0	0
A2004	103.7008	1.175957	73.28692	11.83403	4.107666	0.666922	0.308379	0.250822	0.150493	0	0
B2004	78.37542	0.806014	20.874	8.079721	23.1639	0.337495	0	0.168747	0	0	0
A2005	12.08478	1.40301	6.840179	3.92183	1.735389	0.190065	0.116799	0.055006	0.14044	0	0
B2005	655.7189	2.542344	235.9423	39.4331	16.2278	1.595373	1.906758	2.592481	0	0	0
A2006	276.5833	8.637116	167.3661	28.89282	9.727427	1.271038	0.725883	0.508415	0	0	0
B2006	360.6284	3.333649	119.624	26.47686	4.647601	0.522637	0	0.197829	0	0	0
A2007	206.1907	15.67686	47.15593	11.0733	17.33143	0	0	0	0	0	0
B2007	188.2582	4.094439	97.59276	20.22023	5.889267	0	0.259306	0.777918	0	0.518612	0
A2008	25.45005	0.526329	7.710873	3.970345	0.68544	0.12146	0.12146	0	0	0	0
B2008	36.01773	2.80168	21.79187	8.668153	3.262664	0.124126	0.04106	0.010265	0.010265	0.248252	0
A2009	9.822941	0.5359	38.96444	3.864621	3.148009	0.752055	0.100091	6.053865	0.16474	0	0
B2009	23.00965	8.779278	91.52843	20.44695	8.563399	1.620844	1.326502	0.8791	0	0	0

The other classes, Xanthophyceae, Euglenophyceae, Chrysophyceae, Cryptophyceae, Rhodophyceae and Dinophyceae, presented similar values along years and periods, varying around $0.5.10^3$ individuals per cm^2. Only Chrysophyceae had an increase in density in February/March 2009, and Cryptophyceae in 2001 and 2003, also in the same period (Table 2).

The NMDS separated on the axis 1, especially the years, and on the axis 2, especially the periods (Figure 4). Still on the axis 1, stands out the months August/September of years with high water level, associated with periods of February/March. Positively associated with the axis 1, it was grouped the periphytic community of 2001, 2003 to 2005, 2009, and of the period of August/September 2000. Negatively, it was grouped the community of 2002, 2006 to 2008, February/March 2000 and August/September 1999.

On the axis 2, the communities observed in February/March 1999, 2001 to 2006, 2008 and 2009 have been positively associated, along with those of 2005 and 2007 to 2009 of the period of August/September.

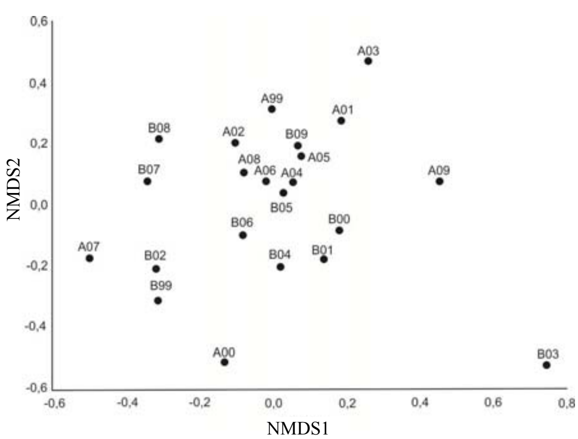

Figure 4. Non-metric Multidimensional Scaling (NMDS) of density of periphytic algal community at Patos Lake (A- February/March and B- August/September), upper Paraná river floodplain, along the 11 study years (1999-2009).

From the multiple linear regression model analysis, the major abiotic factors responsible for the variability in the community structure of periphytic algae were temperature (Temp), electrical conductivity (Cond), alkalinity (Alk), nitrate (NO_3) and water level of the Paraná river (level). Together, the factors explained 45.5% data variability. The predictions of the model are represented according to the equation:

$$nmds1 = -2.47\ Temp + -3.02\ Cond + +3.26\ Alk\ 0.64NO_3 + 1.84\ level + \beta$$

The model also revealed that temperature (Temp) and electrical conductivity (Cond) have been negatively associated with the first axis of the NMDS, whereas the alkalinity (Alk) and nitrate (NO_3) have been positively associated. The other abiotic factors had no significant beta (β) values, indicating the lack of statistical evidence for their consideration. The parameters of the model and their significances are listed in Table 2.

