Spatial variation of phytoplankton and some abiotic variables in the *Pirapó* River -PR (Brazil) in August 1999: a preliminary study

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ABSTRACT. This research provides a study in phytoplankton community and some abiotic variables of the *Pirapó* River. Surface samples were taken along a longitudinal axis, from the river source to *Maringá* Water Station, in August, 1999. The structure of the phytoplankton community and other abiotic variables was evaluated. The *Pirapó* River showed high rates of nutrients and suspended matter. Low density and phytoplanktonic biomass were registered. Diatoms *Nitszchia palea* (Kützing) W. Smith and *Navicula cryptocephala* (Kützing) were dominant in all sampling stations, except at the source, where *Pseudanabaena galeata* Bröcher (Cyanophyceae) predominated. Richness, species diversity and equitability were low, increasing throughout the longitudinal axis. High nutrient concentration and diatom associations with highly pollution-resistant taxa were an indication of the river's high trophy level. These results show the urgency of creating and implementing an appropriate management program for the entire *Pirapó* basin.

Key words: Phytoplankton, abiotic variables, *Pirapó* river, eutrophication.

RESUMO. Variação espacial do fitoplâncton e algumas variáveis abióticas no rio Pirapó, Estado do Paraná (Brasil) em agosto de 1999: um estudo preliminar. Este estudo objetivou caracterizar a comunidade fitoplanctônica e algumas variáveis abióticas do rio *Pirapó*. Para tanto, foram realizadas amostragens de sub-superfície, em agosto de 1999, em uma secção longitudinal naquele rio, desde a nascente até a estação de captação, em *Maringá*. Avaliou-se a estrutura da comunidade fitoplanctônica e algumas variáveis abióticas. O rio *Pirapó* apresentou alta carga de nutrientes e materiais suspensos. Registraram-se baixos valores de densidade e biomassa fitoplanctônica, sendo as diatomáceas *Nitszchia palea* (Kützing) W. Smith e *Navicula cryptocephala* Kützing dominantes em todas as estações, exceto na nascente, onde a cianoprocariota *Pseudanabaena galeata* Bröcher foi dominante. Os valores de riqueza, diversidade e eqüidade foram baixos, aumentando ao longo do eixo longitudinal em direção à estação de captação de água. Elevadas concentrações de nutrientes, bem como associações de diatomáceas, constituídas por táxons altamente resistentes à poluição, indicam um elevado grau de trofia naquele ambiente e ressalta a necessidade de adoção de medidas urgentes no sentido de implementar um programa de gestão e manejo eficazes para a bacia do rio *Pirapó*.

Palavras-chave: Fitoplâncton, variáveis abióticas, rio *Pirapó*, eutrofização.

Introduction

Several reasons can justify phytoplankton studies. Among them, the environments trophic conditions (Huszar *et al.*, 1998; Rojo, 1998; Huszar and Silva, 1999; Melo and Huszar, 2000) may be revealed by the associations of the phytoplankton species (Reynolds, 1997). When these data are related with the environment's abiotic parameters, such as pH, electrical conductivity, water nutrient concentrations and others, they form an excellent tool for the biomonitoring of water environments.

With a 5,023 km^2 draining area, the *Pirapó* River provides water for many towns, some of them with more than 100,000 inhabitants, along its course. However, polluting effluents are extant throughout. Moreover, since it lies on plain land, its basin has been highly exploited by mechanized agriculture with total deletion of its border vegetation.

Soil misuse caused the basin laminar erosion, with heavy discharge of nutrients and agriculture-derived compounds into the river. Needless to say, changes in the water's biotic and abiotic conditions ensue. Cassaro (1999) reported that the indiscriminate use of riparian areas in the *Pirapó* River basin has caused, among other factors, high water turbidity throughout its course.

In spite of Brazilian extensive hydrographic network, few ecology studies in lotic systems are available. Huszar and Silva (1999) mentioned only 13 research works on these systems in a research.

In fact, studies (Cassaro, 1999; Leandrini, 1996; 1999; Leandrini *et al.*, 2002) on the *Pirapó* river are rare and survey on the river's phytoplankton has never been made. Thus the current research, actually part of a preliminary diagnose aiming to create subsidies for the monitored planning of the river, will surely contribute towards the *Pirapó*'s limnological characterization related to phytoplankton community.

