Periphytic Cyanobacteria in different environments from the upper Paraná river floodplain, Brazil.

FONSECA[1], I.A. & RODRIGUES[2], L.

[1,2] Periphyton Ecology, Research Nucleus in Limnology, Ichthyology, and Aquiculture- Nupélia/ PEA/UEM, State University of Maringá, Avenue Colombo, 5790 – 87020-900 Maringá–Pr, Brazil. e-mail: [1]irauzaf@hotmail.com; [2]lrodrigues@nupelia.uem.br

ABSTRACT: Periphytic Cyanobacteria in different environments from the upper Paraná river floodplain, Brazil. The periphytic cyanobacteria community from the upper Paraná river floodplain was studied in two hydrological periods during 2001. In total, 137 taxa were registered, organized in 42 genera, 15 families and 4 orders. Of those, 70 taxa were not previously registered for the upper Paraná river floodplain. Despite the anual variability and anthropogenic impacts, the floodplain is characterized by two distinct periods, high and low waters. The environments presenting the largest numbers of taxa, in decreasing order, during the high water period were Pau Véio backwater, Clara lagoon, Cortado channel and Garças lagoon. However, during low waters, these environments were Clara lagoon, Pau Véio backwater, Cortado channel and Garças lagoon. Considering indicator value index species -INDVAL (simple method to find indicator species and species assemblages characterizing groups of samples), five species can be presumed as indicators for hydrological periods (Calothrix brevissima G.S. West, Leptolyngbya perelegans (Lemmermann) Anagnostidis & Komárek, Lyngbya sp., Merismopedia tenuissima Lemmermann and Oscillatoria limosa Agardh ex Gomont) according to the specie's morphologies.
Key-words: Cyanobacteria, Floodplain, Paraná River, Periphyton.

RESUMO: Cianobactérias perifíticas em diferentes ambientes da planície de inundação do alto rio Paraná, Brasil. A comunidade de cianobactérias perifíticas na planície de inundação do alto rio Paraná foi estudada em dois períodos hidrológicos durante o ano de 2001. No total, 137 táxons foram registrados, organizados em 42 gêneros, 15 Famílias e 4 ordens. Desses, 70 táxons não foram registrados previamente para a planície de inundação do alto rio Paraná. Apesar da variabilidade anual e dos impactos antropogênicos, a planície é caracterizada por dois períodos hidrológicos distintos, águas altas e baixas. Os ambientes com maiores números de táxons, em ordem decrescente, em águas baixas foram o ressaco do Pau Véio, lagoa Clara, canal Cortado e lagoa das Garças. Entretanto, durante as águas baixas, estes ambientes foram a lagoa Clara, ressaco do Pau Véio, canal Cortado e lagoa das Garças. Considerando o índice de valor de indicador de espécies - INDVAL (método simples para encontrar espécies indicadoras e as assembléias que caracterizam grupos amostrais), cinco espécies podem ser presumidas como indicadores nos períodos hidrológicos (Calothrix brevissima G.S. West, Leptolyngbya perelegans (Lemmermann) Anagnostidis & Komárek, Lyngbya sp., Merismopedia tenuissima Lemmermann e Oscillatoria limosa Agardh ex Gomont) de acordo com a morfologia das espécies.
Palavras–chave: Cianobactéria, Planície de inundação, Alto rio Paraná, Perifíton.

Introduction

River-floodplain systems are characterized by pronounced sazonality in the hydrological level reflected in pulses of energy and matter and considered as the main power force acting on the performance of such ecosystems (Neiff, 1990; Junk, 1996; Thomaz et al., 2004).

In periphyton, algae gains prominence, therefore they play basic role as primary producer and, consequently, assumes key position in the food chain of continental aquatic systems (Goldsborough & Robinson, 1996; Lam & Lei, 1999; Cattaneo & Kalf, 1978). The uses of algae periphytic community in environment management have been increased. Especially because its way of sessil life and great wealth of species, they present different preferences and tolerances in environments (Rodrigues et al., 2003).

Cyanobacteria has been noted in several habitats, mainly on tropical areas, therefore rejecting the paradigm that this group is constituted of cosmopolitan species. Great distinction of tropical habitats and ecological diversity can explain the high morphotypic diversity (and speciation) of cyanobacterial types. Such diversity is probably based on fast adaptability and genetic stabilization of new ecotypes and morphotypes in environments (Rejmánková et al., 2004).

The knowledge of species diversity and understanding of ecosystem, as well as environmental changes, are necessary for effective protection and potential use of cyanobacteria communities.

No study has ever been conducted in the upper Paraná river floodplain focusing only cyanobacteria. The main issue to be addressed in this work is whether the cyanobacteria community will respond to hydrological periods on the upper Paraná river floodplain and whether there are indicative species.

Material and methods

Study Site

A qualitative and quantitative survey of periphytic cyanobacteria was conducted in four environments in the upper Paraná river floodplain, on the border between the states of Paraná and Mato Grosso do Sul (22° 45' S; 53° 30' W). The selected environments were: a) Clara lagoon, lentic environment with no communication to the main riverbed, located on Porto Rico Island; b) Garças lagoon, another lentic environment, located on the right margin of Paraná river, with permanent communication through a narrow channel; c) Pau Véio backwater, located on Mutum Island, semilotic environment presenting a dike separating it from Paraná river; d) Cortado channel, a lotic environment in high waters and semilotic in low water periods, located on the left margin of Paraná river (Fig. 1).

Collections of periphytic cyanobacteria community were made in four environments with distinct hydrodynamic regimens semiannually during 2001, encompassing both periods — high waters (HW, February) and low waters (LW, August). The standardized substract used for comparison were mature stalks of Eichhornia azurea Kunth in the adult stadium, as recommendation of Schwarzbold (1990), which is present in all environments studied and represent the most abundant macrophyte in the floodplain.

