

The planktonic community in tropical interdunal ponds (Lençóis Maranhenses National Park, Maranhão State, Brazil)

A comunidade planctônica em lagoas interdunares
(Parque Nacional dos Lençóis Maranhenses, Maranhão, Brasil)

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Abstract: The aim of this study was to characterize the Lençóis Maranhenses ponds (Maranhão State, Brazil) with respect to morphometry and physical and chemical aspects of the water body, in particular, the planktonic community. Lençóis Maranhenses is a tropical coastal region with sand dunes and numerous interdunal ponds, most of them temporary. Ten ponds were studied, and a nictemeral variation was carried out. They have similar physical and chemical characteristics (high temperature - 27.5 to 32.0 °C, acid pH - 4.9 to 6.2, low values of dissolved nutrients, chloride - 0.75 to 1.00 mg.L⁻¹, and electric conductivity - 18.8 to 33.2 μS.cm⁻¹, and light penetration up to the sediment). With respect to the plankton, it is likely that the different histories of colonization, the formation of the ponds, and the initial organisms, affect the species richness, density and dominance observed. The lakes were classified as polymitic and oligotrophic.

Keywords: Lençóis Maranhenses, tropical dune ponds, zooplankton, phytoplankton, morphometry.

Resumo: O objetivo deste trabalho foi caracterizar as lagoas dos Lençóis Maranhenses com relação as variáveis morfométricas e físicas e químicas da água, com ênfase na comunidade planctônica. O Parque Nacional dos Lençóis Maranhenses é uma região costeira com extensa área com dunas e lagoas interdunares. Foram efetuadas coletas de água superficial em dez lagoas. Também foi realizada variação nictemeral na Lagoa Azul. A maioria das lagoas é de caráter temporário e suas águas apresentam como característica marcante elevada temperatura - 27,5 a 32,0 °C, pH ácido - 4,9 a 6,2, baixos teores de nutrientes dissolvidos, cloretos - 0,75 a 1,00 mg.L⁻¹, e condutividade elétrica - 18,8 a 33,3 μS.cm⁻¹, e luz em toda massa de água. As lagoas possuem características físicas e químicas similares. Relativo ao plâncton, provavelmente a história de colonização, compreendendo a formação das lagoas e os organismos iniciais, reflete a riqueza, densidade e dominância de espécies observadas. As lagoas foram classificadas como polimíticas e oligotróficas.

Palavras-chave: Lençóis Maranhenses, lagoa interdunar, zooplâncton, fitoplâncton, morfometria.

1. Introduction

Coastal lagoons are an interface zone between coastal area, inland waters and coastal sea waters (Esteves, 1998). Ecological studies aim to contribute to understanding regarding the metabolism of tropical lacustrine ecosystems and the establishment of conservation programs and rational use of these ecosystems (Esteves et al., 1984). The survey of the biological diversity of these lagoons allows to understand the species distribution and the organization of aquatic communities (Esteves, 1998).

On the Brazilian coast, lagoons vary from small depressions filled with rain and/or sea water, which are of a temporary nature, to extensive bodies of water such as Lagoa dos Patos (Rio Grande do Sul State) (Esteves, 1998).

On the eastern coast of the state of Maranhão (Brazil), innumerable ponds are present in the dune region known as the Lençóis Maranhenses. Although dune ponds are not particularly rare in some parts of the world, limnological studies in these environments are scarce (Leentvaar, 1997). Particularly in northeastern Brazil, few studies had been

carried out. These include: Insecta: neuropteran (Bezerra, 1990), phytosociologic (Carvalho, 1993), vegetation dynamics late Pleistocene (Pessenda et al., 2004), transverse dune field (Parteli et al., 2006). Studies on aquatic communities of the ponds include: periphytic algae (Espíndola et al., 1998), ichthyofauna (Garavello et al., 1998), aquatic macrophytes (Rietzler et al., 1998), zooplankton (Rocha et al., 1998), aquatic biodiversity (Tundisi et al., 1998), and phytoplankton dynamics (Moschini-Carlos and Pompêo 2001).

The algae composition of dune ponds is determined by the adverse and severe external conditions as well as the abiotic factors operating in the environment, such as the chemical composition of the water. Periphytic and phytoplankton algae, when submitted to similar regulating factors, present different physiological abilities for using the available resources (Loeb et al., 1983). Thus, the existence and the growth of the planktonic and periphytic algae in an ecosystem are related to the different strategies for survival resulting from the capacity of each species to respond to changes in environmental factors (Casco and Toja, 1994).

Factors that influence zooplankton dispersion include: a) passive transport, which depends on the distance from the source and effectiveness of the vectors (water, wind, birds, animals, humans); b) size of the lake – the larger the lake, the greater the zooplankton richness; c) productivity of the lake - there is a tendency for more productive lakes to present greater richness; d) climatic factors; and e) biotic interactions (Hobæk et al., 2002).

The aim of this paper was to characterize the Lençóis Maranhenses dune ponds in terms of morphometry, zooplankton and phytoplankton communities, and trophic state. In the Lagoa Azul pond, a sampling was carried out during a nictemeral cycle. Emphasis was given to the planktonic communities.

1.1. Study area

The ten ponds studied are located in the internal edge of the dune formation of the Lençóis Maranhenses, in the region near the Lagoa Azul pond (Figure 1).

