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Effects of cyanobacterial summer bloom on the phytoplankton structure in an urban shallow lake, Guaíba Lake, southern Brazil

Efeito das florações de verão de cianobactérias na estrutura do fitoplâncton em lago urbano raso, Lago Guaíba, sul do Brasil

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Abstract

The present study aimed at evaluating the influence of cyanobacterial summer blooms on the phytoplankton structure in a subtropical urban shallow lake used as a water supply (Guaíba Lake, southern Brazil). Samples were taken close to the water intake site at Belém Novo district, which is operated and processed for public distribution by the Porto Alegre Department of Water and Sewage (DMAE). Monthly samplings were collected from October 2010 to March 2011. The following abiotic parameters were considered: N and P, conductivity, pH and water transparency, besides thermal profile, dissolved oxygen and relative water column stability (subsurface, 1.20 m and 0.5 m from the bottom). Samples for phytoplankton were collected in the water subsurface. Strong influence of high concentrations of total phosphorus and water stability was verified in the establishment of *Planktothricoides raciborskii* (R^2 = 97%, p = 0.01). Decrease in diversity, evenness and species richness evidenced the replacement of phytoplankton species by cyanobacteria biomass, especially due to the low light availability and soluble reactive phosphorus limitation. Changes in rainfall patterns related to the *La Niña* phenomenon might have influenced the abiotic scenario, recruiting inocula deposited on nutritionally enriched layers, favoring bloom-forming species. Additional studies are needed in order to fully understand the mechanisms involved in the complex dynamics of ecological factors related to the success of this group of organisms, especially in ecosystems used as water supply, presenting recurrent episodes of cyanobacterial blooms, as is the case of the Guaíba Lake.

Key words: cyanobacteria, nutrients, La Niña, diversity

Resumo

Florações de cianobactérias são reconhecidamente responsáveis por influenciar a estrutura da comunidade planctônica. O objetivo deste estudo foi avaliar a influência da recorrente floração de verão de cianobactérias na estrutura do fitoplâncton de um lago urbano subtropical utilizado para abastecimento de água (Lago Guaíba, Porto Alegre, RS, Brasil). As amostragens foram realizadas no ponto junto à captação de água do Bairro Belém Novo, sob responsabilidade do Departamento Municipal de Água e Esgotos – DMAE. Coletas mensais foram efetuadas de outubro de 2010 a março de 2011. Os parâmetros abióticos analisados foram: séries N e P, condutividade, pH, estabilidade relativa da coluna d'água e transparência, além do perfil térmico e oxigênio dissolvido (sub-superfície, 1,20m e 0,5m do fundo). As amostras para análise do fitoplâncton foram coletadas na sub-superfície da água. Observou-se forte influência das elevadas concentrações de fósforo total e estabilidade no estabelecimento de *Planktothricoides raciborskii* (R^2 = 97%,

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p = 0.01). Redução na diversidade e riqueza demonstraram a substituição de espécies do fitoplâncton, sobretudo diante da menor disponibilidade de luz e limitação de fósforo solúvel reativo. Alterações nos padrões de chuva devido a La Niña podem ter influenciado o ambiente, aumentando a transparência e recrutando inóculos de cianobactérias depositados em camadas mais enriquecidas. Estudos complementares são necessários para o completo entendimento dos mecanismos que explicam os complexos fatores relacionados ao sucesso ecológico destes organismos, especialmente em ecossistemas utilizados no abastecimento de água, com episódios de florações de cianobactérias, como é o caso do Lago Guaíba.

Palavras-chave: cianobactérias, nutrientes, La Niña, diversidade

Introduction

Cyanobacteria are a group of prokaryotic photosynthetic organisms dating from the Precambrian Period, who were able to colonize virtually every ecosystem on the planet (Fernandes *et al*., 2009; Chaves *et al*., 2009). Often, cyanobacteria are found in freshwater, marine and estuarine ecosystems (Calijuri *et al*., 2006), being associated to bloom events.

Algal blooms are a major problem for water resource management in what concerns water sources for public distribution. They are an excessive proliferation of microorganisms (mainly cyanobacteria), composed of one or more species, which significantly increase their biomass in relation to the original concentration (Oliver and Ganf, 2000). This phenomenon may occur in periods ranging from hours to several days and disappear within a similar time span. However, some cyanobacterial blooms may persist for longer periods throughout summer or a full year, or on a permanent basis (Crossetti and Bicudo, 2008).

In recent years, in several parts of Brazil and the world, there has been a significant increase of cyanobacterial blooms in aquatic environments (e.g. public water supply reservoirs, artificial lakes, brackish lagoons and rivers), as a consequence of eutrophication processes. In addition to climatic factors, punctual and diffuse sources of nutrients, low average depth of reservoirs, long water residence time, intense urban and agropastoral occupation in surrounding areas, and the interaction of hydrological, morphological, physical, chemical and biological factors are directly responsible for eutrophication and the development of cyanobacteria (Yunes *et al*., 2005).

