Nycthemeral cycles and seasonal variation of limnological factors of a subtropical shallow lake (Rio Grande, RS, Brazil)

Variação nictemeral e sazonal de fatores limnológicos de um lago raso subtropical (Rio Grande, RS, Brasil)

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Abstract: Aim: The aim of this study was to describe the nycthemeral cycle and seasonal patterns of the abiotic variables of a subtropical shallow lake. **Methods:** The study was conducted in Biguás Lake, located in the university campus of the Universidade Federal do Rio Grande – FURG in the city of Rio Grande, Rio Grande do Sul State – Brazil. The samples were performed monthly, from June/04 to May/05, each sample were obtained in 6 hours intervals, during 2 days. **Results:** The whole water column temperature varied in warming and cooling cycles throughout the day, and performed a seasonal pattern. The dissolved oxygen concentrations increased gradually during the day and decreased at night. Values of pH, alkalinity, and electrical conductivity showed small variations between the hours scheduled for samplings and between surface and bottom. **Conclusions:** The analyzed variables occur in a uniform way in the water column due to the constant circulation of the whole water mass, facilitated by the slow depth and the constant action of wind.

Keywords: shallow lake, daily cycles, annual cycles, limnological variables, eutrophication.

Resumo: Objetivo: O objetivo deste trabalho foi descrever o padrão nictemeral e sazonal das variáveis abióticas de um lago raso subtropical. **Métodos:** O estudo foi realizado no Lago dos Biguás localizado no campus da Universidade Federal do Rio Grande – FURG na cidade do Rio Grande, Rio Grande do Sul – Brasil. As coletas foram realizadas mensalmente, entre junho de 2004 e maio de 2005, durante dois dias consecutivos, em intervalos de 6 horas. **Resultados:** Ao longo do estudo verificou-se um padrão sazonal de variação de temperatura, entretanto, observaram-se processos diários de aquecimento e resfriamento de toda a coluna d'água ao longo do ano. As concentrações de oxigênio dissolvido aumentaram gradativamente ao longo do dia, diminuindo à noite. Valores de pH, alcalinidade e condutividade elétrica mostraram pequenas variações entre os horários de coleta e entre a superfície e o fundo. **Conclusões:** As variáveis analisadas ocorrem de maneira uniforme na coluna d'água, devido a constante circulação de toda a massa d'água, facilitada pela pequena profundidade e pela ação constante do vento.

Palavras-chave: lagos rasos, ciclos diários, ciclos anuais, variáveis limnológicas, eutrofização.

1. Introduction

The major part of natural and artificial lakes is small and shallow (Wetzel, 1993), however, the knowledge of lentic waters by several years was dominated by researches in the great lakes of Earth. These studies revealed that some aspects such as geographical position and morphometry play an important role in the lakes dinamics. According to Esteves et al. (1988) the proposed models for temperate environments must not be applied directly to tropical lakes. The authors point out that in temperate regions the seasonal pattern, which cycle is practically annual and the presence of well-defined seasons creates persistent distinctive situations. On the other hand, the tropical aquatic environment seems to respond also to chemical, physical and biological short-time environmental alterations (nycthemeral variation).

Lagoons and coastal lakes may also present different functional patterns. At these environments the wind direction usually changes twice a day. In those places without natural obstacles and with large water surface in relation to the depth, it is usual to observe physical, chemical, and also biological homogenization in the water column throughout the year (Petrucio, 1998).

Located at the coastal plains of the Rio Grande do Sul State (32° 01' 40" S and 52° 05' 40" W), the city of Rio Grande comprises a stripe of lowlands in the Atlantic

Coast *Restinga* (coastal forests which form on sandy, acidic, and nutrient-poor soils) of Rio Grande, SW of the mouth of the Patos Lagoon (Vieira and Rangel, 1988). The region has a Humid Subtropical Climate (Cfa at Köppen's Classification) characterized by intense humidity in winter and spring and dry during summer. Northeast winds are frequent most part of the year, however, in the months of autumn and winter, South winds and, especially, southwest winds, become significantly important (Krusche et al., 2002).

The low altimetric quotas of the city of Rio Grande do not allow the formation of large rivers, as a result, small rivers (known as arroios) are the main components of its internal hydrographic network (Vieira and Rangel, 1983). The proximity of the water table to the soil surface makes favorable the occurrence of temporary lagoons when the pluviometric precipitation is heavier. The water is also present in abundance in wetlands (banhados) and small lagoons (Krusche et al., 2002).

Preliminary studies in small and shallow environments in the city of Rio Grande makes clear the development of distinct biological communities (Albertoni et al., 2005; Trindade et al., 2008a; Trindade et al., 2008b). However, little is known about the functional dynamics of these systems, since the limnological researches carried out in the Rio Grande's Restinga have been performed predominantly in the great coastal lagoons, as instance (Schäfer et al., 1980; Schäfer, 1988; Proença et al., 1988; Niencheski et al., 1988).

Facing the lack of information about shallow environments in southern Brazil, the present study aims to describe annual and daily cycles of limnological variables in a shallow eutrophic waterbody.