The Lençóis Maranhenses correspond to a dune series that extends from the Golfão Maranhense to the Parnaíba

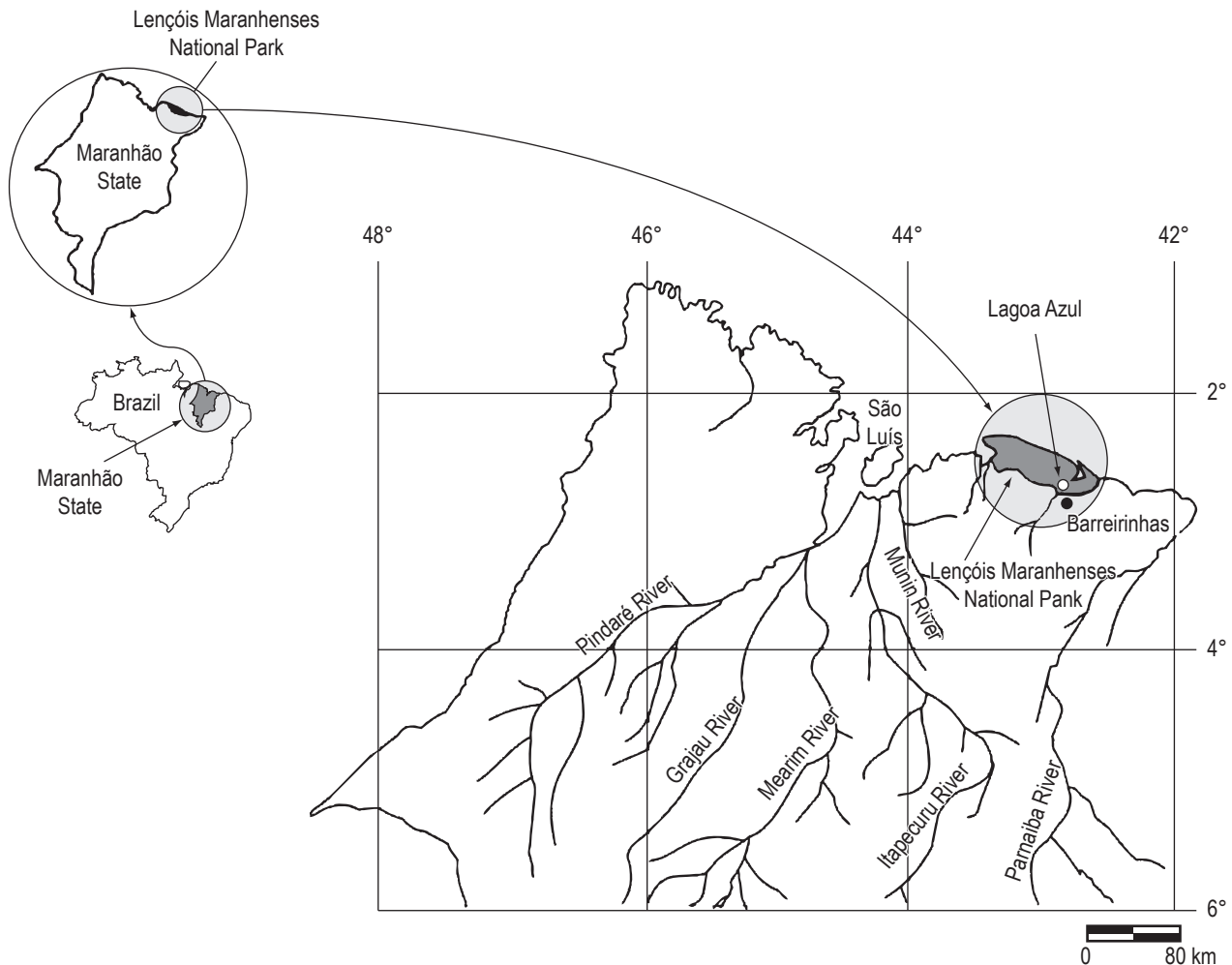


Figure 1. The Lençóis Maranhenses National Park and the study area, near the Lagoa Azul pond (o).

River estuary (Brazil, Maranhão State) (Ibama, 1989). The dunes occur mainly on the coast and advance in the direction of the continent up to a distance of 50 km from the coast. Those dunes that are further away from the shore of the ocean are fixed and have elongated shapes (Radam, 1973). The region is an area of pioneering formation, influenced by the sea and river and, resting vegetation (Bruck et al., 1995). When the dunes become linked together in a continuous line, they take on the form of chains or ribbons, which give a characteristic aspect to this type of coast, as observed in the majority of beaches in northern and northeastern Brazil. The dunes of the Lençóis Maranhenses, however, are especially elevated, reaching thirty meters in height (Freire, 1971).

In the subcoastal region, two periods of dune formation can be identified: a) following the Flandrian transgression, and b) the second much more recent, with the formation of new dunes that cover the fringe of land along the coast (Secretaria de Planejamento da Presidência da República, 1984; Ministério do Meio Ambiente, 1996). New studies suggest that the oldest period of dune formation can be observed in the narrowest portion of the continent, near Caçó Lake (2° 58' S and 43° 25' W). Through the oscillation of the sea level, a wide sandy belt became exposed. Thus, the constant winds carry the sand from the continent, constituting the regions of dunes (Parteli et al., 2006).