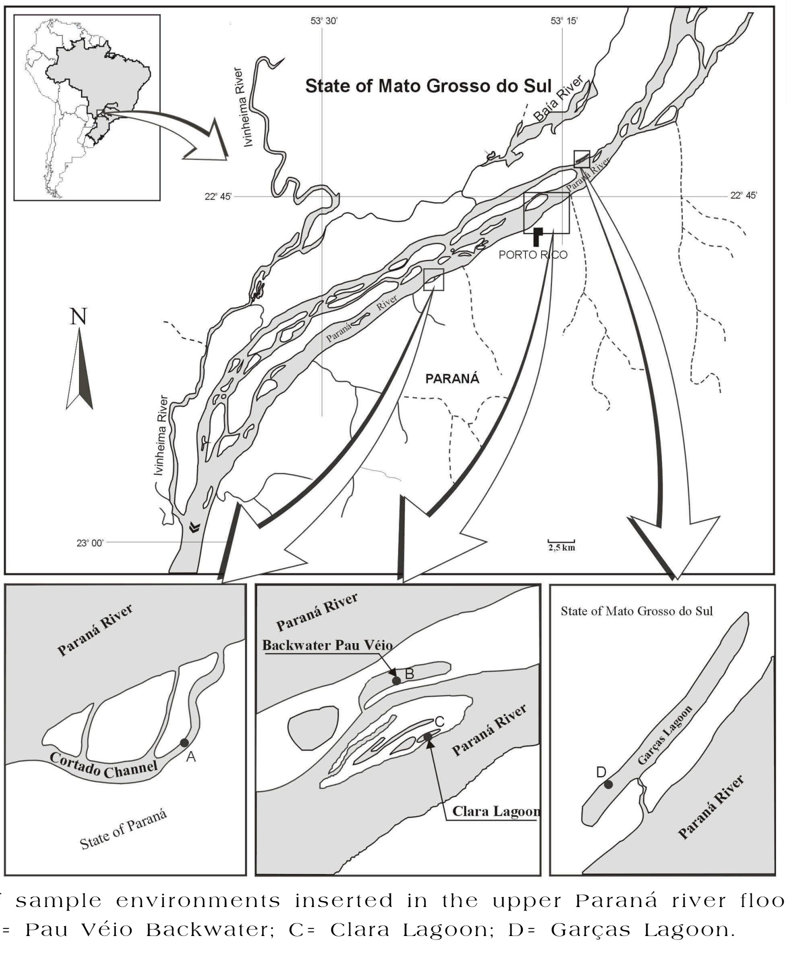

Figure 1: Location of sample environments inserted in the upper Paraná river floodplain. A= Cortado Channel; B= Pau Véio Backwater; C= Clara Lagoon; D= Garças Lagoon.

The petioles were collected random, in different banks of macrophyte, always in replica, and conditioned in humid camera. Removal of periphytic community from substrata were (two petioles of different plants) made in the field, using a shave lamina and gush of destilled water.

Environmental Variables

Abiotic variables like as, transparency (Secchi disk depth), conductivity, turbidity, dissolved oxygen, water temperature, total nitrogen (Guiné et al., 1980), ammonia, total phosphorus, orthophosphate and organic nitrogen (Mackareth et al., 1978) were measured simultaneously to the biotic. Abiotic variables data were supplied by the Laboratory of Basic Limnology, of the Research Nucleus in Limnology, Ichthyology and Aquiculture of the State University of Maringá – Nupélia/UEM.

Periphytic Algae analysis

Periphytic cyanobacteria community was taken to taxonomical analysis. This material was fixed in acetic lugol 5% for quantitative analysis, and for qualitative analysis fixed and preserved in Transeau solution (ratio 1:1). Fresh slides were prepared until no new taxa occurred. This analysis was performed in a binocular microscope, coupled with a micrometric eyepiece and 100X objective lens. Papers of Anagnostidis & Komárek (1988); Anagnostidis & Komárek (1990); Komárek & Anagnostidis (1986) and Komárek & Anagnostidis (1989) were used for the main identification.

Material fixed for quantification of periphytic cyanobacteria community was packed in a known volume and counted according to Utermöhl (1958) and through random fields, as recommended by Bicudo (1990). The results were expressed as organisms per area of substract. Chambers with 2.8 or 2.9 ml were used for the sedimentation of biological material. The density was calculated through an equation based on Ros (1979) and adapted to the area of substract.

Data analysis

Principal Components Analysis (correlation matrix) was accomplished for ordination of hydrological periods and environments, in relation to the limnological variables analyzed. The software used was Pc-Ord, version 5.0 for Windows (McCune & Mefford, 1990).

Analysis of indicating species was used (INDVAL) (Dufrêne & Legendre, 1997), as tool in the determination of the preferences of the identified species for habitats that present specific environments characteristic. This method combines information on abundance of a species in one determined group of samples units and the allegiance of the occurrence of this species in a certain group of samples. Indicative values are calculated for each species inside of each group, and these are tested for the significance statistics using the Monte Carlo test. The software used for multivaried analyses was the program PC-ORD, version 5.0 for Windows (McCune and Mefford, 1990).

The similarity of periphytic algae between different environments and hydrological periods was measured by grouping analysis (UPGMA). In this analysis, it was used the criterion of presence and absence in accordance with program NTSYS version 1.5 (Rohlf, 1989); with determination of the distance through Jaccard index.