The increase in the occurrence of cyanobacterial blooms in water supplies, raises the concern related to the ability of some species of producing and releasing toxins (cyanotoxins), which might, in turn, affect not only the aquatic and terrestrial biota, but also human health and the production of compounds (e.g. geosmin and 2-metilisoborneol - 2MIB) that yield bad taste and odor in water (Yunes *et al*., 2005). Even though, tastelessness and odor characteristics in water do not imply the presence or absence of cyanobacteria (Hudnell, 2008).

Studies on cyanobacteria performance around the world have been conducted seeking to understand the different mechanisms and ecological attributes that would explain cyanobacteria's success compared to other phytoplankton groups. Some studies have already demonstrated a change in the phytoplankton structure during blue-green blooms, with a decrease of species richness, diversity and evenness due to the dominance of cyanobacterial species (Crossetti *et al*., 2008). Several strategies used by blue-green species may allow them to suppress other algae species, for example, creating a light limited condition due to excessive biomass generated by the bloom (Hubble and Harper, 2001). Many factors such as temperature, light, nitrogen, phosphorus, carbon, predation and microbial interactions may be involved in the establishment of these organisms (Dokulil and Teubner, 2000). Among these factors, despite the fact that high nutrient levels due to artificial eutrophication may explain blue-green blooms in several environments, temperature can strongly favor cyanobacterial development (Paerl and Huisman, 2008). In a direct way cyanobacteria generally grow better in higher temperatures (Reynolds, 2006), whereas indirectly the thermal stratification of the water column and a more stable condition may benefit bloom occurrence (Pearl and Huisman, 2008; Fernandes *et al*., 2009; Becker *et al*., 2008). Especially in shallow lakes, mixing patterns and stratification of the water column can manage the availability of nutrients (mainly N and P) and light directly influencing the cyanobacterial blooms and species composition as shown by Bicudo *et al*. (2007).

In this context, considering the several environmental conditions that may favor cyanobacterial blooms and the strategies of blue green species that let them good competitors, the hypothesis that cyanobacterial blooms may reduce phytoplankton species richness, diversity and evenness during bloom events is tested in the present study. So, the objective of this research was to evaluate the influence of cyanobacterial summer blooms in the phytoplankton structure in a shallow urban lake contributing to the comprehension of the driving factors involved in the recurrent summer bloom events in Guaíba Lake, southern Brazil.

Material and methods

Study Area

Guaíba Lake receives the waters from a river basin which covers much of the central and northeastern areas of Rio Grande do Sul State, extending over an approximate area of 84,700 km^2, encompassing more than 250 municipalities, including the city of Porto Alegre (Figure 1). It is a riverine and deposition system with a surface of 496 km^2, composed of the mouths of the Jacuí, Caí, Sinos and Gravataí rivers (Nicolodi, 2007). The Guaíba Lake basin (29° 45’ - 30º 12’ S and 50º 27’ - 51º 12’ W) presents an area of 2,323 km^2 and a population of approximately three million inhabitants, being the city of Porto Alegre responsible for the more intensive occupation (Bendati *et al*., 2003). The lake area is 496 km², the length is 50 km and the width varies from 1 to 20 km. The mean depth is about 2 m, reaching 12 m in the navigation channel (Nicolodi, 2007).

The lake is an important source of water for the surrounding municipalities, providing also other uses for commercial and economic activities (Bendati *et al*., 2003; Rodrigues, 2004). Nevertheless, the Guaíba Lake presents many environmental problems as it covers the most populous and productive contingent of the state (Tavares *et al*., 2003). Records of cyanobacterial blooms in Guaíba Lake have been made since the 1970’s (Torgan, 1989; Maizonave *et al*., 2009), putting on alert public health authorities and those responsible for water supply (Cybis *et al*., 2006).

Samplings

Samplings were collected near the water intake station of the Belém Novo district water treatment station (30°13’02.44” S 51°12’00.82” W). The sampling point was located at 1,800 m from the left margin, straight toward the navigation channel from Guaíba Lake, with a maximum depth of 5.1 m (records made on September 15 and October 6, 2009) and coincided with periods of heavy rain (according to the DMAE Research Division database) (Figure 1). Precipitation data was obtained by the 8° Meteorological District (INMET), in Porto Alegre city. Records on the blooming of cyanobacteria on this site have been made with the monitoring analysis of DMAE.