Lençóis Maranhenses National Park was established between the cities of Primeira Cruz and Barreirinhas, with an area of 155,000 ha (Ibama, 1989). This park is classified for indirect use of resources, prohibiting direct exploitation of the space (Bruck et al., 1995).

In most of the region, including the park, the ground is composed of sand originating from marine alluviums, aeolian deposits and sediments carried by the Parnaíba River. The soil has a low clay content and natural fertility and high salt concentration (Ibama, 1989).

In the region, the mean annual temperature is 26 °C and the total annual rainfall is 1,750 mm, with the highest rainfall from January to June, and a period of drought from July to December (Moschini-Carlos and Pompêo, 2001).

2. Material and Methods

Samples of surface water from the ponds were collected on the 8th and 9th days of May, 1998 (dry season). For each pond, water temperature, electric conductivity (probe YSI 33) and pH (potentiometer Horiba) were measured. Samples were analyzed in order to determine DO (Winkler, Golterman et al., 1978), seston (S), organic seston (OS) and inorganic seston (IS) fractions (Teixeira et al., 1965; Tundisi, 1969). The nutrient concentrations were determined using a Variam 634s spectrophotometer, following criteria described by Mackereth et al. (1978) for nitrite and nitrate, Strickland and Parsons (1960) for orthophosphate, Koroleff (1976) for ammonium, and Valderrama (1981) for total nitrogen

and total phosphorus. Chlorophyll-*a* was determined according to Nusch (1980), using 90% acetone for pigment extraction. The dissolved nutrients, pigments and seston were determined in filtered water (1 L) in Whatman GF/C filters. On the 3rd and 4th days of July, 1998, water samples from the Lagoa Azul pond were taken at different depths every four hours in a nictemeral cycle study.

The zooplankton samples were collected by filtering 100 L of surface water in a 68 µm net and fixed with formaldehyde 8%. The cladocerans and copepods were counted in acrylic plates etched with grids under a stereomicroscope (50X). For the rotifer and protozoan quantification, subsamples of 1 mL were counted in a Sedgewick-Rafter chamber under a microscope (400X). The organisms were identified according the following keys: for Cladocera (Smirnov, 1974; Elmoor-Loureiro, 1997; Smirnov, 1996), Rotifera (Segers et al., 1993; Segers, 1995, Koste, 1978), and Copepoda (Reid, 1985; Matsumura-Tundisi, 1986; Rocha and Matsumura-Tundisi, 1976).

For qualitative analysis of the phytoplankton, subsurface samples were collected with a 20 µm net and fixed with formaldehyde 4%. Total phytoplankton was fixed with lugol and counted under inverted microscope (Zeiss model Axiovert 100) according to Utermöhl (1958).

Morphometric parameters (the length, width, perimeter, total area, volume and maximum depths) and determination of the bathymetric map of the lakes were carried out according to Wetzel and Likens (1991).

3. Results

The surface water temperature in the ponds was high, ranging from 27.5 (pond 7) to 32.0 °C (pond 10) (Table 1). Electrical conductivity (K25) was low, varying from 18.4 (pond 9) to 33.2 µS.cm⁻¹ (pond 6). The pH was acid, ranging from 4.9 (pond 6) to 6.2 (pond 4). The dissolved oxygen concentrations showed a small range of variation, from 7.33 (pond 10) to 7.97 mg.L⁻¹ (pond 7). The oxygen saturation percentage ranged from 91.0 (pond 7) to 104.5% (pond 10). The chloride concentrations also had little variation, from 0.75 (ponds 3, 5, 7 and 9) to 1.25 mg.L⁻¹ (pond 1). The total nitrogen concentrations ranged from 12.7 (pond 4) to 84.0 µg.L⁻¹ (pond 6). Nitrite concentrations ranged from below the detection limit of the method used (pond 7) to 1.1 µg.L⁻¹ (pond 3). The total phosphorus values varied from 3.0 (pond 4) to 12.1 µg.L⁻¹ (pond 3) and the orthophosphate from 1.0 (ponds 5, 6, 7) to 1.8 µg.L⁻¹ (pond 10). The silicate, nitrate and ammonia concentrations were below the detection limit of the methods used.

Seston (S) varied from 1.0 (pond 5) to 4.1 µg.L⁻¹ (pond 9), the inorganic fraction (IS) from 4.1 (pond 2) to 89.8% (pond 10), and the organic fraction (OS) from 10.2 (pond 10) to 95.8 % (pond 2). Chlorophyll ranged

Table 1. Physical, chemical and biological variables of 10 ponds in Lençóis Maranhenses National Park. (Temp = temperature; EC = electrical conductivity; pH = potential of hydrogen; DO = dissolved oxygen; DO% = dissolved oxygen percentage; Total N = total nitrogen; N-NO₂⁻ = nitrite; Total P = total phosphorus; P-PO₄⁻³ = orthophosphate; S = seston; IS = inorganic seston; OS = organic seston; Chl.*a* = chlorophyll-*a*; Phae = phaeophytin; SD = standard deviation).