Dominant species were defined according to Lobo & Leighton (1986), those showing density superior to 50% of total sample density, whereas abundant species as those showing densities superior to the average density on each sample.

The values of fluviometric level of Paraná River was supplied by the Agência Nacional das Águas (ANA) and obtained in the meteorological station of Porto São José (Paraná state).

Results

The hydrological cycle of Paraná river, in the study region, presents two distinct phases: high waters that occur during the period of higher temperatures, and low waters, during colder months (Fig. 2). Therefore, it is obvious that several flood pulses occur during the same hydrological cycle, mainly on high waters. During low waters period, these environments present limnological characteristics best associated to autochthonous processes, whereas during high waters these characteristics tend to be more similar.

Principal Component Analysis (PCA) demonstrated that, the first two axis accounted for 65.8% of total variation, showing two groups. The first axis (43.1%)

separated all environments connected to the main riverbed from that not connected (Clara lagoon), according to the parameters: oxygen and turbidity (positively) and nutrient forms (negatively). The second axis (22.8%) discriminated the hydrological periods (HW and LW) according to conductivity (positively) and water temperature, Secchi's disk depth and total nitrogen (negatively) (Fig. 3; Tab. I).

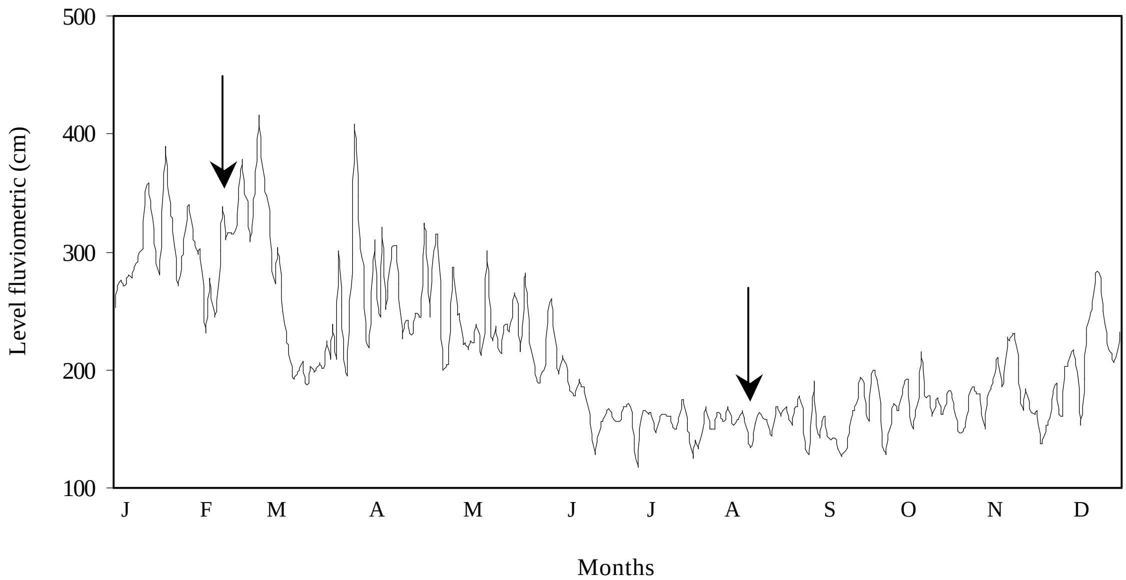

Figure 2: Hydrometric level of Paraná river during 2001. Arrows indicate collection periods. Source: Agência Nacional das Águas (ANA).

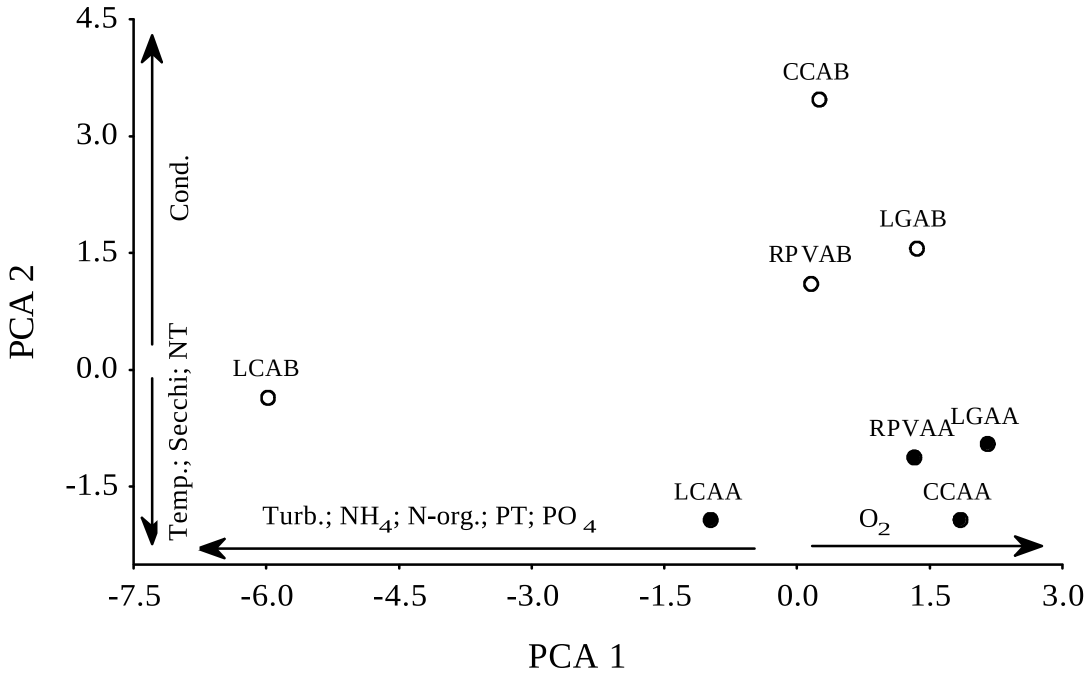

Figure 3: Principal Component Analysis (PCA) related to abiotic variables registered in four environments of the upper Paraná river floodplain, in two hydrological periods. Temp.= temperature; Secchi= Secchi disk depths; NT= total nitrogen; Cond.= conductivity; Turb. Turbidity; NH_4= ammonium; N-org.= organic nitrogen; PT= total phosphorus; PO_4= orthophosphate; O_2= dissolved oxygen .