Material and methods

Study area

The *Pirapó* River, with its source in *Apucarana* city (PR – Brazil), extends 168 km as far as its mouth at the *Paranapanema* River (Figure 1). The *Maringá* Water Station is distant 55 km from the river source. Its main affluent is the 196-km *Bandeirante do Norte* River, with its source at *Arapongas*, state of *Paraná*, southern Brazil.

The city of *Maringá* lies on the so called Third Plateau of the state of *Paraná*, in which basalt volcanic rocks of the "Serra Geral" formation (White, 1908) emerge at the bottom of the river channel. Highly developed red latosoil, nitosoil and alluvial soils are extant in the region, originating from basalt modifications.

The region has a tropical humid mesothermic climate, with rainfalls in the summer and autumn (Deffune *et al.*, 1994). Cattle raising is the chief economic activity in the basin, although big industries have been installed in and around the cities of *Apucarana* and *Maringá*.

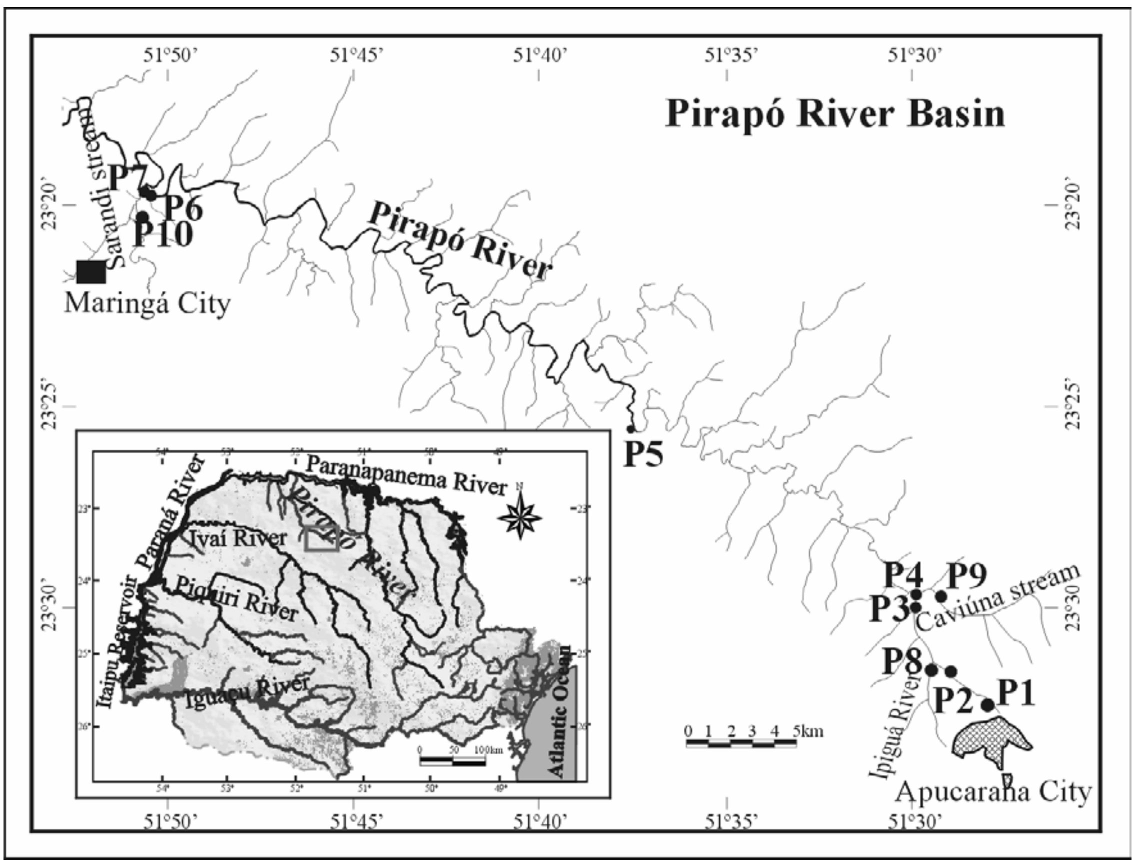


Figure 1. Site and map of the *Pirapó* River, with sampling stations

Samples were taken in 10 collection stations, seven on the *Pirapó* River, extending from its source (P1) to the station downstream the *Maringá* Water Station (P7); 3 sampling stations lay on the tributaries (streams Ipiguá (P8), *Caviúna* (P9) and *Sarandi* (P10)). The source of the *Pirapó* River (P1) lies within the urban zone of *Apucarana*'s municipality, close to an abattoir and meat processing factory. While P2 lay outside the urban zone, P3 was some 8 km distant from the former and downstream a series of sedimentation lakes into which flows the stream *Caviúna* (P9). P4 lay at the junction of P3 and P9.

Station P5 was at an intermediary region between the river source and the *Maringá* Water Station, with P6 properly at the Water Station. P7 was fixed on the *Pirapó* River, after the mouth of *Sarandi* stream; P8 lay on the Ipiguá stream, which receives nutrients of the *Pirapó* and effluents of the *Apucarana* garbage dump-treatment complex. The *Apucarana* Water Station lies on the Ipiguá stream. Station P10 was fixed on the *Sarandi* stream, which receives pollutants of the *Marialva* sewage-treatment pool.

Methodology

Subsurface sampling was undertaken on August 21 and 22, 1999 (winter), in the previously established collection stations. In the above mentioned sampling stations measurements were undertaken for water temperature, by portable digital thermistor; pH and electrical conductivity, by portable digital potentiometers; total alkalinity, according to Mackereth *et al.* (1978) and dissolved oxygen, according Winkler's method modified by Golterman *et al.