pond	Temp (°C)	EC (µS/cm)	pH	DO (mg/l)	DO (%)	Cl- (mg/l)	Total N (µg/l)	N-NO ₂ (µg/l)	Total P (µg/l)	P-PO ₄ ⁻³ (µg/l)	S (mg/l)	IS (%)	OS (%)	Chl. <i>a</i> (µg/l)
1	28.0	27.5	5.4	7.84	95.6	1.25	43.0	0.8	8.2	1.4	2.1	13.5	86.0	0.33
2	31.0	22.5	5.9	7.45	100.0	1.00	24.5	0.6	5.6	1.3	2.1	4.1	95.8	-
3	29.0	18.6	6.0	7.70	100.0	0.75	22.6	1.1	12.1	1.5	1.2	8.2	91.7	-
4	29.0	26.9	6.2	7.70	99.3	1.00	12.7	0.8	3.0	1.7	1.6	5.0	50.0	-
5	31.0	28.8	4.9	7.45	100.6	0.75	53.4	0.9	7.3	1.0	1.0	5.5	94.4	2.68
6	28.0	33.2	5.0	7.84	94.4	1.00	84.0	0.8	3.2	1.0	2.1	79.8	20.2	3.18
7	27.5	28.8	5.2	7.97	91.0	0.75	63.0	0.6	5.0	1.0	1.3	87.5	12.5	0.50
8	29.5	18.5	5.5	7.70	95.4	1.00	69.0	-	5.1	1.1	3.0	28.5	71.4	2.09
9	30.0	18.4	5.6	7.57	97.1	0.75	47.6	-	4.8	1.4	4.1	56.4	43.6	1.51
10	32.0	22.2	5.8	7.33	104.5	1.00	58.1	-	6.2	1.8	3.3	89.8	10.2	1.37
mean	29.5	24.5	5.6	7.66	97.8	0.92	47.9	0.58	6.1	1.3	2.2	42.3	57.6	1.17
SD	1.49	5.20	0.4	0.20	3.8	0.17	22.6	0.42	2.6	0.3	1.0	34.8	34.8	1.18

from 0.33 µg.L⁻¹ (pond 1) to 3.18 µg.L⁻¹ (pond 6). (Table 1).

The greatest depth measured in the Lagoa Azul pond in 1998 was 1.7 m (Moschini-Carlos and Pompêo, 2001), observed during the nictemeral variation. At approximately 11:00 AM, the Lagoa Azul presented a thermal micro stratification, with progressive rise in temperature of the water mass, reaching isothermy (30 °C) at 3:30 PM. (Figure 2). At 9:30 PM., a reduction in temperature was observed, reaching 29 °C at 04:20 AM. The water mass was relatively homogeneous with respect to pH, ranging from 5.1 to 5.5, and the electrical conductivity ranged from 32.5 to 36.8 µS.cm⁻¹ (Table 2).

The S concentrations in the ponds can be considered low, as in the Lagoa Azul pond (Tables 1 and 2). The chlorophyll concentrations also presented low values (0.28 to 2.79 µg.L⁻¹). The dissolved oxygen presented values near saturation, except at 9:30 AM at the 1.0 m depth (Table 2).

The nutrients ranged from 39.5 to 96.3 µg.L⁻¹ (total nitrogen), 0.5 to 0.9 µg.L⁻¹ (nitrite), 0.38 to 7.35 µg.L⁻¹ (ammonium) and 2.17 to 4.4 µg.L⁻¹ (orthophosphate) (Table 2). Nitrate and silicate forms were not detected with the methods employed. In relation to the nutrients nictemeral variation, there is no clear definite pattern in the profiles.

With respect to morphometry (Table 3), pond 2 presented the largest values for all the parameters, whereas pond 7 had the smallest values for length, width, area, volume and perimeter. Relative to the bathymetric map of the ponds, pond shapes varied (Figure 3). For the Lagoa Azul pond in the year 1998, morphometric and bathymetric variations can be observed (Table 4 and Figure 4), with a modification on the maximum length, minimum length, area, volume, depth and perimeter.

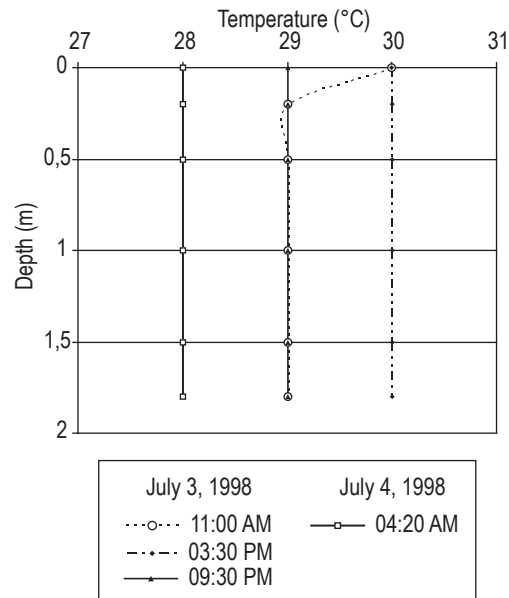


Figure 2. Lagoa Azul pond temperature profiles in nictemeral variation (in July 3 and 4, 1998).

The zooplankton community was composed mainly of rotifers and cladocerans (Tables 5 and 6). Protozoa and copepod were also observed. The rotifer group has the best representation, with nine species, followed by the cladocera, with only three species. Two species of protozoa were found and only one of copepod. Pond 7 presented the greatest species richness (eight species), followed by ponds 1, 8 and 9 (with seven species). In pond 5, only *Notodiaptomus cearensis* was observed. Only *Diaphanosoma birgei*, *Cephalodella* sp. and *Proales* sp., were present in ponds 7, 4 and 8, respectively. *Lecane* sp. and *Eggypha alveolata* presented greater frequency, being observed in six of the ten ponds studied.