Table I: Correlations of variables with Principal Components 1 and 2.

Variable	Axis 1	Axis 2
Secchi	-0.1291	-0.4107
Temperature (H_2O)	0.2655	-0.4116
Conductivity	0.0116	0.4298
Turbid	-0.3686	-0.0274
Oxygen	0.3624	0.0752
TN	-0.2751	-0.3871
NH_4	-0.3187	0.0385
N-org	-0.3123	-0.2524
TP	-0.3673	0.0333
PO_4	-0.2930	0.2476
% Variation explained	**43.1**	**22.8**
Broken-stick	3.2	2.2

The periphytic cyanobacteria community in the four analyzed environments totaling 137 taxa organized in 42 genus, 15 families and 4 orders. The most representative order was Oscillatoriales (73) and the most representative family was Pseudanabaenaceae (24 taxa) (Tab II).

Among taxa surveyed, 70 were not yet reported for the upper Paraná river floodplain. According to taxon abundance, the high waters period presented the highest number (73 taxa) compared to low waters (58 taxa), demonstrating a significant difference (p= 0.00)

Table II: Species of cyanobacteria in the environments for each studied hidrological period in 2001. CC= Cortado Channel, RPV= Pau Véio Backwater, LG= Garças Lagoon, LC = Clara Lagoon; HW= High waters, LW= Low waters.

Water Phases	HW				LW			
Sampling sites	**CC**	**RPV**	**LG**	**LC**	**CC**	**RPV**	**LG**	**LC**
Order Chroococcales								
Family Chroococcaceae								
Chlorogloea sp						x		
Chroococcus dispersus (Keissler) Lemmermann		x						
C. cf. major Komárek & Komárková-Legnerová *				x	x	x		
C. limneticus Lemmermann	x				x			
C. minor (Kützing) Nägeli*				x				x
C. minutus ((Kützing) Nägeli*			x					
Chroococcus sp		x			x			x
Chroococcus sp1				x				x
Family Chamaesiphonaceae								
Chamaesiphon sp		x	x					x
Family Microcystaceae								
Anacystis sp			x					
Anacystis sp1				x		x		
Aphanothece microscopica Nägeli *		x						
Aphanothece sp	x	x						
Aphanocapsa parasitica (Kützing) Komárek & Anagnostidis*				x				
Aphanocapsa sp		x		x	x		x	x

Table II: Cont.

Aphanocapsa sp1		x						
Aphanocapsa sp2		x						
Cyanodiction sp	x							
Gomphosphaeria sp				x				x
Merismopedia duplex Playfair*				x				
M. cf. minima Beck*					x			
M. glauca (Ehrenberg) Nägeli*					x			
M. tenuissima Lemmermann	x		x	x				x
Merismopedia sp	x		x					x
Synechocystis aquatilis Sauvageau*				x				x
S. pevalekii Ercegovic*		x						x
Synechocystis sp				x				
Synechococcus elongatus (Nägeli) Nägeli*						x		
S. cf. sulfuricus Dor*						x		
S. mundulus Skuja*		x	x	x			x	x
Synechococcus sp		x		x				x
Synechococcus sp1		x		x				
Order Nostocales								
Family Microchaetaceae								
Microchaete tenera Thuret			x					
Microchaete sp			x					
Family Nostocaceae								
Anabaena affinis Lemmermann*			x					
A. cylindrica Lemmermann		x	x	x	x		x	x
A. subcylindrica Borge*		x		x				
A. sphaerica Bornet & Flahault*			x	x				
Anabaena sp								x
Anabaena sp1		x						
Anabaena sp2				x				
Anabaenopsis sp		x	x					x
Aphanizomenon flos-aquae (L.) Ralfs*		x						
Cylindrospermopsis raciborski (Woloszynska) Seenayya & Suba Rajir			x	x			x	x
Cylindrospermum catenatum Ralfs*		x						
C. musicola Bornet & Flahault		x		x				x
Nodularia sp			x					
Nostoc muscorum Agardh*	x	x						
Nostoc sp		x	x	x		x		
Family Rivulariaceae								
Calothrix brevissima West	x	x	x	x			x	
C. cylindrica Frémy*			x					
C. fusca (Kützing) Bornet & Flahault	x		x	x		x	x	
Calothrix sp	x		x					

Table II: Cont.