Water sampling for chemical, physical and biological analysis were carried out monthly from October 2010 to March 2011, in order to follow cyanobacterial bloom episode. The thermal profile, dissolved oxygen and pH (APHA, 1992) were investigated at three depths: ± 20 cm under the surface (subsurface), 1.20 m and 0.50 m from the bottom (bottom), *in situ* with probe. The thermal stratification was inferred by calculating the relative water column stability (RWCS), according to Padisák *et al.* (2003), from the temperature data. Water transparency was measured with a Secchi disk and the euphotic zone (Zeu) was estimated following Cole (1983). Analysis of total dissolved phosphorus (TDP), soluble reactive phosphorus (SRP), ammonia (N-NH$_3^-$), nitrite (N-NO$_2^-$), nitrate (N-NO$_3^-$) and electrical conductivity were made from samples collected at 1.20 m, following DMAE sampling protocol, according to the techniques described in APHA (1992). Samples for phytoplankton analysis were collected in the subsurface water (± 20 cm surface) and aliquots were preserved in amber glass bottles of 200 ml and fixed with acetic Lugol’s solution of 0.5%. The organisms were identified, whenever possible, with specialized literature up to their specific or infraspecific level. Komárek and Anagnostidis (1986, 2005), Komárek (1989, 1999), Komárek *et al*. (2003) and Komárek and Komárková (2004) were adopted for the identification of cyanobacterial species. Quantitative analysis of phytoplankton was carried out according to Utermöhl (1958), systematically in longitudinal and vertical transects. Sample settling time was 4 hours for each centimeter of height of the chamber (Lund *et al*., 1958). The number of fields to be counted was determined by the graphical method of rarefaction of species obtained from the number of species added with increased sampling area (Bicudo, 1990). From the quantified organisms, the biomass (mm^3.L^{-1}) was estimated using the biovolume obtained by multiplying each species’ density by the mean vol-

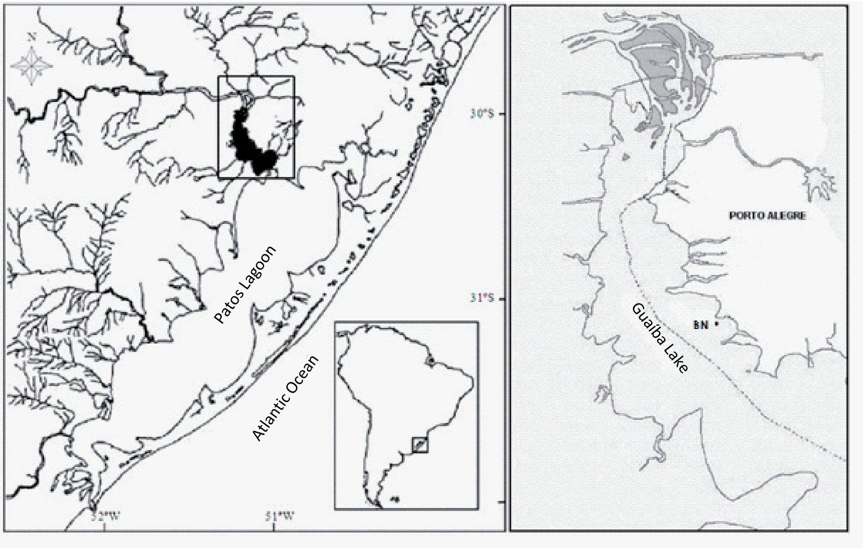

Figure 1. Location and map of Guaíba Lake showing the sampling site. Source: Research Division of DMAE.

ume of its cells, according to Sun and Liu (2003) and Hillebrand *et al*. (1999). The total diversity index (Shannon and Weaver, 1963), evenness (Lloyd and Ghelardi, 1964) and dominance (Simpson, 1949) were calculated through the biomass data. Species richness was expressed through the number of taxa. Species considered biological descriptors species were those whose relative biomass contributed to at least 1% of the total biomass.

The data were analyzed through descriptive statistics. After testing data distribution, as for the integrated analysis, it was assessed by Pearson correlations at a confidence level of 95% (α =0.05), and simple and multiple linear regressions by the use of the most important variables indicated in the correlations, with Systat software version 12.0 (SYSTAT, 2007).

Results

Abiotic variables

During the current study, total precipitation values were lower than the historical means, being the lower values observed in December (17.7 mm) and October 2010 (42.5 mm) (Figure 2). The air temperature presented an average of 24.5°C, being the minimum value observed in October 2010 (22°C) and the maximum in February 2011 (26.0°C). This pattern directly influenced water temperature which also showed minimum values in October 2010 (20°C) and maximum values in February 2011 (27°C) (Table 1). Thermal profile of the water column showed strong thermal stratification in November 2010, when the highest values of RWCS were observed (Figures 3 and 4). Although with lower values of RWCS, some water stability has also been observed in October, 2010, January and February, 2011. In general, the depth of Guaíba Lake presented little variation during the period of the study, with an average of 4.2 m, with the maximum depth recorded in January 2011 (4.7 m) and minimum

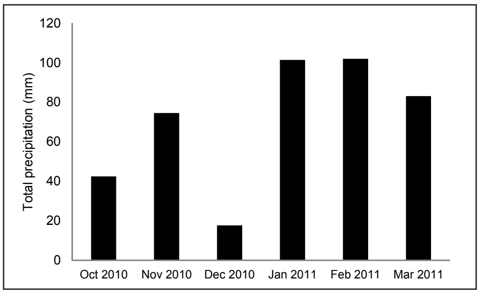

Figure 2. Total precipitation (mm) in Guaíba Lake, from October 2010 to March 2011.