Table 2. Physical, chemical and biological variables of Lagoa Azul pond in Lençóis Maranhenses National Park. (pH = potential of hydrogen; EC = electrical conductivity; DO = dissolved oxygen; DO% = dissolved oxygen percentage; S = seston; IS = inorganic seston; OS = organic seston; Chl-*a* = chlorophyll-*a*; Total N = total nitrogen; N-NO⁻² = nitrite; N-NH⁺⁴ = ammonium; P-PO₄⁻³ = orthophosphate).

Hour	Depth (m)	pH	EC (µS.cm ⁻¹)	DO (mg.L ⁻¹)	DO% (%)	S (mg.L ⁻¹)	IS (%)	OS (%)	Chl- <i>a</i> (µg.L ⁻¹)	Total N (µg.L ⁻¹)	N-NO ₂ ⁻ (µg.L ⁻¹)	N-NH ₄ ⁺ (µg.L ⁻¹)	P-PO ₄ ⁻³ (µg.L ⁻¹)
11:00 AM	0.0	5.1	36.8	7.03	92.6	7.4	68.9	31.1	0.56	96.3	0.6	7.3	3.5
	0.5	5.2	36.8	7.18	93.0	4.5	42.2	57.8	-	86.4	0.5	6.8	4.4
	1.0	5.3	36.8	7.33	95.0	4.1	46.3	43.9	1.12	59.9	0.9	4.3	2.2
3:30 PM	0.0	5.4	36.8	7.33	96.6	6.3	57.1	42.8	1.39	72.2	0.7	7.3	2.9
	0.5	5.4	36.8	7.43	97.9	4.4	25.0	75.0	0.84	69.5	0.7	4.3	2.4
	1.0	5.4	36.8	7.38	97.2	3.9	28.2	71.8	2.79	53.5	0.8	0.4	2.9
9:30 PM	0.0	5.3	32.5	5.49	71.2	5.4	27.8	72.2	0.56	48.1	0.7	1.9	3.8
	0.5	5.5	32.5	6.87	89.0	3.7	5.4	94.6	1.12	58.3	0.7	3.4	2.6
	1.0	5.4	32.5	3.66	47.5	4.3	44.2	55.8	1.12	50.2	0.7	6.8	2.9
4:20 AM	0.0	5.4	33.2	6.41	81.7	3.6	63.8	36.2	0.84	39.5	0.8	2.9	3.9
	0.5	5.5	33.2	7.92	100.9	3.8	63.2	36.8	1.12	44.4	0.7	5.8	3.8
	1.0	5.4	33.2	6.92	88.2	3.7	78.4	21.6	0.28	46.0	0.9	-	4.1

-: below the method detection limit

Table 3. Morphometric parameters of the 10 ponds in the Lençóis Maranhenses National Park (C_m = maximum length; L_m = minimum length; A = area; V = volume; P_m = maximum depth; P = perimeter; sd = standard deviation).

Pond	C _m (m)	L _m (m)	A (m ²)	V (m ³)	P _m (m)	P (m)
1	121.0	16.0	1083.7	234.2	0.55	250.0
2	270.0	86.0	33309.1	15377.0	0.95	653.0
3	175.0	52.5	1433.5	451.2	0.62	435.0
4	62.0	34.0	1604.9	535.7	0.63	154.0
5	67.5	54.0	2271.1	842.6	0.75	190.0
6	63.0	34.0	1660.6	626.9	0.72	154.0
7	30.6	8.4	167.8	43.3	0.62	69.0
8	34.4	23.2	592.8	147.2	0.55	91.0
9	53.6	20.0	956.3	373.9	0.72	15.3
10	80.0	23.5	1461.7	386.1	0.42	19.0
Mean	95.6	35.1	4,454.1	1,901.8	0.62	233.9
Sd	74.8	23.2	10,155.7	4,740.4	0.17	178.6

Table 4. Morphometric parameters of Lagoa Azul pond.

Morphometric parameters	03/04/98	09/02/98	11/11/98
Area (m ²)	1098.2	26452.2	282.8
Volume (m ³)	130.3	12272.1	13.8
Maximum depth (m)	0.32	1.20	0.12
Minimum length (m)	74.8	287.0	36.4
Maximum length (m)	20.0	129.0	13.8
Perimeter (m)	173	690	63

The phytoplankton species richness ranged from 18 to 27 taxa and the density from 58 to 575 ind.mL⁻¹ (Table 7). In relation to classes, the phytoplankton showed a relatively uniform distribution in all the ponds (Table 8). Zygnemaphyceae and Bacillariophyceae presented the greater species richness in the ponds studied.

The most common taxa in decreasing order were: *Cocconeis placentula*, *Peridinium pusillum*, *Actinotaenium wollei* and *Pleurotaenium minutum* (Table 7). The distri-

bution of the number of individuals was irregular among the ponds. *Cocconeis placentula* presented around 478 and 339 µg.L⁻¹ in ponds 8 and 10, respectively, whereas it was not observed in ponds 4, 5 and 6. Thus, the phytoplankton communities are not homogeneous among the ponds, and the patterns observed are probably due to the environmental condition (high temperature, high incident light intensity, and low nutrient concentration).