Calothrix sp1		x						
Calothrix sp2				x				
Rivularia cf. aquatica Wild*		x						
R. cf. globiceps West*		x						
Rivularia sp	x		x	x				
Family Scytonemataceae								
Scytonema chiastrum Geitler*		x						
S. mirabilis (Dillw) Bornet*		x						
Order Oscillatoriales								
Family Borziaceae								
Borzia trilocularis Conh ex Gomont*	x	x		x				
Borzia sp			x	x				
Komvophoron crassum (Vozzen) Anagnostidis & Komárek*	x		x	x				
K. schmidlei (Jaag) Anagnostidis & Komárek*				x				
Komvophoron sp					x		x	
Family Homoeotrichaceae								
Heteroleibleinia Kuetzingii (Schmidle) Compère*						x	x	x
Family Oscillatoriaceae								
Lyngbya cebenensis (Gomont) Compére*						x		
L. lagerheimii (Möbius) Gomont	x							
L. comperei Senna	x					x		
L. gomontiana Senna*		x						
L. nigra Agardh ex Gomont			x					
L. cf. polysiphonae Frémy*		x						
Lyngbya sp			x	x				
Lyngbya sp1	x	x						
Lyngbya sp2			x	x			x	
Oscillatoria annae van Goor*			x	x				
O. limosa Agardh*				x				
O. princeps Vaucher ex Gomont	x	x		x			x	
O. proteus Skuja*	x			x				
O. cf. proteus Skuja*	x							
O. rupicola Hansgirg*	x							
O. trichoides Szafer*	x							
O. cf. sancta Kützing*		x						
O. sancta Kützing*		x						
O. subbrevis Schmidle*				x				
Family Phormidiaceae								
Phormidium amphibium (Agardhii ex Gomont)Anagnostidis & Komárek	x	x						
P. irriguum (Kützing ex Gomont) Anagnostidis & Komárek *		x						

Table II: Cont.

P. cf. javonensis Vouk*	x							
P. willei (Gardner) Anagnostidis & Komárek*		x					x	
P. autumnale (Agardhii) Gomont*				x				
P. molle Gomont*	x							
P. natans (Küetzing ex Gomont) Senna & Compére *	x	x	x					
P. Retzii (Agardhii) Gomont*	x	x						
P. cf. favosum Gomont*		x						
P. jadinianum Gomont	x							
P. simplicissimum (Gomont) Anagnostidis & Komárek *		x						
P. cf. simplicissimum (Gomont) Anagnostidis & Komárek*		x	x					
Phormidium sp						x		
Planktothrix agardhii (Gomont) Anagnostidis & Komárek	x						x	
P. prolifica (Gomont) Anagnostidis & Komárek*	x							
Porphyrosiphon martensianus (Meneghini ex Gomont) Anagnostidis & Komárek				x				
Spirulina laxa Smith*	x			x				
S. princeps West & West				x				x
Spirulina sp	x				x			
Trichodesmium lacustre (Klebahn) Ehrenberg ex Gomont*	x	x	x	x				
Tychonema granulatum (Gardner) Anagnostidis & Komárek*				x			x	
Tychonema sp	x							
Family Pseudanabaenaceae								
Geitlerinema splendidum (Greville ex Gomont) Anagnostidis	x	x		x		x		
Geitlerinema unigranulatum (Singh) Komárek & Azevedo*	x		x	x		x		
Jaaginema geminatum (Meneghini ex Gomont) Anagnostidis & Komárek		x	x	x		x		
J. cf. homogeneum (Frémy) Anagnostidis & Komárek*	x			x				
J. pseudogeminatum (Schmid) Anagnostidis & Komárek*		x				x		
J. quadripunctulatum (Brühl & Bisw) Anagnostidis & Komárek		x	x			x		
J. cf. subtilissimum (Kutzing ex De Toni) Anagnostidis & Komárek		x						
J. cf. thermalis (Lemmemann) Anagnostidis & Komárek	x							
Leibleinia epiphytica (Hieronymus) Anagnostidis & Komárek	x	x		x	x	x		
L. cf. epiphytica (Hieronymus) Anagnostidis & Komárek				x				
L.subtilis Anagnostidis & Komárek*		x						
Leptolyngbya fragilis (Gomont) Anagnostidis & Komárek*		x						
L. perelegans (Lemmermann) Anagnostidis & Komárek*	x	x		x	x	x		x
L. purpurascens (Gomont ex Gomont) Anagnostidis & Komárek*					x			
L. ramosa (Petersen) Anagnostidis & Komárek*	x				x			
L. valderiana (Gomont) Anagnostidis & Komárek *					x			
L. thermalis (Lemmermann) Anagnostidis*	x	x	x	x	x	x	x	x
Planktolyngbya tallingii Komárek & Kling *					x			
Pseudanabaena catenata Lauterborn	x	x	x		x			

Table II: Cont.

P. galeata Böcher*				x				x
P. moniliformes Komárek & Kling*			x	x				
Pseudanabaena sp				x				
Pseudanabaena sp2	x							
Pseudanabaena sp3	x	x	x					x
Family Schizotrichaceae								
Schizotrhix lamyi Gomont*	x							
Order Stigonematales								
Family Mastigocladaceae								
Hapalosiphon arboreus West & West			x					x
H. luteolis West & West*			x	x				x
Family Stigonemataceae								
Stigonema sp		x						
Stigonematales								x

* first citation for the upper Paraná river floodplain.

Twenty nine exclusive taxa were registered in Pau Véio backwater, followed by Cortado channel (21) and Clara lagoon (17), whereas Garças lagoon only 8 exclusive taxa.

Only nine taxa out of the total sample (Pseudanabaena sp3, Leptolyngbya thermalis, Geitlerinema unigranulatum, Trichodesmiun lacustre, Oscillatoria princeps, Calothrix fusca, Calothrix brevissima, Anabaena cylindrica and Aphanocapsa sp.) occurred in all environments studied, and therefore can be considered as largely distributed ecologically.

The cluster analysis revealed low similarity among sampling periods, although two groups can be recognized: Group 1 encompassed all environments during high waters and group 2 during low waters (r= 0.93) (Fig. 4).