Table 2. Results of the regression of variability in the structure of periphyton assemblage grouped on the first axis of the NMDS according to temperature, electrical conductivity, alkalinity, nitrate (NO_3) and water level of the Paraná river (level). The fitted model was significantly related to the axis 1 of the NMDS ($F = 4.67672$; $p < 0.007217$).

NMDS1	Coefficient	t	p
Water temperature	-2.47	-2.47	0.0244
Electrical conductivity	-3.02	-2.58	0.0196
Alkalinity	3.26	3.13	0.0061
Nitrate (NO_3)	0.64	2.89	0.0102
Water level	1.84	2.52	0.0219

Discussion

The study years (1999-2009) were marked by a pronounced interannual variability, altered by the water level, which was also marked by irregular fluctuations during the study.

In several environments of the upper Paraná river floodplain, higher densities of periphytic algae were found in the low water period (ALGARTE et al., 2006, 2009). This behavior has not observed in 2002 to 2004, probably due to the long atypical period, with drought and absence of floods. After 2005, when the flood pulse took place, it was registered the return of increased density in August/September.

Each flooding process can present specific effects on the system attributes (TOCKENER et al., 2000). Timing, duration, intensity and speed of change of the level can influence physical and chemical characteristics of the water, by increasing the productivity of flooded areas, increasing the input of nutrients, which promote the additional productivity of the macrophyte-periphyton complex (WANTZEN et al., 2008b).

It was noticed a marked variation in abiotic factors between periods. This seasonal variation has the pulse as the major factor, which floods the lowlands and homogenizes the system as a whole. The studied lake is permanently connected to the Ivinhema River, but is especially controlled by the pulses of the Paraná River, when it exceeds 4.5 m. The NMDS ordination occurred as a function of years and periods, with higher density values negatively associated with the first axis, mainly due to the class Bacillariophyceae, and the second axis separated more markedly the high water periods positively, along with years that presented high water levels in the low water period.

The high density value observed in 2002 was due to the increased number of individuals of the genus *Fragilaria*, which according to Schmidt et al. (2004) present an increase of density under high values of pH, variable that had the highest values in this period (Table 1). The lowest density of the study was verified in February/March 2005, concurrent with the highest level of the Paraná river. One of the reasons for this reduction in density is the type of pulse, with great intensity (6.25 m) and low amplitude (approximately 15 days). This may have led the community to early successional stages, such as those found soon after the disturbance. Another reason may also be the increased turbidity (Table 1), which alters the quality of light available for photosynthesis, impairing some groups of algae, especially green algae.

Bacillariophyceae was the class with higher density in all years and periods, probably owing its adaptation to different environmental conditions and ecological tolerance. The greater relevance of diatoms in terms of contribution to the total density can be explained by the availability of nutrients, as well as the lower availability of light. Liess et al. (2009) verified that in environments with low light availability is common the dominance of some diatom species whose adaptive strategies, like the length/width ratio (high profile) of cells, collaborate to maintain the group under these conditions. The high profile maintains some species on upper layers of the periphyton matrix, enabling a greater access to the light. The availability of dissolved nutrients, most likely resuspended from sediment due to water circulation in both high and low waters, has also favored the increase of this class in both periods.

The second class in density values was Cyanophyceae that presented higher densities in February/March. The abundance of cyanobacteria is related to diverse strategies of this group, in which stands out the ability to store phosphorus in cells, to fix atmospheric nitrogen, and the best kinetics to absorb CO_2 in relation to other algal groups (LAMPERT; SOMMER, 2007).

The class Oedogoniophyceae had higher density values in August/September. Filamentous algae can characterize advanced successional periods as occurred in this period of the year, when the level variation was not great. These algae also increase the surface for colonization by other algal classes, such as Bacillariophyceae, contributing to its increase.

The level, as above discussed, is the major driving force in the upper Paraná river floodplain, affecting directly or indirectly all individual factors that influence the periphyton community. The flood pulse can also operate as a disturbance to the density of periphytic algae, once the changes in the system hydrodynamics can “clean up” the substrate, reducing the density, and increasing the richness, since there is a larger space for colonization by new species, with the displacement of propagules into the lake. The absence of pulse in the months of August/September also corroborates to the greater densities in this period.