During the nictemeral variation, both species richness and density in Lagoa Azul pond were low, ranging from 6 to 13 and 19 to 163 µg.L⁻¹, respectively (Table 9). At 3:30 PM, at a depth of 0.0 m, the highest algae density (130 ind.mL⁻¹) was observed, and was represented almost exclusively by *Pleurotaenium minutum* (Ralfs) Delp. Zygnemaphyceae and Chlorophyceae predominated. *Eutetramorus fottii* was the most frequent species and had the most uniform distribution during the 24 hour study period (Table 9).

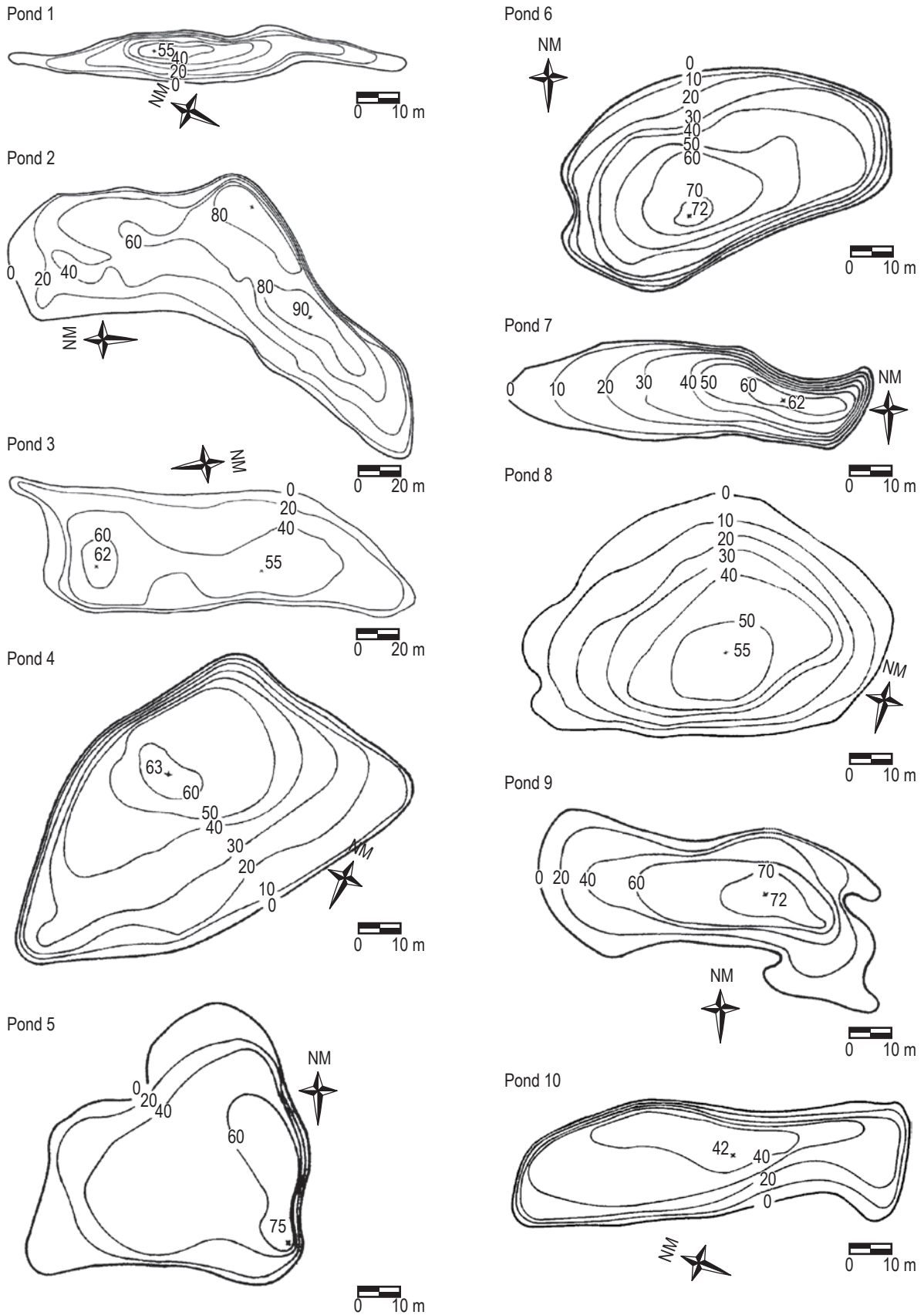


Figure 3. Bathymetric maps of 10 ponds in Lençóis Maranhenses National Park, measured in 1998.