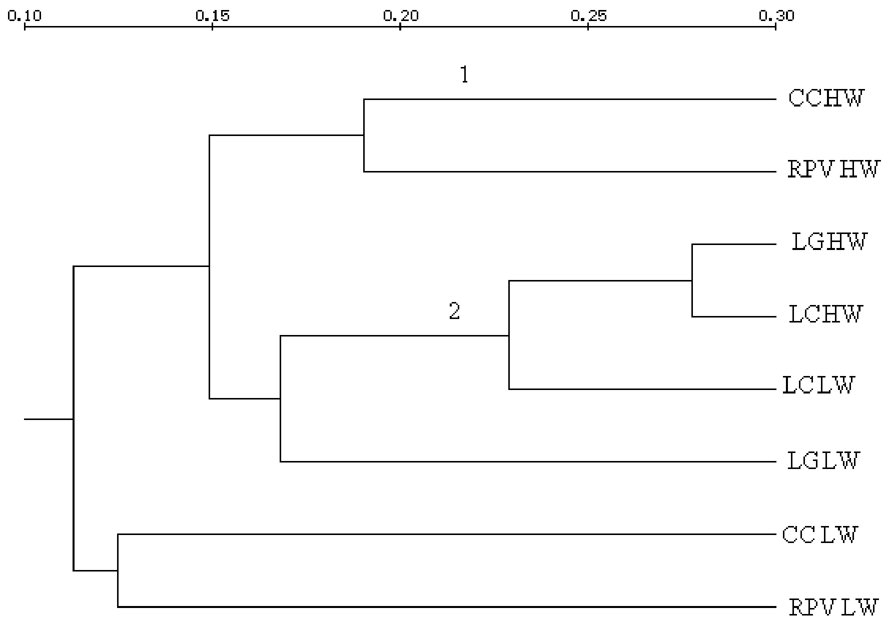

Figure 4: Cluster among periphytic cyanobacteria communities in four environments (LG- Garças Lagoon; LC – Clara Lagoon; RPV – Pau Véio Backwater; CC – Cortado Channel) in the upper Paraná river floodplain, in two hydrological periods (HW-high waters and LW-low waters).

During high waters, Pau Véio backwater presented the highest number of species (56 taxa), followed by Clara lagoon, Cortado channel and Garças lagoon. During low waters, Clara lagoon presented higher richness (24 taxa), followed by Pau Véio backwater, Cortado channel and Garças lagoon. There was no significant difference among the various hydrodynamic regime (environments) and the corresponding hydrological periods (HW and LW) (respectively, p= 0.2 and p= 0.3).

Dominant species, were not found in the study environments, whereas, 61 taxa were considered abundant. All environments presented a larger number of abundant taxa during the high water period, except for Clara lagoon, where there was no variation.

Leptolyngbya thermalis was found in all environments and hydrological periods, evidencing the abundance of this taxon in the upper Paraná river floodplain. This species promptly responded to oxygen, pH, PO_4, inorganic N, water temperature and Secchi's disk depth values. Environmental variables O_2, pH and water temperature followed the same pattern as that observed in the Leptolyngbya thermalis density, whereas PO_4, inorganic N and Secchi's disk depth patterns were reversed (Fig. 5).

Considering INDVAL values over 50%, five species can be considered as indicators for environmental conditions, representing the hydrological periods: Calothrix brevissima, Leptolyngbya perelegans, Lyngbya sp, Merismopedia tenuissima and Oscillatoria limosa (Tab. III).

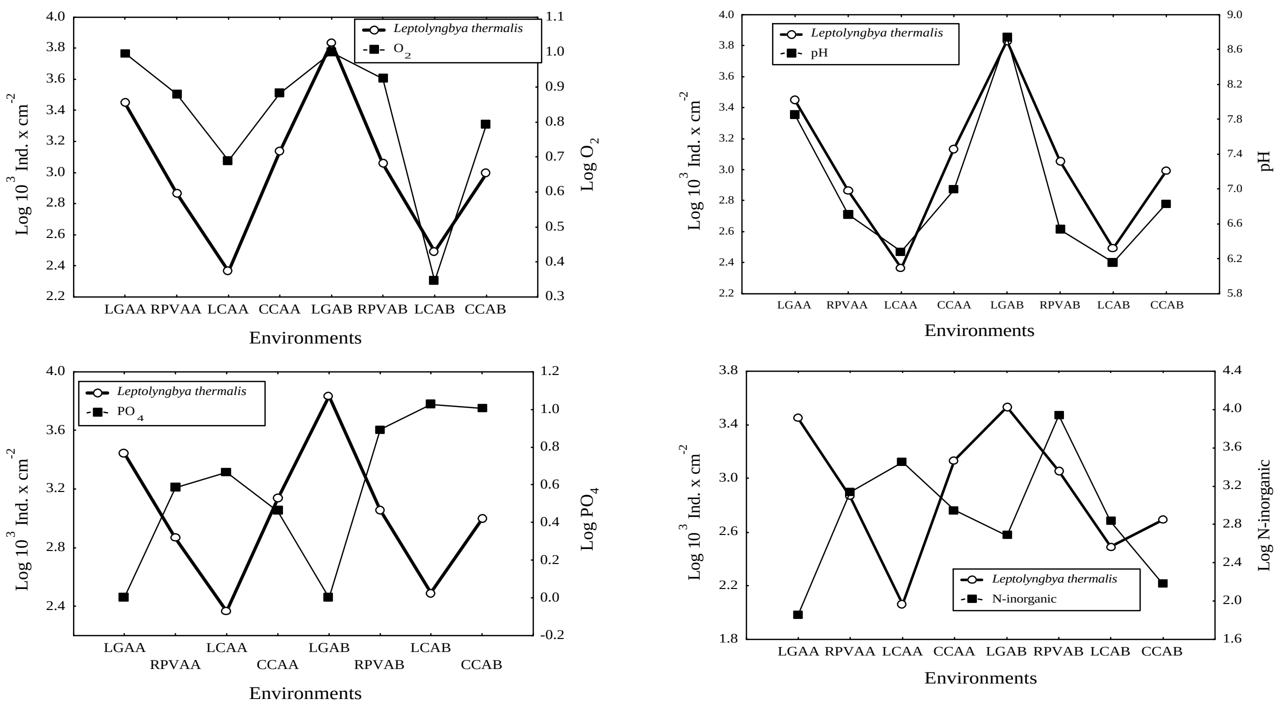

Figure 5: Relationship of environmental variables with Leptolyngbya thermalis density. Solid lines= Leptolyngbya thermalis density, and dashed lines= variables environmental.