* (1978). Water aliquot was taken to the lab and suspended matter measured by gravimeter technique (Wetzel and Likens, 1991). Total phosphorus concentrations, dissolved reactive phosphorus (DRP), total dissolved phosphate (TDP), total Kjeldahl nitrogen, N-nitrate, N-ammonia were determined according to Mackereth *et al.* (1978). At the same time, phytoplankton was collected and counted, according to Utermöhl (1958), and the density was calculated according to APHA (1985). Appropriate volume aliquots (according to the seston concentration) were taken for quantitative studies, at least one hundred individuals (cells, colonies and filaments) were counted, determining a 95% level of confidence (Lund *et al.*, 1958). Phytoplankton biomass was estimated by biovolume, multiplying the density of each species by its respective cell volume. The latter was calculated by stereometric formulae (Edler, 1979; Wetzel and Likens, 1991). The chlorophyll-*a* was measured according to Golterman *et al.* (1978).

Species diversity was estimated by Shannon and Wiener index (Shannon and Weaver, 1963). Species richness was considered as the number of taxa present in each sample. Dominant species were defined as those that occurred in densities or biovolume over than 50% of total density or biovolumes for sample. Abundant species were defined as those which occurred in densities or biovolumes higher than the average density or biovolume for each sample (Lobo and Leighton, 1986; Huszar, 1994). Rare species were those present in a single sample and with low density rates (< 5 ind.mL^{-1}).

Principal Components Analysis (PCA) (PC-ORD 2.0) was used to reduce data greatness and ordinate the different sampling stations according to abiotic characteristics. With the exception of pH, all variables were log-transformed. By means of statistic package PC-ORD 2.0, a Detrended Correspondence Analysis (DCA) was done, based on phytoplankton species density data, evaluating species responses to environmental gradients (McCune and Mefford, 1995).

Results and discussion

Water temperature values at the sampling stations increased towards downstream stations (Figure 2 a). The pH rates were close to neutral in all sampling stations (close to 7), showing a low photosynthetic activity along the whole *Pirapó* length (Figure 2c). Lower values at its source indicated decomposition processes. High dissolved oxygen values were reported in 8 out of 10 sampling stations, with mean values of 8.5 mg.L^{-1} (Figure 2d), as a consequence of the fast water flow. Low concentrations at P1 and P2 may be related to the liquid effluents from the city and industries (Cassaro, 1999). Low flow speed in this specific region favors organic matter decomposition and oxidation by aerobic bacteria, decreasing oxygen concentrations.