2. Material and Methods

2.1. Study area

The Biguás Lake is located in the university campus of the Universidade Federal do Rio Grande – FURG (32° 04' 43" S and 52° 10' 03" W), in the city of Rio Grande, Rio Grande do Sul State – Brazil (Figure 1). The FURG's campus Carreiros has an area of approximately 250 ha and is found in the way to downtown Rio Grande. In addition, is located near to the Environmental Protected Area of Verde Lagoon, the Atlantic Ocean and Taim Ecological Station (Votto et al., 2006).

The university campus possesses a group of small waterbodies that were the main water source for the city of Rio Grande until the 70's. Anthropic activities which exist since the beginning of the campus's construction in 1978

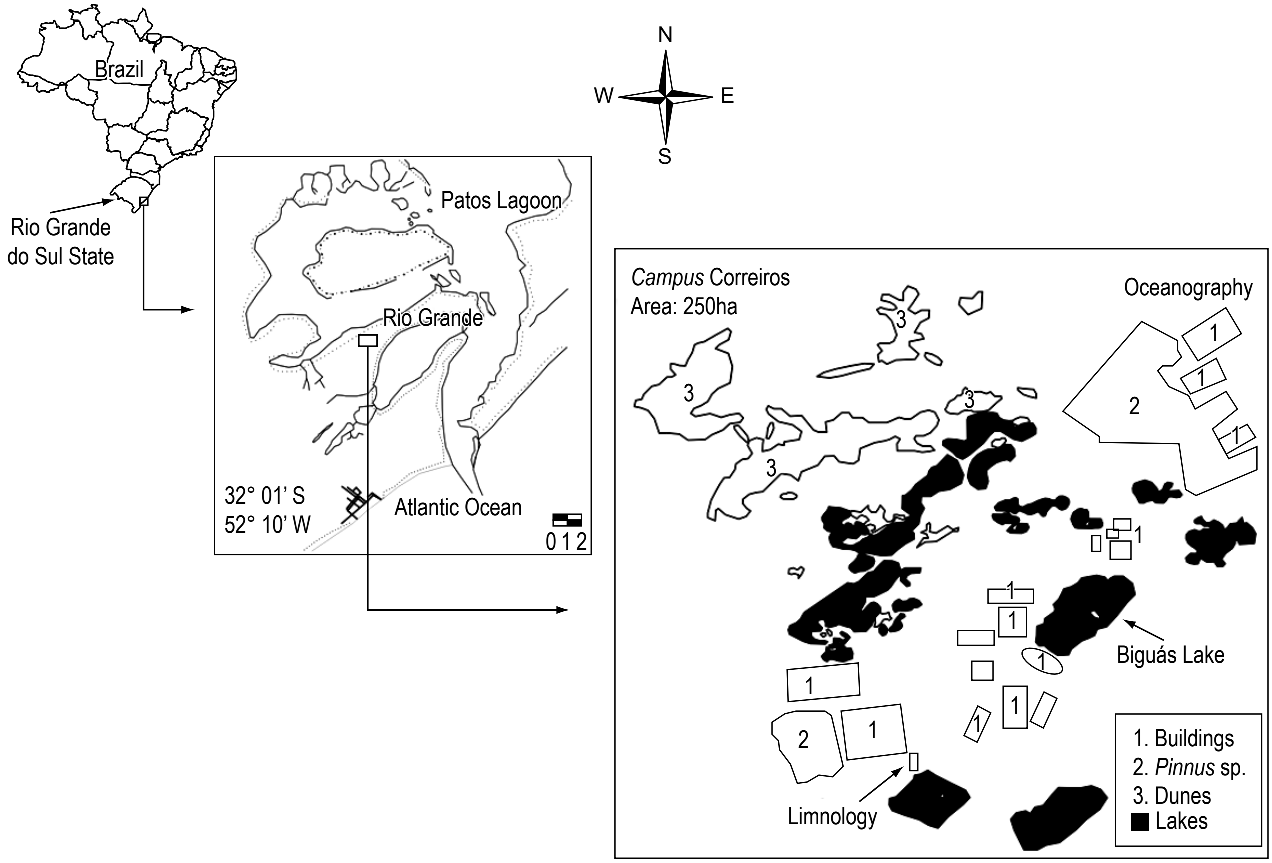

Figure 1. Study site. Biguás Lake, located at campus Carreiros, FURG, (Rio Grande, Rio Grande do Sul State, Brazil).

have promoted several alterations in the line of margins, depth, coastal vegetation, etc. Therefore, these small lagoons are a mix of original environments modified and environments completely built by human activities.

The Biguás Lake may be considered as an environment that has been modified during the last 35 years. It has a surface area of approximately 1.5 ha and depth that varies accordingly to the pluviosity, but not trespassing 2 m depth. In its margins it is observed the presence of fixed floating aquatic macrophytes, with predominance of *Nymphoides indica* (L.) Kuntze, and the amphibians and/or emergents *Polygonum hydropiperoides* Michx. Its surroundings are constituted basically by grass and some shrubs, with occurrences of *Erytrina crista-galli* L. and *Salix humboldtiana* Willd. In the center of the lake there are two artificial islets used as shelter and resting place for cormorants, herons, teals and domestic geese. Due to the occurrence of birds in the lake there is an excessive input of organic matter, which is the main source of nutrient enrichment, accelerating the eutrophication process. As a result, frequent microalgae blooms occur and, in the summer months (drought season), it was observed cyanobacterial blooms followed by great mortality of fish (personal observation).