Table III: Indicative Values (INDVAL) of species according to hydrological periods (HW= high waters and LW=low waters); p is type I error probability, obtained by Monte Carlo testing. Highlighted values represent indicative species in any hydrological period. CV = variation coefficient of indicative values for randomized groups.

Species	**INDVAL**			
	HW	**LW**	**p**	**CV**
Calothrix brevissima	63	0	0.026	62.5
Leptolyngbya perelegans	63	0	0.024	62.5
Lyngbya sp.	100	0	0.001	100
Merismopedia tenuissima	1	59	0.019	59
Oscillatoria limosa	63	0	0.026	62.5

Discussion

Hydrological level of Paraná river assumes a key role in temporal and spatial variation patterns of the systems in the upper Paraná river floodplain (Agostinho & Zalewiski, 1996; Thomaz et al., 2004; Rodrigues & Bicudo, 2001). They also showed the controlling role that the hydrodynamical regime of environments associated to the river take on over their functioning, as it was observed in the present study. The hydrological pulse is one of the most important macrofactors determining the periphytic cyanobacteria community in environments in the upper Paraná river floodplain.

The littoral area of water bodies is an excellent habitat for aquatic communities, mainly during the high waters period, since the presence of aquatic macrophyte stimulates development of periphytic algae and therefore of cyanobacteria, by supplying substratum for fixation and due to the large quantity of nutritive material created by the process of aging and death (Rodrigues & Bicudo, 2001).

The highest specific abundance during the high waters period is probably based in the homogenizating effect of the floodplain as proposed by Thomaz et al. (2004), when fluctuations on hydrometric levels keep the river-floodplain connection determine seasonality of limnological factors. Also, the larger number of species in that period is possibly related to higher water temperatures, intake of propagules and low concentration of phosphorus, since the storage of phosphorus in cyanobacteria may be higher than in other microalgae, providing competitive advantage (Paerl, 1998; Oliver & Ganf, 2000). The lower conductivity in this hydrological period potentiate the development of this group of algae (Branco et al., 2001). According to Biggs (1990), conductivity has no direct relationship to cyanobacteria, but it indicates the relative level of nutrients available to this community.

The high abundance in Clara lagoon was probably influenced by its high turbidity, (Oliver & Ganf, 2000), it was found an inverse correlation between cyanobacteria and solar radiation intensity, as there was a decrease in photopigments (phycocyanin and Chlorophyll a) on high levels of solar radiation.

Abundance of periphytic cyanobacteria in four environments in the upper Paraná river floodplain is indirectly characterized by nutrient availability. As the increase or decrease of phosphorus and nitrogen forms (Paerl, 1998; Huszar et al., 2000), it is directly related to hydrometrical level. The community of periphytic cyanobacteria is influenced by hydrological period, hydrodynamic regime and temperature, which are the determining factors in the composition of this group of algae (Steinberg & Hartmann, 1988; Huszar & Caraco, 1998).

The hydrological period has also influenced the morphological types of cyanobacteria species prevailing in both periods (Komárek et al., 2003; Watson et al., 1997). Considering INDVAL, the high waters period presented filamentous indicative species, whereas in low waters the species had a colonial coccoid morphology. According to Paerl (1998), several genera of cyanobacteria, colonial or filaments, are capable of regulating their development to physiological and environmental requirements. Dokulil & Teubner (2000) refer the formation of colonies or aggregates of decisive importance to physiology and environmental response of cyanobacteria.

Acknowledgements

The authors would like to thanks the Research Nucleus in Limnology, Ichthology, and Aquaculture- Nupelia/PEA/UEM for logistical support and CAPES for granting the master scholarship. This study is part of the Long Term Ecological Research (LTER) program, site 6, conducted by Nupélia, that it is inserted in the International Long Term Ecological Research (ILTER).

References

Agostinho, A.A. & Zalewiski, M. 1996. A planície alagável do alto Rio Paraná: importância e preservação. EDUEM, Maringá. 100p.

Anagnostidis, K. & Komárek, J. 1988. Modern approach to the classification system of cyanophytes. 3 - Oscillatoriales. Arch. Hydrobiol. Suppl., 50:327-472.

Anagnostidis, K. & Komárek, J. 1990. Modern approach to the classification system of cyanophytes. 5 - Stigonematales. Arch.