Moreover, the temperature is considered a strong factor acting on the community, since it influences the algal metabolism (DeNICOLA, 1996). According to Seaburg and Park (1983), based on algal growth responses to different temperatures, the temperature alone is probably an important variable in regulating seasonal changes in the algal community structure. The temperature with negative coefficient indicates the greater densities in periods with lower temperatures, which coincides with the period of August/September, late winter in the study area. This is due to the predominance of diatoms that increase density under low temperatures and availability of nitrate (FLYNN, 2001) corroborating the pattern found in the study and defined by the model that presented nitrate with positive coefficient. In agreement with Murakami and Rodrigues (2009), the relative densities of the genera of diatoms were always greater in treatments with addition of nitrogen.

In turn, the alkalinity expresses the buffering capacity of the water and maintains the pH values with low variation, and the lower pH variation the better the photosynthetic activity, and therefore the algal development (LAMPERT; SOMMER, 2007). Low conductivity can be associated with the amount of humic substances that influence the penetration of light in the water column (LAMPERT; SOMMER, 2007), favoring thus classes such as Bacillariophyceae and Crysophyceae that thrive under low light availability.

Conclusion

With this study we verified that during the 11 years-time series the variation in the periphytic community is marked between periods, especially in those without extensive or intense pulses. Therefore the hypothesis that the flood pulse is the driving force on the periphytic community was accepted and strengthened the already stated by Tockener et al. (2000), who showed the need to maintain the variation in the water level depending on the organisms adapted to different conditions, to a greater or lesser degree. With this, we noted that these variables affect the community to a greater extent than nutrients, differently from hypothesized in this work. Among nutrients that indirectly influenced the community, stands out nitrogen. The continuity of natural phenomena without human interference on the floodplain environments is critical to their maintenance as a spatio-temporal dynamic ecosystem, subjected to cycles of expansion, shrinkage and fragmentation.

Acknowledgements

To Nupélia - *Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura* for the support, to PEA-UEM, to Capes, for the scholarship. This study is part of the Program PELD - Long-Term Ecological Research, site 6, coordinated by Nupélia, inserted in the International Long Term Ecology Research (Ilter).

References

AGOSTINHO, A. A.; THOMAZ, S. M.; GOMES, L. C. Threats for biodiversity in the floodplain of the upper Paraná river: effects of hydrological regulation by dams. **Ecohidrology e Hidrobiology**, v. 4, n. 3, p. 255-256, 2004.

ALGARTE, V. M.; MORESCO, C.; RODRIGUES, L. Algas do perifíton de distintos ambientes na planície de inundação do alto rio Paraná. **Acta Scientiarum. Biological Sciences**, v. 28, n. 3, p. 243-251, 2006.

ALGARTE, V. M.; SIQUEIRA, N. S.; MURAKAMI, E. A.; RODRIGUES, L. Effects of hydrological regime and connectivity on the interannual variation in taxonomic similarity of periphytic algae. **Brazilian Journal of Biology**, v. 69, n. 2, p. 609-616, 2009.

BOVO-SCOMPARIN, V. M.; TRAIN, S. Long-term variability of the phytoplankton community in an isolated floodplain lake of the Ivinhema river State Park, Brasil. **Hydrobiologia**, v. 610, n. 1, p. 331-344, 2008.

DeNICOLA, D. M. Periphyton Responses to Temperature at different Ecological Levels. In: STEVENSON, R. J.; BOTHWELL, M. L.; LOWE, R. L. (Ed.). **Algal ecology**: freshwater bentic ecosystems. London: Academic Press, 1996. p. 150-183.

FLYNN, K. J. A mechanistic model for describing dynamic multi-nutrient, light, temperature interactions in phytoplankton. **Journal of Plankton Research**, v. 23, n. 9, p. 977-997, 2001.

HAIR, J. J. F.; ANDERSON, R. E.; TATHAM, R. L.; BLACK, W. C. **Análise multivariada de dados**. 5. ed. Porto Alegre: Bookman, 2005.

HOFMANN, H.; LORKE, A.; PEETERS, F. Temporal scales of water-level fluctuations in lakes and their ecological implications. **Hydrobiologia**, v. 613, n. 1, p. 85-96, 2008.

JUNK, W. J. Flood pulsing and the linkages between terrestrial, aquatic, and wetland systems. **Verhandlungen des Internationalen Verein Limnologie**, v. 29, n. 1, p. 11-38, 2005.