High electrical conductivity and total alkalinity values in all sampling stations (Figure 3), chiefly at P2, were probably due to sewage discharge, which also increased nutrient concentrations. According to Hynes (1976), salt concentrations in water where organic pollutants are discharged are extremely high; they are prone to get lower along the river course until they reach their normal level. Opposite to reports on less-impacted rivers of the same *Paraná* basin such as Xambre and Piquiri (Rodrigues *et al.*, *in prep.*), these values remain high throughout its entire course.

High concentrations of total Kjedahl Nitrogen, N-nitrate, N-ammonia, total phosphorus, dissolved phosphorus and dissolved reactive phosphorus (Figures 4 a, b) show that the *Pirapó* has eutrophic and hypereutrophic conditions (Tundisi, 1990; Nürnberg, 1996) since its source. However, a decrease in phosphorus concentration occurred along the river course, as a consequence of self-depuration process, giving it mesotrophic characteristics, while nitrogen concentrations were still high. High values in *Sarandi* stream (P10) also show a high trophic degree, as a result of effluents from the *Marialva* sewage treatment pool.

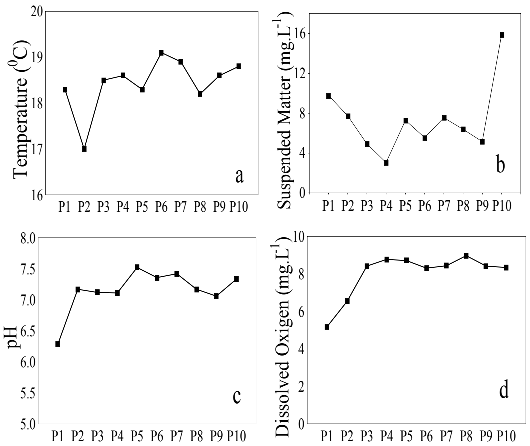


Figure 2. Temperature (a), suspended matter (b), pH (c) dissolved oxygen (d) along the *Pirapó* River and tributaries

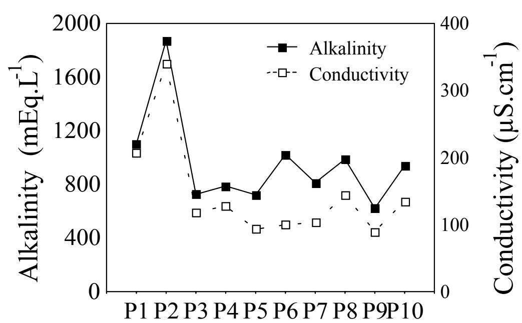


Figure 3. Alkalinity and electrical conductivity along the *Pirapó* River and tributaries

Throughout its whole extension, the *Pirapó* River has presented a high rate of suspended matter (Figure 2b) and nutrients, with low species richness and algal biomass (Figure 5 b, 6 and 7). The better preserved rivers of the same basin, such as the *Paraná*, Ivinhema (Train and Rodrigues, 1997), Piquiri and Xambre (Rodrigues *et al.*, *in prep.*) have higher biomass and species richness in the phytoplankton community.

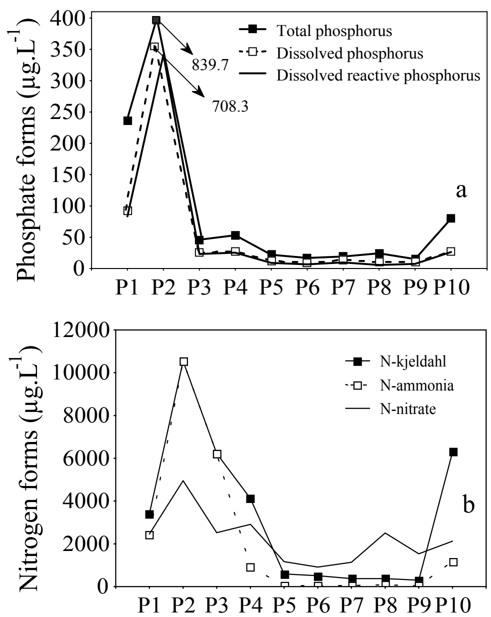


Figure 4. Phosphate (a) and nitrogen forms (b) along the *Pirapó* River and tributaries