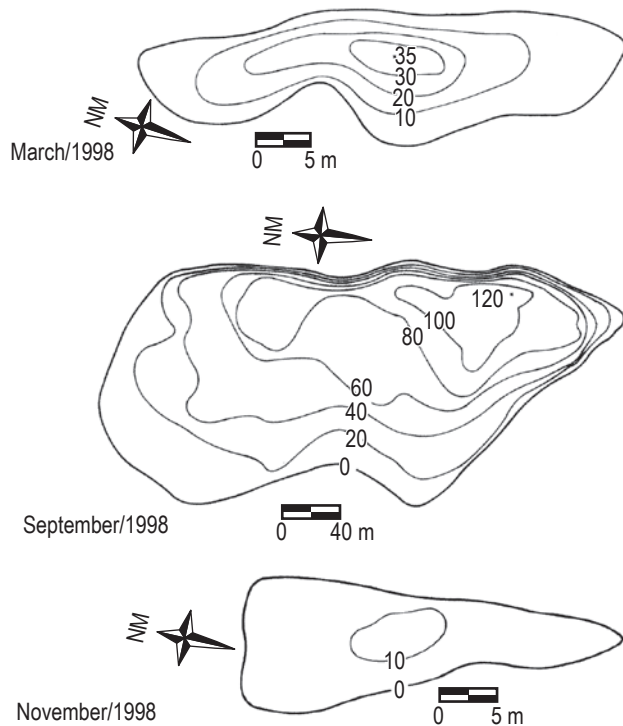


Figure 4. Bathymetric maps of Lagoa Azul pond, at different periods of the year. Isolines in centimeters.

4. Discussion

Like observations of Moschini-Carlos and Pompêo (2001), the data suggest that the Lençóis Maranhenses ponds present a daily process of circulation, probably due to low depth and the continuous action of the wind. The ponds are of a temporary nature, and are considered to be small, shallow, acidic, and poor in nutrients.

The Lagoa Azul pond can be considered to be permanent and oligotrophic environment, with water, acid, with light up to sediment (Moschini-Carlos and Pompêo, 2001). During the year 1998, the lake presented great variation in area, volume, depth, length and width, as a consequence of the marked periods of rains (January to June) and drought (July to December) (Moschini-Carlos and Pompêo, 2001). These authors suggest that this pond presents modifications in species richness throughout the year, but with low density and high phytoplankton dominance. The periphytic flora attached to the sediment on the bottom is also a source of organisms for the phytoplankton composition. In the periods of expansion in lake dimensions, the phytoplankton density is low (July and September 1998), whereas in March and November of 1998, a different situation was observed. In the 10 ponds, modification of phytoplankton composition and density occurs.

Table 5. Zooplankton density (ind.L⁻¹) in 10 ponds (P1 to P10) of Lençóis Maranhenses National Park.

Ponds Taxa	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Cladocera										
<i>Diaphanosoma birgei</i>	-	-	-	-	-	-	395	-	-	-
Korinck 1981										
<i>Macrothrix</i> sp.	100	-	-	-	-	-	-	3600	-	-
<i>Moina minuta</i> Hansen 1989	-	-	-	-	-	66	99	-	100	-
Sub-total	100	-	-	-	-	66	494	3600	100	-
Copepoda										
<i>Notodiaptomus cearensis</i>	-	14555	-	208	1275	33	790	-	-	-
Sub-total	-	14555	-	208	1275	33	790	-	-	-
Rotifera										
<i>Anuraeopsis</i> sp.	-	-	-	-	-	-	-	1800	-	3850
<i>Cephalodella</i> sp.	-	-	-	10375	-	-	-	-	-	-
<i>Collurella uncinata</i> EHRB	16000	-	-	4725	-	-	3950	-	2000	1925
<i>Gastropus</i> sp.	-	-	12750	-	-	-	-	-	12000	1295
<i>Lecane (M) monostyla</i>	-	-	-	8300	-	-	1975	18000	8000	1925
Daday										
<i>Lecane (M) sp.</i>	112000	-	14875	8300	-	-	11850	9000	-	1925
<i>Lepadella</i> sp.	-	-	-	-	-	-	-	-	2000	1925
<i>Polyathra</i> sp.	-	-	210375	388025	-	-	-	133200	864000	-
<i>Proales</i> sp.	-	-	-	-	-	-	-	9000	-	-
Sub-total	128000	-	238000	419725	-	-	17775	171000	888000	12845
Protozoa										
<i>Euglypha alveolata</i>	18000	2050	4250	-	-	-	1975	1800	6000	-
<i>Diffugia</i> sp.	2000	-	-	-	-	-	27650	-	-	-
Sub-total	20000	2050	4250	-	-	-	29625	1800	6000	-
Others										
Nematoda	800	-	-	-	-	-	99	-	-	-
Tartigrada	500	-	106	-	-	-	-	-	2000	-
Insect larvae	800	-	-	104	-	99	-	45	-	193
Sub-total	2100	-	106	104	-	99	99	45	2000	1930
Total	132,200	16,605	242,356	420,037	1,275	198	48,783	176,445	896,100	14,775

Table 6. Zooplankton relative density (%) in 10 ponds (P1 to P10) of Lençóis Maranhenses National Park.

Ponds Group	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Cladocera	0.18	0.00	0.00	0.00	0.00	33.33	1.01	2.04	0.01	0.08
Copepoda	0.00	87.65	0.00	0.05	100.00	16.67	1.62	0.00	0.00	0.00
Rotifera	96.82	0.00	98.20	99.93	0.00	0.00	36.44	96.91	99.10	96.82
Protozoa	1.51	12.35	1.75	0.00	0.00	0.00	60.73	1.02	0.67	1.51
Others	1.59	0.00	0.05	0.02	0.00	50.00	0.20	0.03	0.22	1.59
Total	100	100	100	100	100	100	100	100	100	100

Table 7. Phytoplankton density (ind.mL⁻¹) and richness (number of the taxa) in 10 ponds in Lençóis Maranhenses National Park.