KÉRY, M.; HATFIELD, J. S. Normality of raw data in general linear models: the most widespread myth in statistics. **Bulletin of the Ecological Society of America**, v. 82, n. 1, p. 92-94, 2003.

LAMPERT, W.; SOMMER, V. **Limnoecology, the ecology of lakes and streams**. 2nd ed. Oxford: University Press, 2007.

LIESS, A.; KATHARINA, L.; SCHULZ, F.; PIGGOTT, J.; MATTHAEI, C. D.; TOWNSEND, C. R. Light, nutrients and grazing interact to determine diatom species richness via changes to productivity, nutrient state and grazer activity. **Journal of Ecology**, v. 97, n. 2, p. 326-336, 2009.

MURAKAMI, E. A.; RODRIGUES, L. Respostas das algas perifíticas às alterações de temperatura e ao enriquecimento artificial de nutrientes em curto período de tempo. **Acta Scientiarum. Biological Sciences**, v. 31, n. 3, p. 273-284, 2009.

NEIFF, J. J. Ideas para la interpretación ecológica del Paraná. **Interciencia**, v. 15, n. 6, p. 424-441, 1990.

RODRIGUES, L.; BICUDO, D. C.; MOSCHINI-CARLOS, V. O papel do perifíton em áreas alagáveis e nos diagnósticos ambientais. In: THOMAZ, S. M.; BINI, L. M. (Org.). **Ecologia e manejo de macrófitas aquáticas**. Maringá: Eduem, 2003. p. 211-230.

RODRIGUES, L.; OLIVEIRA, C. E. M.; FONSECA, I. A.; ZANON, J. E.; ALGARTE, V. M.; SIQUEIRA, N. S.; MURAKAMI, E. A. Perifíton. In: BENEDITO, E. (Org.). **Ecologia do ribeirão Diamante, Estação Ecológica do Caiuá, PR**. Maringá: Eduem, 2009. p. 49-58.

SCHMIDT, R.; KAMENIK, C.; LANGE-BERTALOT, H.; KLEE, R. *Fragilaria* and *Staurosira* (Bacillariophyceae) from sediment surfaces of 40 lakes in the Austrian Alps in relation to environmental variables, and their potential for palaeoclimatology. **Journal of Limnology**, v. 63, n. 2, p. 171-189, 2004.

SCHWARZBOLD, A. Métodos ecológicos aplicados ao estudo do perifíton. **Acta Limnologica Brasiliensia**, v. 3, n. 1, p. 545-592, 1990.

SEABURG, K. G.; PARKER, B. C. Seasonal differences in the temperature ranges of growth of Virginia algae. **Journal of Phycology**, v. 19, n. 4, p. 380-386, 1983.

STEVENSON, R. J. Scale-dependent determinants and consequences of benthic algal heterogeneity. **Journal of the North American Benthological Society**, v. 16, n. 1, p. 248-262, 1997.

THOMAZ, S. M.; PAGIORO, T. A.; BINI, L. M.; ROBERTO, M. C.; ROCHA, R. R. A. Limnological characterization of the aquatic environments and the influence of hydrometric levels. In: THOMAZ, S. M.; AGOSTINHO, A. A.; HAHN, N. S. (Ed.). **The upper Paraná river and its floodplain**: physical aspects, ecology and conservation. The Netherlands: Backhuys Publishers, 2004. p. 75-102.

THOMAZ, S. M.; BINI, L. M.; BOZELLI, R. L. Floods increase similarity among aquatic habitats in river-floodplain systems. **Hydrobiologia**, v. 579, n. 1, p. 1-13, 2007.

TOCKENER, K.; MALARD, F.; WARD, J. V. An extension of the flood pulse concept. **Hydrological Process**, v. 14, n. 16/17, p. 2861-2883, 2000.

WANTZEN, K. M.; JUNK, W. J.; ROTHHAUPT, K. O. An extension of the floodpulse concept (FPC) for lakes. **Hydrobiologia**, v. 613, n. 1, p. 151-170, 2008a.

WANTZEN, K. M.; ROTHHAUPT, K. O.; MÖRTL, M.; CANTONATI, M.; TÓTH, L. G. FISCHER, P. Ecological effects of water-level fluctuations in lakes: an urgent issue. **Hydrobiologia**, v. 613, n. 1, p. 1-4, 2008b.

Received on January 22, 2013.
Accepted on May 16, 2013.