2.2. Sampling procedures

Samplings were carried out monthly during the period of June/04 and May/05, collected in a small boat in the center of the lake. Sampling frequency for determination of nycthemeral variation of temperature, dissolved oxygen, pH, electrical conductivity and alkalinity was performed in intervals of 6 hours, during two consecutive days, at 6:00 AM, 12:00 PM and 6:00 PM. Depth and water transparency were measured with a 20 cm diameter Secchi disk (always at 12:00 PM). Temperature and dissolved oxygen concentration (DO) were measured at each 10 cm depth onward to the bottom of the lake using a digital oximeter (Oakton®, USA). Samples from surface, medium and bottom of water column were collected using a pressure pump attached to a hose and conditioned in plastic bottles and immediately transported to the laboratory for the measurement of pH and electrical conductivity (pHmeter Hanna®, UK). The alkalinity was estimated by the Gran method (potentiometric titration using 0,01N H_2SO_4) according to Carmouze (1994).

The temporal variations of chlorophyll-*a*, suspended material, and total nitrogen and phosphorus concentrations were obtained monthly from water surface samples. Chlorophyll-*a* concentration was determined from the retained material of replicas from 250 mL water samples, filtered through a fiber glass filter (GF/C Whatman®, USA). The pigment extraction was carried out in 90% ethanol during 24 hours (kept refrigerated at dark), and the estimative of the chlorophyll-*a* concentration was achieved with a fluorometer Turner TD-700 (Turner BioSystems®, USA), according to Welschmeyer (1994).

The suspended material concentration was measured by the filtration of 250 mL water (GF/C Whatman®, USA). The filters were kept in a 60 °C oven for 48 hours and subsequently weighted, performed according to the gravimetric method described by Paranhos (1996). The determination of total-N and total-P was carried out in separated aliquots of 500 mL water samples. The samples were conditioned in polyethylene bottles and kept frozen (–20 °C) for posterior analysis in the Agency for the Development of the Mirim Lagoon, Pelotas, Rio Grande do Sul State, according to Tedesco et al. (1995). The air temperature, pluviometric precipitation, wind velocity and direction were obtained from the Meteorological Station – FURG.

3. Results

The results of meteorological variables are presented in Table 1. Values of depth, suspended matter, chlorophyll-*a*, total nitrogen and total phosphorus are shown in Table 2.

Table 1. Meteorological data during the study, values of: air temperature (°C); wind speed ($m.s^{-1}$); wind direction; precipitation (mm) and days of precipitation. Source: Meteorological Station FURG.

Month	Air Temperature		Wind Speed	Wind Direction	Precipitation	Days of precipitation
	Min.	Max.				
June	11.1	19.7	1.4	SP	62.6	15
July	9.6	17.8	2.6	NE	132.8	9
Aug.	10.8	19.8	2.3	NE	70.5	11
Sept.	12.5	21.5	3.1	SE	47.0	12
Oct.	13.4	22.3	3.0	SP	145.5	8
Nov.	16.2	23.8	3.5	E	107.5	13
Dec.	18.1	26.4	3.6	NE	56.1	5
Jan.	20.0	29.7	3.3	SP	17.2	3
Feb.	19.5	28.6	4.4	SE	38.9	8
Mar.	18.4	28.5	3.0	SE	76.4	9
Apr.	14.3	24.4	2.2	SP	262.5	15
May	13.5	21.5	2.5	NE	163.4	19

Table 2. Limnological variables in Biguás Lake during the study. Depth values (m); suspension materials (SM = mg.L^{-1}); chlorophyll-*a* (Chl-*a* = μg.L^{-1}); total nitrogen (TN = mg.L^{-1}) and total phosphorous (TP = mg.L^{-1}).

Month	Depth	SM	Chl-*a*	TN	TP
June	1.5	0.02	88.9	7.0	0.1
July	1.5	0.02	102.9	5.8	3.1
Aug.	1.5	0.02	117.6	5.6	2.5
Sept	1.4	0.04	60.1	5.0	2.4
Oct.	1.5	0.02	31.8	2.8	1.7
Nov.	1.5	0.03	34.8	5.6	3.0
Dec.	-	-	-	-	-
Jan.	0.9	0.05	453.1	7.0	3.1
Feb.	0.7	0.01	47.5	4.2	3.0
Mar.	-	-	-	-	-
Apr.	1.2	0.01	36.7	3.0	2.4
May	1.7	0.01	21.4	3.8	2.8

(-) Not measured parameters.

The analysis of the thermal structure of Biguás Lake allowed the observation of a seasonal variation of water temperature, that reaches lower values in the winter (14.9 and 16.3 °C) and higher levels in the summer (23.4 and 30.6 °C), according to the changes in the atmospheric temperatures (Figure 2). However, by means of the nycthemeral analysis in the four climatic seasons, it is also possible to note that the lake presents similar processes of warming and cooling of the whole water column during the daily cycles (Figure 3). The lower values of temperature were observed in the first hours of the day (6:00 AM) and increasing gradually until 12:00 PM. In the afternoon, between 12:00 and 6:00 PM, it was observed the cooling of surface waters and at night, between 6:00 PM and 6:00 AM of the next day, it was verified a decrease in the water temperature in the whole water column.