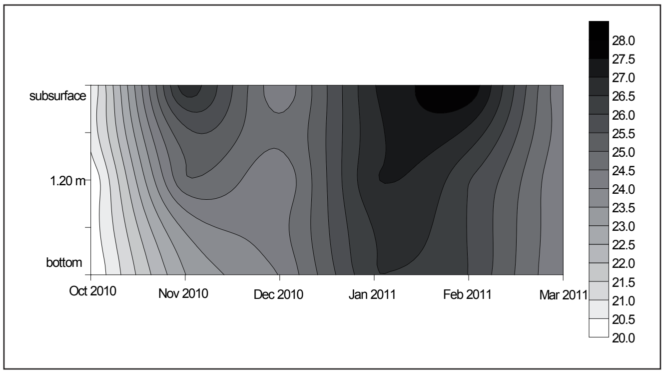

Figure 3. Depth-time diagram of water temperature (°C) in Guaíba Lake, from October 2010 to March 2011.

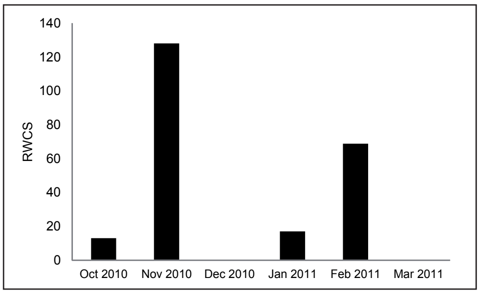

Figure 4. RWCS of water column in Guaíba Lake, from October 2010 to March 2011.

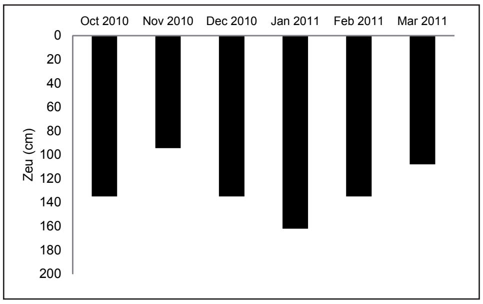

Figure 5. Euphotic zone (Zeu, cm) of water column in Guaíba Lake, from October 2010 to March 2011.

in March 2011 (3.9 m). Transparency presented an average of 47.5 cm being the maximum transparency registered in January, 2011 (60 cm) and the minimum (35 cm) in February, 2011. The euphotic zone presented the same tendency, presenting higher values in January, 2011 (162 cm) (Figure 5).

Considering the pH, the minimum value (6.9) was recorded in March, 2011 in the middle of the water column and the maximum (8.7) was observed in January, 2011 at the subsurface. The conductivity tended to increase from November 2010 until February 2011, when the maximum value was observed (79.4 µS.cm^{-1}).

The dissolved oxygen profile showed chemical stratification throughout the study period, except in March, 2011, when oxygen values were homogeneous throughout the water column. Maximum values were observed in October, 2010 and January, 2011 (8.6 mg.L^{-1}) at the subsurface. The lowest value was observed in February, 2011 (7.2 mg.L^{-1}) (Figure 6, Table 1).

Regarding the nutrients, N-NO_3^- and N-NO_2^- showed the same trend throughout the study period, presenting the highest concentrations in November 2010 (90 and 1090 µg.L^{-1}, respectively) and the lowest in January 2011 (10.0 and 480, 0 µg.L^{-1}, respectively). Although in February, 2011 a peak in the N-NH_3^- concentration was observed (590 µg.L^{-1}), in January 2011 and March 2011 it was below the analytical method. Similarly, SRP concentrations were below the detection limit during all the period of the study, meanwhile TP showed a maximum of 160 µg.L^{-1} in March 2011 and a minimum of 90 µg.L^{-1} in October, 2010 (Figure 7).

Table 1. Minimum (min), maximum (max), mean values and standard deviation of environmental variables in Guaíba Lake, from October 2010 to March 2011. SRP values (dashes) were below the limit of the analytical method (<30 µg.L^{-1}).