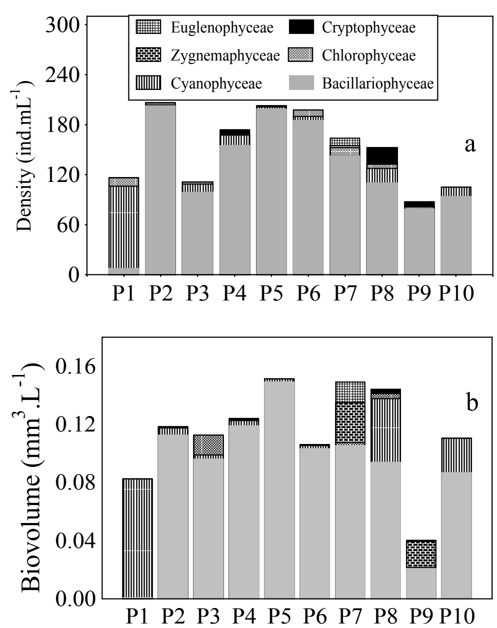


Figure 5. Density (a) and biovolume (b) of phytoplankton classes in the *Pirapó* River and tributaries

From all taxa, 83.9% belonged to the Class Bacillariophyceae (Table 1), especially in P7 station. The same Class had also the highest contribution in total phytoplankton biomass. As a rule, Bacillariophyceae is the second better-represented Class in the *Paraná* river basin lotic environments

(Train and Rodrigues, 1997; 1998; Train *et al.*, 2000). Low diversity and species richness were reported (Figure 7), without any significant differences in species diversity rates over density and biovolume rates. This is due to the fact that such attributes followed the same distribution standard along the *Pirapó* River longitudinal axis, with diatoms predominance in almost all stations.

Low rates in phytoplankton density and biomass (Figure 5 and 6a, b) may be due to the high water flux, high concentration of suspended matter and turbidity, probably caused by the silting process, which was worsened by rainfalls (Cassaro, 1999). Such conditions benefit R-strategist species (Reynolds, 1988, 1997), such as *Nitszchia palea*, *Navicula cryptocephala* and *Anomoeoneis* sp., dominant in density in all stations, except P1, since they are resistant to water turbulence and low light intensity (Tilman *et al.*, 1986; Sommer, 1988; Reynolds, 1994). High nitrate concentration may have also favored the development of these species.

Table 1. Occurrence of taxa registered in sampling stations at the *Pirapó* River and tributaries

	P1	P2	P3	P4	p5	P6	P7	P8	P9	P10
CHLOROPHYCEAE										
Closteriopsis sp.		x					x			
Coelastrum reticulatum (Dang.) Senn						x		x		
Crucigenia tetrapedia (Kirch.) W. et G. S. West				x	x	x	x			
Eutetramorus globosus Walton								x		
Monoraphidium contortum (Thur.) Kom.-Legn.	x						x			
Pediastrum duplex Meyen			x	x						
Scenedesmus bicaudatus (Hansg.) Chod.							x			x
Scenedesmus javanensis Chod.							x			x
Scenedesmus obliquos var. *dimorphus* (Turp) Hansg						x		x		
CYANOPHYCEAE										
Cylindrospermopsis raciborskii (Wol.) Seen. E Sub. Raj.	x	x						x		x
Lyngbia sp.					x					
Oscillatoria sp.			x					x		
Pseudanabaena galeata Böcher	x		x	x		x		x		
BACILLARIOPHYCEAE										
Achnantes minutissima Kütz.		x		x	x			x	x	
Amphipleura lindheimeri Grun.			x							
Amphipleura sp.					x		x			
Brachysira neoxilis Lange-Bertalot				x	x		x		x	x
Anomoeoneis sp.					x			x	x	
Anomoeoneis sp.1						x			x	x
Aulacoseira ambigua (Grun.) Simon.				x		x				x
Cocconeis sp.						x		x		
Cocconeis sp.1										
Cyclotella stelligera l. u. Grun						x	x		x	
Cymbella silesiaca Bleisch										x
Cymbella tumida (Bréb.) Van Heurk						x	x	x		
Cymbella sp.				x		x	x		x	
Fragilaria goulardii Bréb.					x	x	x			
Fragilaria ulna (Nitzsch) Ehr.				x	x	x	x			
Frustulia sp.					x					x
Gomphonema augustum Agardh						x				
Gomphonema gracile Ehr.					x					
Gomphonema parvulum (Kütz.) Kütz.				x	x	x	x			x
Gomphonema sp.	x			x	x					
Gyrosigma sp.			x		x			x		x
Navicula cryptocephala Lang.-Bert.		x	x			x	x			
Navicula cryptotenella Kütz.		x	x	x		x	x	x		x
Navicula sp.1		x	x	x			x	x		x
Navicula sp.2		x	x			x				
Nitschia palea (Kütz) W. Smith		x		x	x			x	x	x
Nitszchia tubicola Grun.		x				x	x			x
Nitszchia sp.			x				x			
Nitszchia sp.1						x				x
Nitszchia sp.2										x
Pinnularia sp.		x	x	x			x	x		x
Pinnularia sp.1		x								
Synedra sp.		x	x							
Surirella splendida (Ehr.) Kütz.								x		
Surirella sp.										x
CRYPTOPHYCEAE										
Cryptomonas sp.				x				x	x	
EUGLENOPHYCEAE										
Trachelomonas volvocinopsis Swir.							x			
ZYGNEMAPHYCEAE										
Closterium sp.							x		x	x