Lower concentrations of dissolved oxygen (3.05 mg.L^{-1}) were found in October (spring), however, during the whole period studied it was not verified oxygen deficits in the water column (Figure 2). The analysis of the nycthemeral variation of dissolved oxygen showed a gradual increase in its concentration along the day, reaching maximum values at 6:00 PM, and decreasing during the night, verified at 6:00 AM in the next morning (Figure 4). Regarding the oscillations observed during the day, the lake presented a high degree of dissolved oxygen saturation in the water column in the three scheduled hours of samplings. The lowest percentages of oxygen saturation were found in October, in the deepest region (in the three scheduled time of sampling). During the months of January and February, at the end of the nocturnal period, it was not observed an

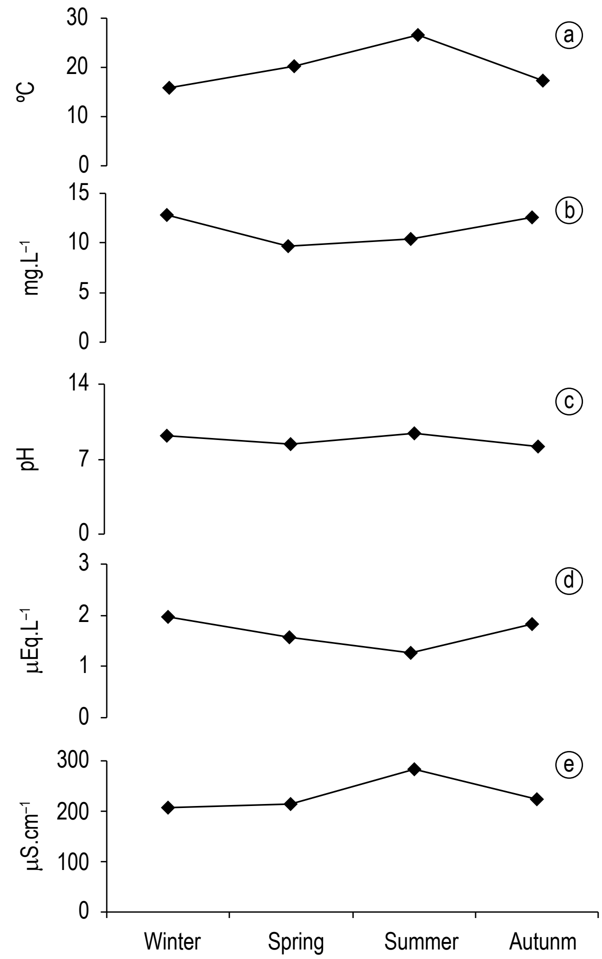

Figure 2. Seasonal variation of: a) temperature (°C); b) dissolved oxygen (mg.L^{-1}); c) pH; d) alkalinity (μEq.L^{-1}); e) electrical conductivity (μS.cm^{-1}), in Biguás Lake. Mean values were calculated for all variables.

oxygen deficit in the lake. This fact indicates that despite the influences of temperature in the solubility of the oxygen, the production carried out in the superficial layers supplies the bottom layers by the water circulation, preventing the occurrence of anoxic situations.

In this study it was found values of pH between 6.78 and 10.3 (Figure 2), with lower values during periods of higher rainfall. Higher pH values were observed on the surface mainly on the summer season (Table 3). The alkalinity observed ranging between 2.37 μEq.L^{-1} and 0.32 μEq.L^{-1} (Figure 2). The nycthemeral variation patterns are different for each sampling month, with the higher amplitudes observed in April and during the winter months (Table 4), but with small variations between surface and bottom. The electrical conductivity has remained higher than 150 μS.cm^{-1} (Figure 2 and Table 5). In addition to the fluctuations between the scheduled times of samplings, no differences were observed between surface and bottom.

The values of the water transparency remained always below 0.1 m, particularly when the suspended material