Variables	min	max	mean	sd
Air temperature (°C)	22.00	26.00	24.50	1.38
Water temperature (°C)	20.00	27.00	24.33	2.42
Depth (m)	3.90	4.70	4.18	0.33
Transparency (cm)	35.00	60.00	47.50	8.80
Conductivity (µS.cm-1)	69.40	79.40	73.28	3.76
pH	6.90	7.70	7.43	0.28
Dissolved oxygen (mg.L-1)	7.20	8.10	7.83	0.34
N-NH3- (µg.L^{-1})	0.00	590.00	190.00	221.54
N-NO2- (µg.L^{-1})	10.00	90.00	40.00	28.28
N-NO3- (µg.L^{-1})	480.00	1090.00	808.33	258.10
SRP (µg.L^{-1})	-	-	-	-
TP (µg.L^{-1})	90.00	160.00	115.00	25.10

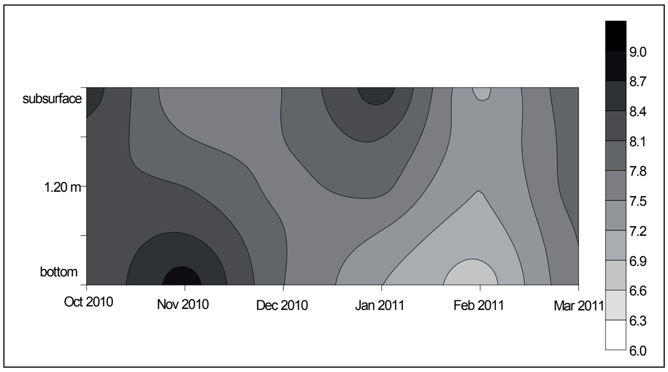

Figure 6. Depth-time diagram of dissolved oxygen (mg.L^{-1}) in Guaíba Lake, from October 2010 to March 2011

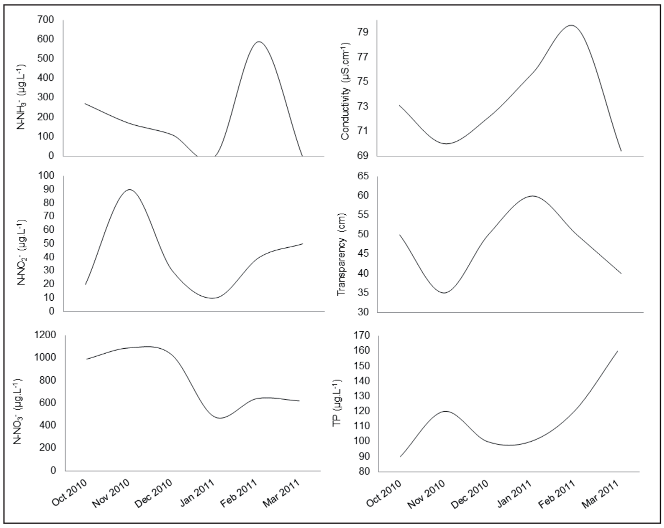

Figure 7. Ammonia (N-NH_3^-), nitrite (N-NO_2^-, µg.L^{-1}), nitrate (N-NO_3^-), conductivity (µS.cm^{-1}), transparency (cm) and total phosphorus (µg.L^{-1}) in Guaíba Lake, from October 2010 to March 2011.

Biological variables

The highest phytoplankton biomass was observed in the months of February and March, 2011 (10.3 and 30.9 mm^3.L^{-1}, respectively). During the sampling period there was a tendency of increasing from the beginning of January, 2011 (Figure 8).

Considering the floristic composition, 57 taxa were identified in nine taxonomic classes of algae. The most representative class in terms of species richness were Chlorophyceae (40.4%) and Cyanobacteria (14.0%) followed by Bacillariophyceae and Chrysophyceae (12.3%). Throughout the study period, changes in the contribution of phytoplankton classes were observed. Cryptophyceae contributed with more than 50% of total biomass in October and November, 2010 (1.7 and 2.4 $mm^3.L^{-1}$, respectively). Diatoms' higher biomass was registered in December, 2010, also reaching more than 50% of total biomass (2.3 $mm^3.L^{-1}$). From December on, cyanobacterial occurrence was noted (0.01 $mm^3.L^{-1}$), with its increment reaching its higher values in March, 2011 (29.2 $mm^3.L^{-1}$) (Figure 8).

Increase tendency was observed on diversity, species richness and evenness values from October, 2010 to January, 2011 (Figure 9). The low values of these parameters were registered in October, November, 2010 and February, 2011, meanwhile, in this month the highest value of dominance (0.35) was observed.

Nine descriptor species contributed to more than 90% of total biomass found in the study. Tracking the tendencies showed by the classes, it is possible to highlight *Cryptomonas curvata* Ehrenberg emend Penard and *C. brasiliensis* Castro, C. Bicudo and D. Bicudo occurrence in October and November, 2010, *Cyclotella meneghiniana* Kützing in December 2010 and *Planktothricoides raciborskii* (Wolosz.) Suda et M. M. Watanabe in Suda *et al*. from December, 2010 onwards (Figure 10).