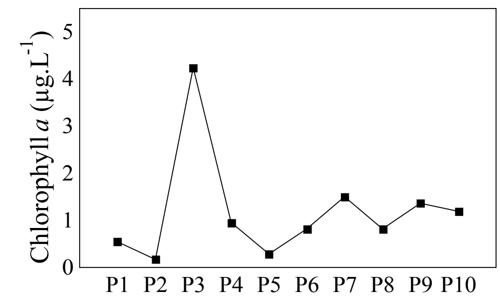


Figure 6. Chlorophyll-*a* along the *Pirapó* River and tributaries

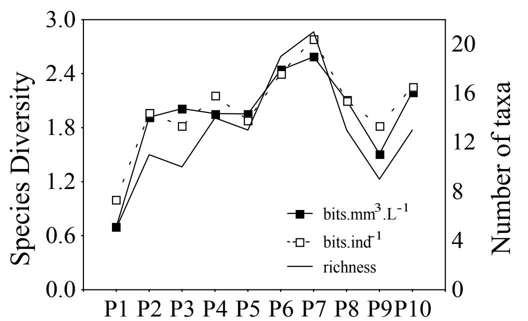


Figure 7. Species diversity, estimated by biovolume and density, and species richness along the *Pirapó* River and tributaries

Dominance of *Nitszchia palea* and *Navicula cryptocephala* in the *Pirapó* is a great concern, since the species are a sign of pollution by nitrogen organic compounds and commonly reported in rivers and streams polluted by industrial chemical effluents (Lange-Bertalot, 1979; Train, 1990).

Pseudanabaena galeata (Cyanophyceae) was dominant in P1, in condition of low luminosity and high nitrogen concentrations. In fact, many cyanoprokariotes have been frequently reported in high trophic environments (Harper, 1990; Branco and Senna, 1994; Huszar and Reynolds, 1997; Sivonen and Jones, 1999).

Low phytoplankton richness and diversity, as the dominant and abundant species in the *Pirapó* River, found in this only sample, are also characteristics of eutrophic and hypereutrophic environments (Huszar and Reynolds, 1997). The above is a clear sign of intense organic and inorganic contamination (Sladécek, 1973; Shoeman, 1973; Lange-Bertalot, 1979; Train, 1990; Moro and Fürstenberger, 1997), confirming the strong damage of the *Pirapó* and its affluents, which merely benefits species already adapted to such conditions. Nevertheless, it must be considered that the samples were done in winter period, which may contribute for this low density.

The PCA claimed two axes (principal components) with eigenvalues 6.7 and 1.8 for axes 1 and 2, respectively. According to Broken Stick criterion (Jackson, 1993), only the first axis was significant since it accounted for 67.0% of total data variability (Figure 8).