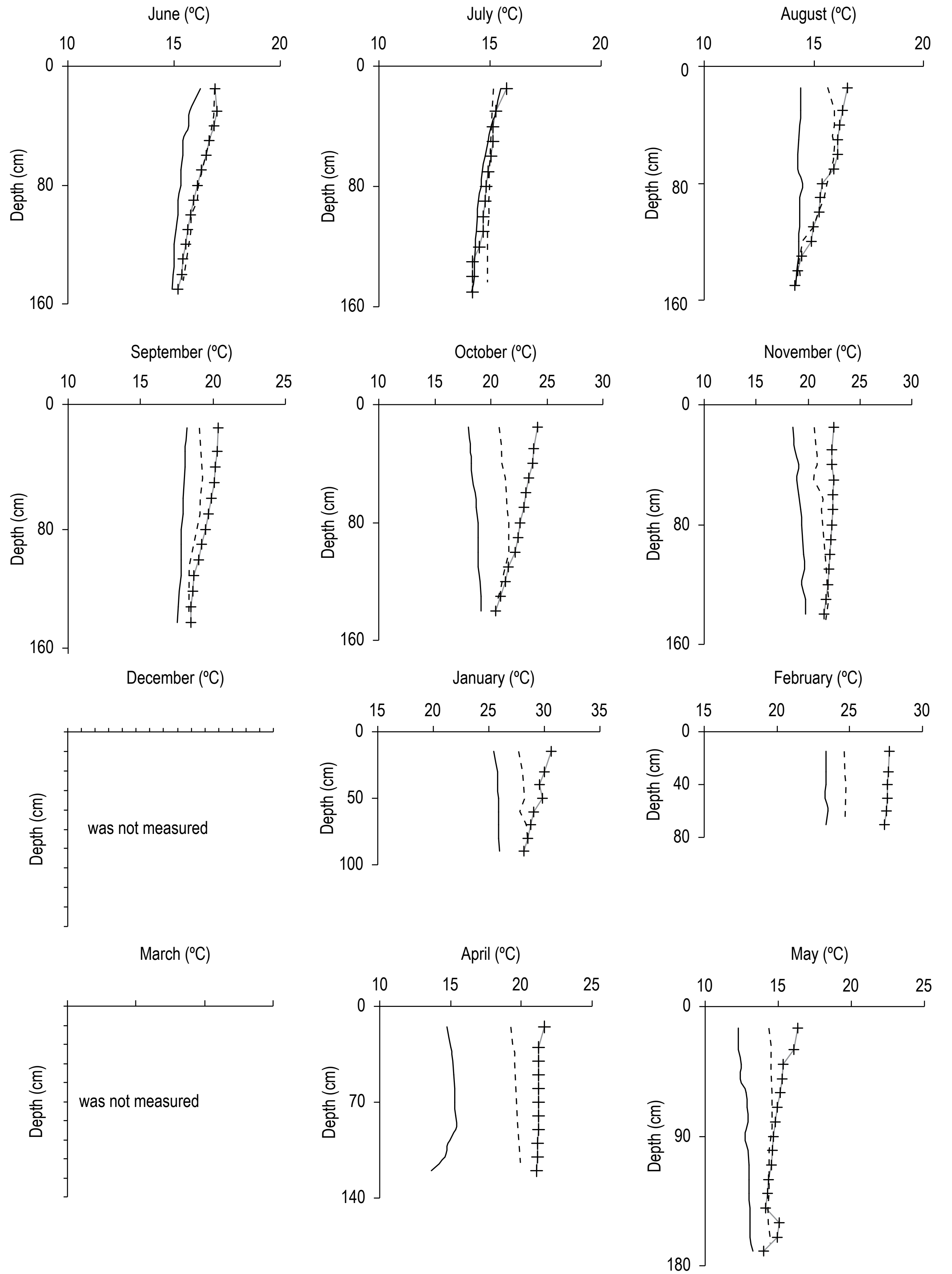

Figure 3. Vertical profiles of Temperature (ºC) in Biguás Lake. Mean values of two days of sampling. (______6:00 AM; …+…+…12:00 PM; - - - - - - -6:00 PM).