Integrated analyses

Pearson correlations pointed out the significant relation of TP into the establishment of *P. raciborskii* (0.907; p = 0.01) and, consequently, of Cyanobacteria (r = 0.897; p = 0.01). Simple linear regression showed that TP significantly influenced the increment of

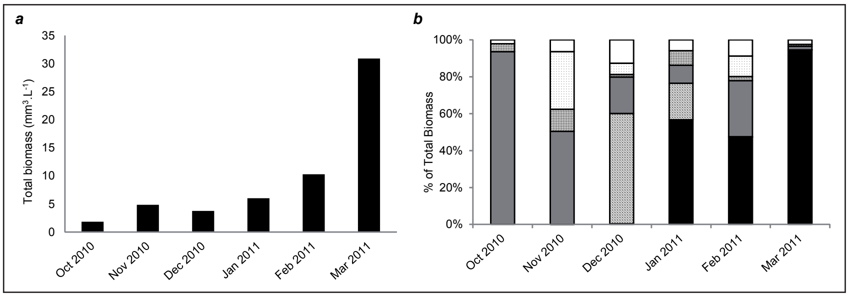

Figure 8. Total biomass (a) (mm^3 L^{-1}) and percentage of phytoplankton classes' contribution (% of total biomass) (b) in Guaíba Lake, from October 2010 to March 2011. Legends: ■ = Cyanobacteria; ▩ = Cryptophyceae; ▒ = Chlorophyceae; ▨ = Bacillariophyceae; □ = Other.

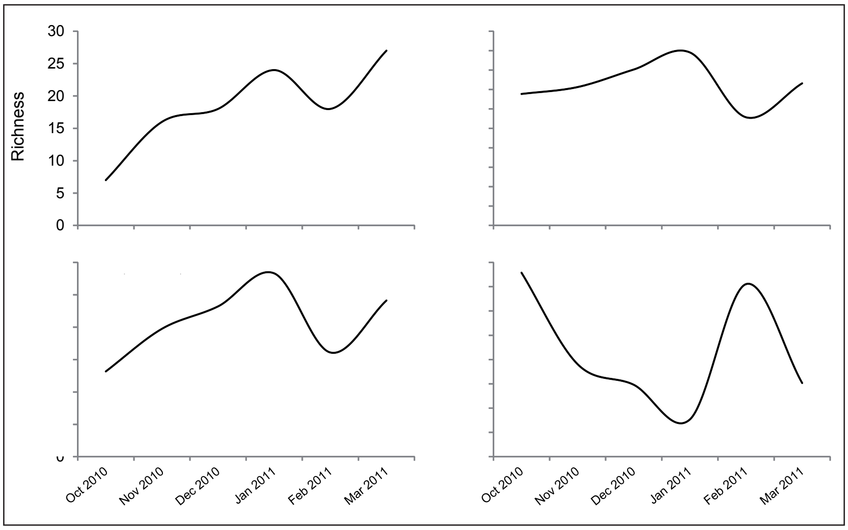

Figure 9. Species richness (number of taxa), diversity (bits.ind^{-1}), equitability and dominance index in Guaíba Lake, from October 2010 to March 2011.

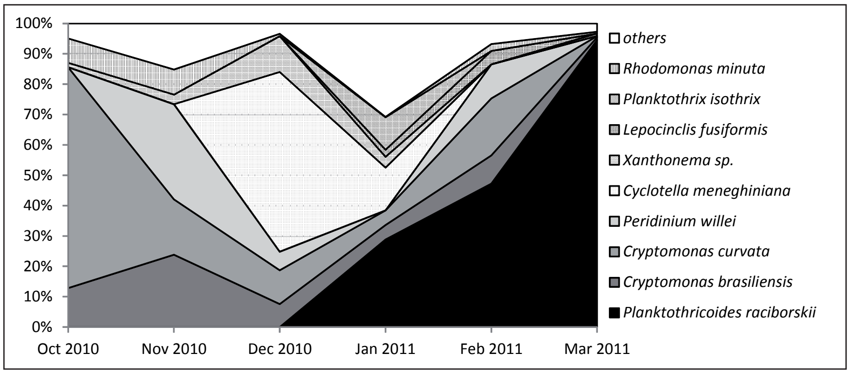

Figure 10. Descriptors species variation (% of total biomass) in Guaíba Lake from October 2010 to March 2011.

P. raciborskii (Figure 11) biomass, explaining 82% of the species variance. Although RWCS was not indicated as a descriptive variable ($p > 0.05$), the multiple regression, considering TP and RWCS as explanatory variables, summarized 97% of the *P. raciborskii* variance (Figure 11). A tendency of other phytoplankton classes' replacement by blue-greens was evidenced by a simple regression, even though it was not significant (Figure 11).

Discussion

The structure of phytoplankton was clearly influenced by cyanobacterial summer bloom in the Guaíba Lake. Blue-greens dominance suppressed other planktonic groups, decreasing species diversity in January and February 2011. The low values of diversity found in October 2011 may be associated with the low values of P and mixed water column, which favored *Cryptomonas* spp. dominance as well as the highest values found in March, may be due to the highest TP concentrations. Many factors might be related to the cyanobacterial success in the present study. One of them is the temperature. The indirect positive effects of temperature in cyanobacteria success are manifold (Wagner and Adrian, 2009). Through these direct and indirect effects of temperature, in combination with reduced wind speed and reduced cloudiness, summer heat waves boost the development of harmful cyanobacterial blooms (Jönk *et al*., 2008).