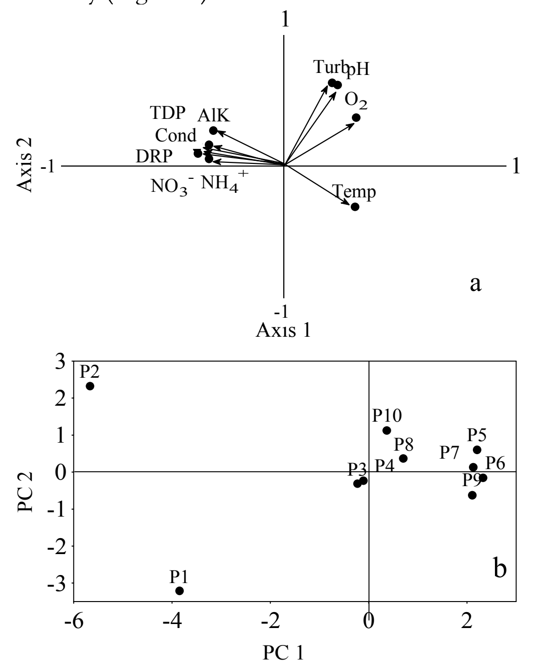
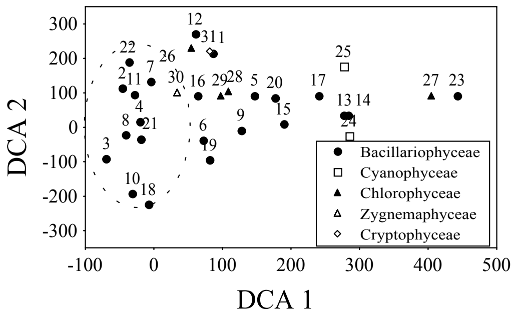


Figure 8. Pearson's correlation among the original variables and scores (a). The sample scores are identified by sites-months (b)

The first axis was negatively affected by electrical conductivity, total alkalinity, N-ammonia, N-nitrate, total dissolved phosphorus and dissolved reactive phosphorus. It was positively affected by turbidity, pH, dissolved oxygen and temperature.

The occurrence of high nutrient values, electrical conductivity and total alkalinity in P1 and P2, decreasing along the source-downstream direction of the *Pirapó*, kept them apart from the other stations (Figure 8 a, b). This fact may be explained by means of the self-depuration process in the *Pirapó* River, especially from P3, below the seven sewage-treatment pools. The latter have aquatic macrophytes, which somewhat improve the river's eutrophic conditions, but do not guarantee its decontamination.

DCA showed that the phytoplankton community is distributed along the longitudinal axis of the *Pirapó* and most species occurred at increasingly distant sites from the source (Figure 9; Table 1). Diatom associations, formed by pollution resistant taxa (*Nitszchia palea, Navicula cryptocephala*), and high nutrient concentrations, enhance the need for biomonitoring the river.



1	*Achnantes minutissima*	17	*Nitszchia* sp.
2	*Anomoeoneis* sp.	18	*Nitszchia* sp.2
3	*Anomoeoneis* sp.1	19	*Nitszchia tubicola*
4	*Aulacoseira ambigua*	20	*Pinnularia* sp.
5	*Cocconeis* sp.	21	*Fragilaria goulardii*
6	*Cyclotella* sp.	22	*Fragilaria ulna*
7	*Cymbella* sp.	23	*Fragilaria* sp.
8	*Cymbella tumida*	24	*Cylindrospermopsis raciborskii*
9	*Gyrosigma* sp.	25	*Pseudanabaena galeata*
10	*Gomphonema augustum*	26	*Crucigenia tetrapedia*
11	*Gomphonema parvulum*	27	*Monoraphidium contortum*
12	*Gomphonema* sp.	28	*Closteriopsis* sp.
13	*Navicula cryptocephala*	29	*Scenedesmus bicaudatus*
14	*Navicula* sp.1	30	*Closterium* sp.
15	*Navicula* sp.2	31	*Cryptomonas* sp.
16	*Nitszchia palea*		

Figure 9. Dispersion of phytoplankton taxa along the first two DCA axes. Codes are shown

In the wake of the demographic growth in the municipalities comprising the *Pirapó* River basin, particularly *Maringá*, with increasing fresh water demands and the degradation of this basin's water resources, urgent measures are required to implement an efficient management program for the *Pirapó* basin.

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