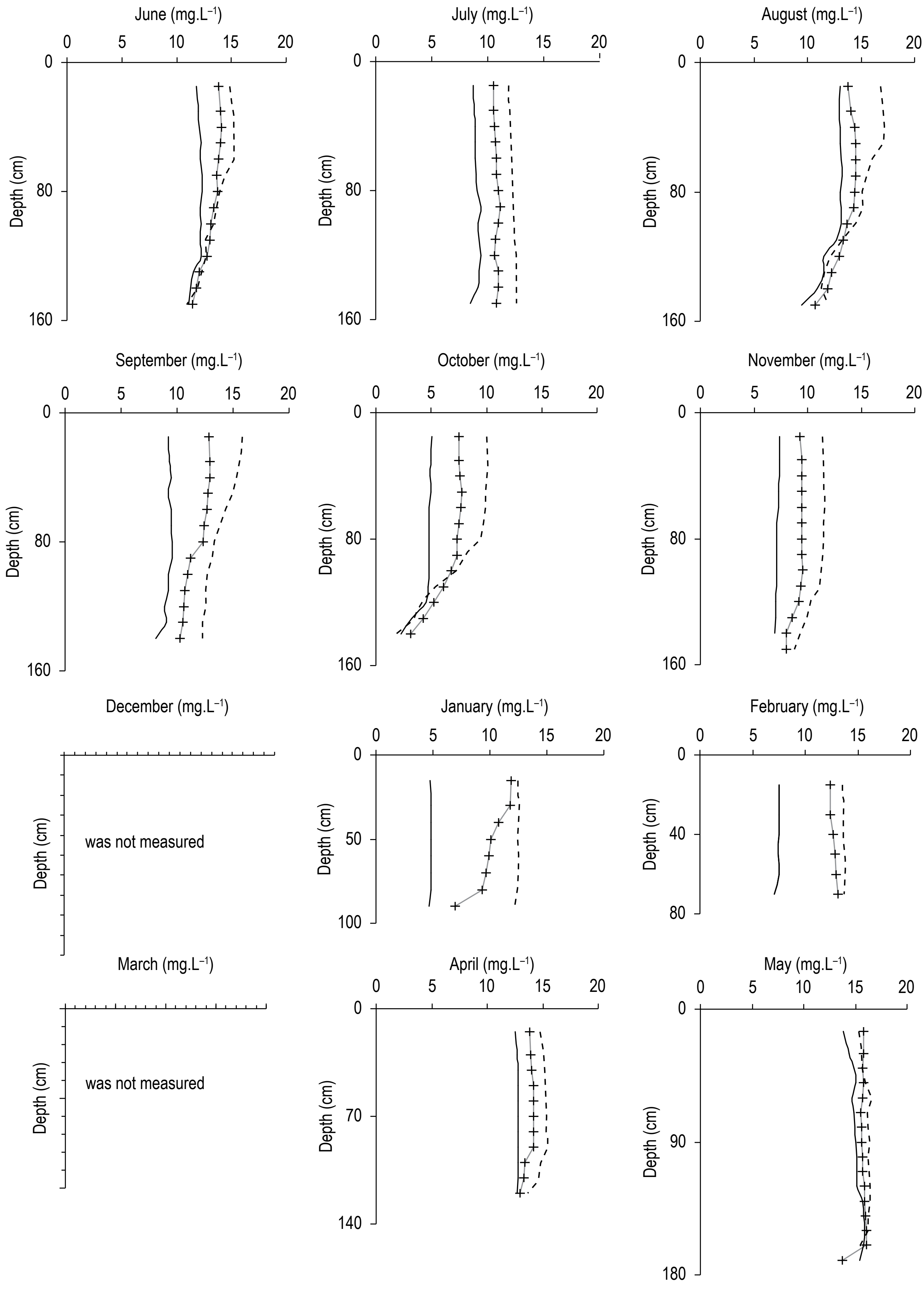

Figure 4. Vertical profiles of dissolved oxygen (mg.L^{-1}) in Biguás Lake. Mean values of the two days of sampling (________6:00 AM; …+…+…12:00 PM; - - - - - - -6:00 PM).

Table 3. Nycthemeral variation of pH in Biguás Lake throughout one year. Mean values at three depths (surface, middle and bottom) followed by standard deviation.

Month	1st day			2nd day		
	6:00 AM	12:00 PM	6:00 PM	6:00 AM	12:00 PM	6:00 PM
June	9.2 ± 0.13	9.2 ± 0.34	9.3 ± 0.24	9.1 ± 0.05	9.5 ± 0.17	9.5 ± 0.23
July	8.4 ± 0.09	8.1 ± 0.34	9.1 ± 0.05	7.9 ± 0.27	9.3 ± 0.04	9.5 ± 0.03
Aug.	8.6 ± 0.52	8.7 ± 0.38	8.9 ± 0.70	9.0 ± 0.28	9.0 ± 0.42	8.8 ± 0.85
Sept.	8.7 ± 0.36	9.3 ± 0.18	9.4 ± 0.17	9.0 ± 0.20	9.4 ± 0.14	9.5 ± 0.15
Oct.	7.0 ± 0.28	7.8 ± 0.57	8.2 ± 0.48	7.5 ± 0.03	8.0 ± 0.22	7.7 ± 0.17
Nov.	7.3 ± 0.09	7.9 ± 0.19	8.0 ± 0.22	7.3 ± 0.12	8.0 ± 0.32	8.6 ± 0.47
Dec.	-	-	-	-	-	-
Jan.	9.4 ± 0.07	9.9 ± 0.12	10.0 ± 0.09	9.6 ± 0.11	9.8 ± 0.23	10.1 ± 0.22
Feb.	9.4 ± 0.21	9.3 ± 0.17	9.4 ± 0.06	9.0 ± 0.17	9.5 ± 0.09	9.0 ± 0.90
Mar.	-	-	-	-	-	-
Apr.	8.6 ± 0.02	8.5 ± 0.17	8.8 ± 0.14	8.3 ± 0.13	8.7 ± 0.14	8.9 ± 0.05
May	8.0 ± 0.09	8.1 ± 0.01	8.1 ± 0.12	8.1 ± 0.03	8.3 ± 0.13	8.3 ± 0.21

(-) Not measured parameters.

Table 4. Nycthemeral variation of alkalinity (μEq.l^{-1}) in Biguás Lake throughout one year. Mean values at three depths (surface, middle and bottom) followed by standard deviation.

Month	1st day			2nd day		
	6:00 AM	12:00 PM	6:00 PM	6:00 AM	12:00 PM	6:00 PM
June	1.77 ± 0.14	1.98 ± 0.38	2.23 ± 0.40	1.34 ± 0.09	1.54 ± 0.20	1.57 ± 0.11
July	1.39 ± 0.10	1.58 ± 0.34	1.69 ± 0.09	1.45 ± 0.45	1.98 ± 0.27	1.67 ± 0.82
Aug.	3.41 ± 0.46	1.97 ± 0.31	2.16 ± 0.28	1.87 ± 0.00	2.23 ± 0.14	2.06 ± 0.02
Sept.	1.51 ± 0.06	1.35 ± 0.07	1.46 ± 0.03	1.19 ± 0.10	1.37 ± 0.16	1.35 ± 0.12
Oct.	1.27 ± 0.05	1.17 ± 0.09	1.18 ± 0.05	1.18 ± 0.07	1.32 ± 0.12	1.24 ± 0.07
Nov.	1.94 ± 0.16	2.08 ± 0.15	2.11 ± 0.08	1.98 ± 0.27	2.06 ± 0.05	2.15 ± 0.10
Dec.	-	-	-	-	-	-
Jan.	1.90 ± 0.21	1.78 ± 0.27	2.20 ± 0.09	2.03 ± 0.05	2.07 ± 0.08	2.13 ± 0.09
Feb.	0.69 ± 0.42	0.35 ± 0.15	0.23 ± 0.05	0.35 ± 0.10	0.57 ± 0.16	0.47 ± 0.17
Mar.	-	-	-	-	-	-
Apr.	0.23 ± 0.01	2.00 ± 0.04	2.20 ± 0.08	1.86 ± 0.57	2.21 ± 0.15	1.69 ± 0.27
May	1.96 ± 0.45	1.74 ± 0.08	2.43 ± 0.13	2.05 ± 0.39	2.18 ± 0.34	2.07 ± 0.56

(-) Not measured parameters.