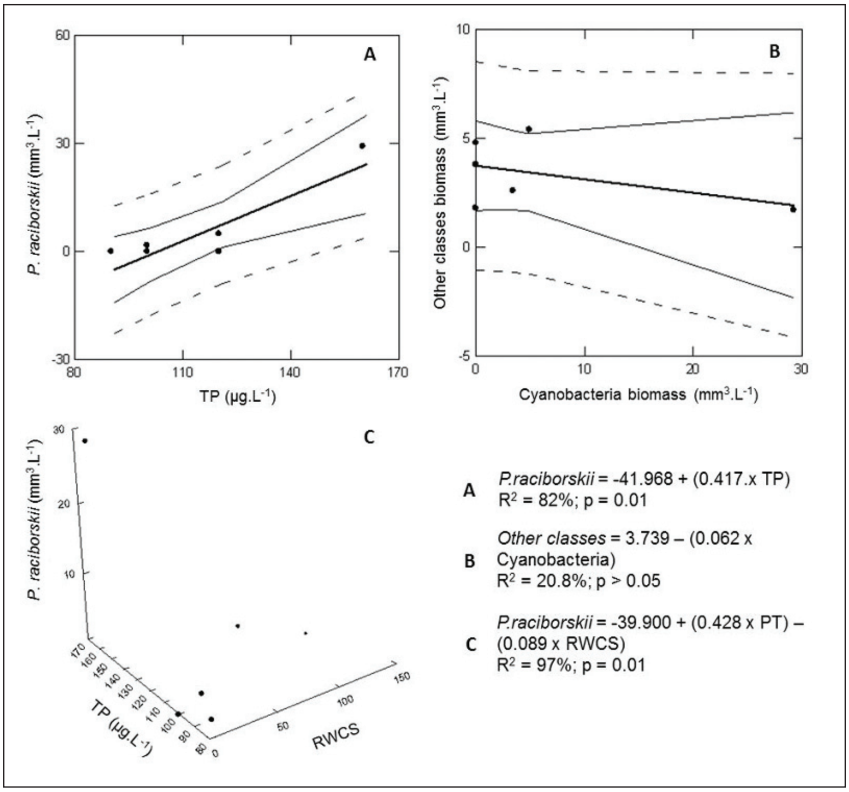

Figure 11. Linear regressions between (A) *P. raciborskii* biomass ($mm^3.L^{-1}$) (dependent variable) and total phosphorus (TP, $\mu g.L^{-1}$) (explanatory variable), (B) biomass of algae classes other than blue-greens ($mm^3.L^{-1}$) (dependent variable) and cyanobacteria biomass ($mm^3.L^{-1}$) (explanatory variable) and (C) *P. raciborskii* biomass ($mm^3.L^{-1}$) (dependent variable) and total phosphorus (TP, $\mu g.L^{-1}$) and RWCS (explanatory variables). Legends: dotted line = upper and lower prediction limits; thick line = regression estimate; continuous line = upper and lower confidence limits.

Despite the fact that cyanobacteria's growth is heightened during periods of higher temperatures in comparison to other phytoplankton algae, as diatoms and green algae, warmer temperatures occurring during drought periods increase discharges of subsidies and the water residence time, resulting in an increase of the nutrient load, what favors cyanobacteria (Pearl and Huisman, 2008). Previous monitoring in Guaíba Lake evidenced that during dry periods (La Niña, 2003-2006), residence time was higher, which enhanced the biomass increment and the blue-green development, benefited by the higher nutrient availability (Andrade and Giroldo, 2010). In the present study, the development of cyanobacteria initially occurred in December 2010, during a less stable water period.

The fact that the sampling point of the present study is in basin, in a location away from the navigation channel of the lake, may also be reinforced since it constitutes greater stability to the site, favoring cyanobacteria development and contributing to the summer bloom recruitment in Guaíba Lake. According to Reynolds (2006) one of the preconditions for the blooming of cyanobacteria is the stability of the water column. Other studies have shown the relationship between stratification patterns and the development of cyanobacterial blooms (Bicudo *et al*., 2007; Crossetti and Bicudo, 2008; Becker *et al*., 2008).

It is noteworthy the *La Ninã* effects on Guaíba Lake catchment area and its influence on the environmental scenario for phytoplankton structuring. Changes on phytoplankton structure patterns and production, as a response to a severe drought caused by *La Niña* was already registered in subtropical freshwater ecosystems (Odebrecht *et al*., 2005; Abreu *et al*., 2009; Andrade and Giroldo, 2010; Borges and Train, 2009). Interestingly, Rodrigues *et al*. (2009) reported the dominance of cyanobacteria in *La Niña* periods, characterized by lower precipitation and reduced fluviometric levels of Paraná River.