Hydrobiol. Suppl., 59:1-73.
Bicudo, C.E.M. 1990. Considerações sobre metodologias de contagem de algas do perifíton. Acta Limnol. Bras., 3:459-475.
Biggs, B.J.F. 1990. Periphyton communities and their environments in New Zeland rivers. N. Z. Mar. Freshwater Res., 24:367-386.
Branco, L.H.Z., Necchi, O.J. & Branco, C.C.Z. 2001. Ecological distribution of cyanophyceae in lotic ecosystems of São Paulo State. Rev. Bras. Bot., 24:99-108.
Cattaneo, A. & Kalf, J. 1978. Seasonal changes in the epiphyte community of natural and artificial macrophytes in Lake Memphremagog (Que & VT). Hydrobiologia, 60:135-144.
Dokulil, M.T. & Teubner, K. 2000. Cyanobacterial dominance in lakes. Hydrobiologia, 438:1-12.
Dufrêne, M. & Legendre, P. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol. Monogr., 67:345-366.
Guiné, M.F., Bergamin, H., Zagatto, E.A.G. & Reis, B.F. 1980. Simultaneous determination of nitrite and nitrate by flow injection analysis. Anal. Chim. Acta, 114:191-197.
Goldsborough, L.G. & Robinson, G.G.C. 1996. Pattern in wetlands. In: Stevenson, R.J., Bothwell, M.L. & Lowe, R.L. (eds.) Algal ecology: freshwater benthic ecosystems. Academic Press, San Diego. p.77-117.
Huszar, V.L.M. & Caraco, N.F. 1998. The relationship between phytoplankton composition and physical-chemical variables: a comparison of taxonomic and morphological-functional descriptors in six temperate lakes. Freshwater Biol., 40:679-696.
Huszar, V.L.M., Silva, L.H.S., Marinho, M., Domingos, P. & Sant'Anna, C.L. 2000. Cyanoprokaryote assemblages in eight productive tropical Brazilian waters. Hydrobiologia, 424:67-77.
Junk, W.J. 1996. Ecology of floodplain: a challenge for tropical limnology. In: Schiemer, F. & Boland, K.T. (eds.) Perspectives in tropical Limnology. Academic Publishing, Amsterdam. p.255-265.
Komárek, J. & Anagnostidis, K. 1986. Modern approach to the classification system of cyanophytes. 2- Chroococcales. Arch. Hydrobiol. Suppl., 43:157-226.
Komárek, J. & Anagnostidis, K. 1989. Modern approach to the classification system of cyanophytes. 4 - Nostocales. Arch. Hydrobiol. Suppl., 56:247-345.
Komárek, J., Komárkova, J. & Kling, H. 2003. Filamentous cyanobacteria. In: Wehr, J.D. & Sheath, R.G. (eds.) Freshwater algae of North America: ecology and classification. Academic Press, Amsterdam. p.117-196.
Lam, P.K.S. & Lei, A. 1999. Colonization of periphytic algae on artificial substrates in a tropical stream. Diatom Res., 14:307-322.
Lobo, E.A. & Leighton, G. 1986. Estructuras comunitarias de las fitocenosis planctônicas de los sistemas de desembocaduras de rios y esteros de la zona central de Chile. Rev. Biol. Mar., 22:1-29.
Mackereth, F.Y.H., Heron, J. & Talling, J.J. 1978. Water analysis: some revised methods for limnologist. Freshwater Biological Association, Ambleside. 120p.
McCune, B. & Mefford, M.J. 1999. Multivariate analysis of ecological data. Version 4.01. MjM Software. Gleneden Beach, Oregon.
Neiff, J.J. 1990. Ideas para la interpretación ecológica del Paraná. Interciência, 15:424-441.
Oliver, R.L. & Ganf, G.G. 2000. Freshwater blooms. In: Whitton, B.A. & Potts, M. (eds.) The ecology of cyanobacteria: their diversity in time and space. Kluwer Academic Publishers, Dordrecht. p.150-189.
Paerl, H.W. 1998. Growth and reproductive strategies of freshwater blue-green algae (cyanobacteria). In: Sandgreen, C.D. (ed.) Growth and reproductive strategies of freshwater phytoplankton. Cambridge University Press, Cambridge. p.261-325.
Rejmánková, E., Komárek, J. & Komárková, J. 2004. Cyanobacteria - a neglected component of biodiversity: patterns of species diversity in inland marshes of northern Belize Central America. Divers. Distrib., 10:189-199.
Rodrigues, L. & Bicudo, D.C. 2001. Similarity among periphyton algal communities in a lentic-lotic gradient of the upper Paraná river floodplain, Brazil. Rev. Bras. Bot., 24:235-248.
Rodrigues, L., Bicudo, D.C. & Moschini-Carlos, V. 2003. O papel do perifíton em áreas alagáveis e nos diagnósticos ambientais. In: Thomaz, S.M. & Bini, L.M. (eds.) Ecologia e manejo de macrófitas aquáticas. EDUEM, Maringá. p.211-230.
Rohlf, F.J. 1989. NTSYS-PC. Numerical taxonomy and multivariate analysis

system, version 1.50. Exerter Publishing, New York.
Ros, J. 1979. Práctica de Ecología. Omega, Barcelona. 181p.
Schwarzbold, A. 1990. Métodos ecológicos aplicados ao estudo do perifíton. Acta Limnol. Bras., 3:545-592.
Thomaz, S.M., Pagioro, T.A., Bini, L.M., Roberto, M.C. & Rocha, R.R.A. 2004. Limnological characterization of the aquatic environments and the influence of hydrometric levels. In: Thomaz, S.M., Agostinho, A.A. & Hanh, N.S. (eds.) The Upper Paraná River and its floodplain: physical aspects, ecology and conservation. Backhuys Publishers, Leiden. p.75-102.
Utermöhl, H. 1958. Zur vervollkommung der quantitativen phytoplankton-methodik. Mitt. Int. Ver. Limnol., 9:1-38.
Watson, S.B., MCcauley, E. & Downing, J.A. 1997. Patterns in phytoplankton taxonomic composition across temperate lakes of differing nutrient status. Limnol. Oceanogr., 42:486-495.

Received: 04 September 2006
Accepted: 10 April 2007