Table 5. Nycthemeral variation of electrical conductivity (μS.cm^{-1}) in Biguás Lake throughout one year. Mean values at three depths (surface, middle and bottom) followed by standard deviation.

Month	1st day			2nd day		
	6:00 AM	12:00 PM	6:00 PM	6:00 AM	12:00 PM	6:00 PM
June	193.1 ± 2.7	198.5 ± 10.2	201.0 ± 3.5	201.0 ± 3.6	199.1 ± 4.3	201.3 ± 4.2
July	210.0 ± 7.0	223.0 ± 6.2	196.0 ± 21.5	201.7 ± 0.6	204.7 ± 3.2	204.7 ± 1.5
Aug.	224.7 ± 10.1	216.3 ± 6.4	209.0 ± 1.7	202.7 ± 1.5	206.0 ± 16.5	203.7 ± 15.3
Sep.	197.0 ± 1.0	224.7 ± 2.1	216.3 ± 5.5	230.7 ± 15.9	194.0 ± 1.0	211.0 ± 17.3
Oct.	210.0 ± 2.0	223.7 ± 4.0	216.3 ± 3.6	214.3 ± 3.2	222.7 ± 3.2	216.7 ± 2.5
Nov.	188.3 ± 0.6	190.7 ± 2.3	216.3 ± 12.4	211.7 ± 1.5	224.0 ± 1.0	224.0 ± 5.2
Dec.	-	-	-	-	-	-
Jan.	249.3 ± 0.6	253.3 ± 23.9	233.7 ± 17.2	235.0 ± 10.5	275.3 ± 17.0	255.7 ± 2.9
Feb.	322.0 ± 8.0	324.3 ± 3.8	315.0 ± 3.6	274.3 ± 1.5	300.7 ± 21.7	301.0 ± 25.1
Mar.	-	-	-	-	-	-
Apr.	219.3 ± 6.8	251.7 ± 0.6	244.0 ± 2.0	234.0 ± 15.1	218.3 ± 2.5	221.7 ± 14.2
May	219.0 ± 1.0	212.7 ± 16.6	195.7 ± 12.7	217.7 ± 7.5	196.0 ± 17.0	219.7 ± 2.3

(-) Not measured parameters.

has increased its concentration, as observed in August and January 0.42 and 0.45 $mg.L^{-1}$, respectively (Table 2). The concentration of total nitrogen measured during the study ranged between 2.8 $mgN.L^{-1}$ (October) and 7.0 $mgN.L^{-1}$ (January), while the total phosphorus values varied between 0.17 $mgP.L^{-1}$ (October) and 0.38 $mgP.L^{-1}$ (April). The average concentration of chlorophyll-*a* ranged between 21.33 $\mu g.L^{-1}$ (May) and 453.08 $\mu g.L^{-1}$ (January), respectively (Table 2).

4. Discussion

The Biguás Lake is a shallow environment with a relatively large surface area in relation to its depth. This characteristic facilitates the water circulation promoted by the wind action, making the water column physical and chemical homogenized, which was observed in this study during the daily cycles in all seasons. According to Esteves (1998) lakes with permanent circulation of the entire water column (nonstratified) are denominated as holomitic-polimitic lakes. In these conditions the water density is practically the same in all depths, without physical and/or chemical barriers that would restrict the vertical distribution of the biological communities.

In spite of the variation of temperatures between the scheduled hours of samplings, the water column remained homogeneous during the daily cycles in the four climatic seasons. According to Petrucio (1998) the homeothermy of the water column, explained mainly by the frequent water mass circulation, is a consequence of the small depth and continuous exposition to the action of the wind. This pattern is similar to the one found by Esteves et al. (1988) in the Lagoa Imboassica, Rio de Janeiro State, attributed to the lake localization which is perpendicular to the coastline, exposed to the action of the marine and terrestrial breezes. In the city of Rio Grande there are no natural or artificial barriers that can obstruct the action of wind on the surface of aquatic environments. Notwithstanding, even located approximately 16 km from the coastline, the Biguás Lake is constantly under the action of the wind.

Among the gases dissolved in natural waters, the oxygen is one of the most important for the dynamics and characterization of the aquatic ecosystems (Wetzel and Likens, 1991). The main oxygen sources for the aquatic environments are the atmosphere and photosynthesis, and the mineralization (decomposition of the organic matter and the respiration of the organisms) is the main responsible for the losses of this gas (Petrucio, 1998). In our study, the wind may have been responsible both for the input of dissolved oxygen due to the gas exchange between atmosphere and the aquatic environment, as well as for its distribution in the whole water column by means of the circulation of water mass, facilitated by the shallowness of the lake.