The samplings of the present study were conducted during the *La Niña* period, which was characterized by low rainfall. This phenomenon led to the decrease on inflow of Guaíba Lake tributaries, increasing the transparency levels. This scenario benefited species which explore P from the sediment. This is the case of *Planktothricoides raciborskii*, which is very similar to those species that typically occur in illuminated metalimnion of eutrophic environments (Reynolds *et al*., 2002).

Planktothrix and *Planktothricoides* are very similar genera. One of the most important dissimilarities is the fact that *Planktothricoides* have solitary trichomes attenuated towards their ends and sometimes slightly bent near the apex (Komárek and Komárková, 2004; Komárek and Anagnostidis, 2005). Though both genera are morphologically similar, *Planktothricoides* comprises an independent phylogenetic cluster from *Planktothrix* based on 16S rDNA sequence analysis (Komárek and Anagnostidis, 2005).

In Guaíba Lake, *P. raciborskii* was the species that contributed most to the cyanobacteria total biomass. Its development started in December, probably driven by an increase in transparency, which might have recruited *P. raciborskii* inoculum from the non-nutrient limited deepest layers. Subsequently, the biomass rose along the stratified months, reaching the maximum value of biomass under the highest concentrations of TP ($r = 0.907$, $p = 0.01$), lower values of transparency and absence of stratification. According to functional groups scheme (Reynolds *et al*., 2002; Padisák *et al.*, 2009), this species would belong to the codon **S1**, of shade-adapted cyanoprokaryotes, typical of turbid mixed environments. Despite the fact that the highest biomass occurred in mixed periods, the multiple regression performed for this study showed that, together with TP, RWCS was important for *P.raciborskii* variance.

Considering the other descriptive species on Guaíba Lake, the frequent occurrence of cryptomonads stood out. *Rhodomonas minuta* Skuja and *Cryptomonas brasiliensis* presented its best development in October, under a weakly stratified water column. According to Reynolds *et al*. (2002), these species are indicative of clear mixed environments, as observed in the present study. At the same time, *Cryptomonas curvata* presented higher biomass at the beginning of the present study, occurring all over the sampling period. Notwithstanding, according to Klaveness (1988), the relative contribution of cryptomonads may relate to environmental disturbances due to their opportunistic features. The occurrence of *Cyclotella meneghiniana,* which is sensible to stratification onset (Reynolds *et al*., 2002), coincided with the lower values of RWCS in December, just like *Xanthonema* sp. that may similarly adapt to turbulent ecosystems (Reynolds *et al*., 2002). Euglenoids occurrence was represented by *Lepocinclis fusiformis* (Carter) Lemm. emend. Conr. biomass which might indicate the incidence of organic matter in Guaíba Lake (Padisák *et al*., 2009), especially by the end of the study period, coinciding with the higher TP concentrations observed. Despite the higher contribution of *Planktothricoides raciborskii* to the total biomass of cyanobacteria, *Planktothrix isothrix* was also determined as a biological descriptor. This species, who is also well-adapted to the low availability of light and mixed environments (Reynolds *et al.*, 2002; Padisák *et al*., 2009), contributed more in January but did not develop.

Considering the changes on phytoplankton structure during the bloom episode, a tendency of other phytoplankton species' replacement by blue-greens was evidenced, although the simple regression has not pointed out significant variation, probably due to the reduced sample size. Cyanobacteria have several strategies which make them good competitors in comparison to other algae groups. Surface blooms may shade underlying phytoplankton (Pearl and Huisman, 2008), outcompeting non-adapted species, affecting the community structure which is dominated by blue-greens (Hubble and Harper, 2001). Moreover, many species can seek for the best position in the water column due to gas vacuoles (Mischke, 2003; Chu *et al*., 2007) and may trickle low nutrient availability by forming heterocytes (Huszar *et al*., 2000) or storing P (Calijuri *et al*., 2002; Mateo *et al*., 2006).

Furthermore, after the blue-greens development, decrease on diversity, richness and evenness were registered, indicating that only very adapted algae could occupy a highly selective environment with low availability of light and limiting SRP. In Guaíba Lake, SRP limitation was verified during the whole studied period. SRP limitation in eutrophic ecosystems was already identified in other studies as a result of fast uptake by phytoplankton species, leading to concentrations under the analytical thresholds (Crossetti and Bicudo, 2008; Ramírez and Bicudo, 2005). No N limitation was recorded on Guaíba Lake during the studied period.

In summary, cyanobacterial summer bloom outcompeted other phytoplankton species, decreasing biodiversity in Guaíba Lake, corroborating other studies findings. Among the environmental driving factors, water column stability, total phosphorus increment and transparency patterns were important for recruitment and establishment of cyanobacteria, possibly as a consequence of rainfall alterations caused by *La Niña*.

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