The daily variation recorded in our study is similar variations found by Ramirez and Bicudo (2003) in the Garças reservoir, São Paulo State. The increase of the dissolved oxygen concentration during the day and its reduction during the night were also related to the metabolism of the lake, with the dominance of diurnal processes of production and nocturnal mineralization. According to Schäfer et al. (1980) the degree of involvement of these processes in the water affects the daily variation of oxygen, so that the production depends on the light available, and each level of production correspond to two levels of consumption, respiration and decomposition. It was most evident during two occasions: in spring, coinciding with the increase in precipitation and elevation of suspended material, which may have facilitated the process of decomposition of organic matter in the sediment and, consequently, the oxygen consumption; and during summer, characterized by small pluviometric precipitation, high temperatures and intense luminosity, factors that contribute to the photosynthetic activity of the phytoplanktonic community, increasing lake production during the day, as well as the consumption at night by the mineralization processes.

The water circulation re-suspends the precipitated material and seems to beneficiate the processes of the oxidation of organic matter in the deep regions and, consequently, to decrease the dissolved oxygen concentration. These results coincide with low values of pH found at the bottom, suggesting the occurrence of decomposition processes and inorganic CO_2 release (Sipaúba-Tavares, 1996). Mercante and Bicudo (1996) have observed lower values of pH during the rainy seasons in Jacaré Pond, São Paulo State.

Higher pH values observed on the surface, mainly on the summer season, were associated to photosynthesis of phytoplanktonic algae. The small pH variations indicate high buffering capacity for the lake, which may be supported by the elevated alkalinity observed. Environments with elevated alkalinity present small variations of pH, even with the occurrence of high photosynthetic rates, when the consumption of CO_2 is immediately compensated by the HCO_3^- dissociation (Esteves, 1998).

The variation of the electrical conductivity was dependent on both the variation of the water level as well as the seasonal metabolic activity, and consistent patterns were observed in the nycthemeral variation. During the summer, with the lowest volume of water, the absolute values of conductivity reached its maximum, probably by the natural increase of the ionic concentration in a smaller volume of water. In January, the lake has developed a growth of algae (bloom), which may have limited these figures, since later in February, with the decrease in chlorophyll-*a* values and consequent decrease in phytoplankton biomass, there was an increase in the values of conductivity.

The values of water transparency remained when it was detected increases in the suspended material concentration. The low transparency values observed on the lake is probably related to its shallowness, which together with the action of wind facilitates the movement of the water column and, consequently, the re-suspension of the material deposited in the sediment, besides the phytoplankton biomass. According to alternative stable states theory of shallow lakes from Scheffer et al. (1993), the lakes can be in two alternative stable states: clear with abundant submerged macrophytes or turbid with few submerged plants characterized by high algal biomass. The authors emphasize that in the turbid state, fish promote phytoplankton growth by recycling nutrients and controlling the development of zooplankton that could otherwise help clear the water of phytoplankton. Also fish and waves may stir up sediments in shallow lakes with little or no vegetation. In this situation, light limitation and disturbance of the sediments make it difficult for submerged plants to settle. On the other hand, once submerged plants are abundant, they can greatly reduce turbidity by a suit of mechanisms resulting in control of excessive phytoplankton development and prevention of wave re-suspension of sediments (Scheffer and Van Nes, 2007).

The re-suspension of sediments also collaborates for the increase of the nutrient concentrations in water column (Panosso and Kubrusly, 1998). During the study the elevated values of suspended material coincided with the higher values of total-N and total-P. In some concentrations nitrogen and phosphorus may cause exaggerated growth of aquatic macrophytes or the blooming of microalgae, mainly cyanobacteria (Ringelberg and Baard, 1988; Gophen, 2001). In this study both nutrients were found at higher concentrations in spring, period of the highest incidence of birds in the lake. This input of nutrients favored the growth of microalgae, fact noted by the variation in chlorophyll-*a* concentration in summer, which showed a considerable increase. The concentrations of chlorophyll-*a* above 10 $\mu g.L^{-1}$ are typical of eutrophic environments (Lampert and Sommer, 1997), which confirms the lake classification. During this period were also observed the highest values of conductivity, suspended matter, pH and alkalinity, with small variation between the scheduled hours of samplings.

The results obtained in the Biguás Lake have demonstrated that besides the seasonal alterations suffered, daily changes in its metabolism are also relevant for the understanding of its dynamics. Regional climatic variations such as: air temperature, wind speed, precipitation and sunlight are responsible for thermal and chemical changes in this lake. These processes occur uniformly in the water column due to the constant circulation of the whole water mass, facilitated by the low depth and action of the wind, which prevents the formation of physical and chemical stratifications. The constant input of organic matter from birds must be better understood, because this seems to be the main factor responsible by the enrichment of the lake, increasing its productivity and, consequently, the processes of respiration and mineralization of the organic matter, triggering series of alterations in the chemical characteristics of water. This study has demonstrated, in a general way, the dynamics of functionality of a shallow lake located in the south of the coastal plains of the Rio Grande do Sul State (Brazil). The information presented herein will serve as subside for future researches in these environments, contributing to the preservation and/or conservation of these ecosystems.

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