Ponds Genus/species	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Cyanophyceae										
<i>Merismopedia punctata</i>	2.0	1.0	-	-	-	-	-	-	-	1.0
<i>Phormidium</i> sp.					2.0	1.0	-	-	-	-
<i>Phormidium tenue</i>	1.0	1.0	-	1.0	-	1.0	-	-	-	-
<i>Phormidium molle</i>	3.0	-	-	1.0	2.0	1.0	1.0	-	-	-
<i>Pseudoanabaena</i> sp.	4.0	-	1.0	1.0	11.0	12.0	9.0	28.0	12.0	3.0
<i>Anabaena</i> sp.	-	4.0	1.0	1.0	-	-	1.0	-	1.0	1.0
<i>Geitlerinema amphibium</i>	1.0	-	1.0	-	1.0	-	-	-	3.0	-
<i>Lyngbya</i> sp.	-	-	-	-	-	-	1.0	-	-	-
<i>Leptolyngbya</i> sp.	-	-	-	-	-	-	-	-	4.0	-
<i>Oscillatoria</i> sp.	-	-	-	-	-	-	2.0	-	-	-
Zygnemaphyceae										
<i>Actinotaenium wollei</i>	39.0	3.0	13.0	53.0	10.0	1.0	1.0	6.0	3.0	21.0
<i>Actinotaenium globosum</i>	-	-	4.0	-	-	-	-	-	-	-
<i>Pleurotaenium minutum</i>	-	8.0	1.0	98.0	1.0	1.0	1.0	-	-	-
<i>Cylindrocystis brebissonii</i>	1.0	5.0	10.0	1.0	17.0	2.0	3.0	6.0	8.0	11.0
<i>Tetmemorus</i> sp.	3.0	2.0	4.0	1.0	10.0	-	9.0	4.0	4.0	3.0
<i>Penium</i> sp.	-	-	-	-	61.0	1.0	9.0	6.0	8.0	6.0
<i>Netrium</i> sp.	-	-	-	-	1.0	1.0	-	-	1.0	-
<i>Cosmarium quadrum</i>	8.0	2.0	11.0	-	26.0	1.0	2.0	3.0	-	-
<i>Cosmarium</i> sp.1	1.0	1.0	1.0	1.0	2.0	-	2.0	1.0	1.0	1.0
<i>Cosmarium</i> sp.2	-	-	1.0	1.0	2.0	-	1.0	2.0	2.0	3.0
<i>Cosmarium</i> sp.3	-	-	-	1.0	1.0	-	-	-	-	-
<i>Cosmarium</i> sp.4	-	-	-	-	-	-	-	5.0	1.0	-
<i>Euastrum</i> sp.	-	-	-	-	-	-	-	-	-	1.0
<i>Closterium</i> sp.	-	-	-	-	6.0	1.0	1.0	-	-	-
<i>Closterium gracile</i>	-	-	-	-	2.0	-	-	-	-	1.0
<i>Arthrodesmus</i> sp.	1.0	-	-	-	-	-	-	-	-	-
<i>Ichtyocercus longispinus</i>	1.0	-	1.0	-	1.0	-	1.0	2.0	2.0	2.0
<i>Micrasterias arcuata</i>	1.0	1.0	-	-	-	-	-	-	-	-
<i>Staurastrum leptocladum</i>	-	3.0	-	-	-	-	-	-	-	-
<i>Staurastrum</i> sp.	-	-	1.0	-	1.0	-	-	1.0	1.0	-
<i>Mougeotia</i> sp.	2.0	1.0	1.0	-	-	2.0	-	-	-	1.0
<i>Spirogyra</i> sp.1	-	-	-	1.0	1.0	-	-	-	-	-
<i>Zygonium</i> sp.	-	-	-	-	-	1.0	-	-	-	-
Chlorophyceae										
<i>Eutetramorus fottii</i>	-	3.0	-	-	-	-	-	-	-	-
<i>Chlamydomonas</i> sp.	-	1.0	3.0	-	19.0	18.0	3.0	-	-	-
Bacillariophyceae										
<i>Cocconeis placentula</i>	40.0	3.0	7.0	-	-	-	55.0	478.0	64.0	339.0
<i>Navicula</i> sp.1	13.0	2.0	3.0	1.0	12.0	5.0	3.0	2.0	2.0	1.0
<i>Navicula</i> sp.2	-	2.0	1.0	1.0	17.0	6.0	8.0	4.0	1.0	1.0
<i>Navicula angustata</i>	-	5.0	-	-	-	-	-	-	-	-
<i>Pinnularia</i> sp.	1.0	6.0	7.0	3.0	63.0	3.0	5.0	7.0	2.0	1.0
<i>Fragillaria</i> sp.	-	1.0	-	-	-	-	-	-	-	-
<i>Cyclotella</i> sp.	-	2.0	1.0	9.0	-	-	-	-	-	-
<i>Gomphonema</i> sp.	-	1.0	-	-	1.0	-	-	-	-	-
<i>Eunotia</i> sp.	-	-	-	-	4.0	-	-	-	1.0	-
<i>Anomoeoneis</i> sp.	-	-	-	-	-	-	-	-	3.0	-
Euglenophyceae										
<i>Trachelomonas</i> sp.	-	-	-	1.0	73.0	-	6.0	1.0	-	-
<i>Euglena</i> sp.	-	-	-	-	-	-	-	1.0	-	-
<i>Peridinium pusillum</i>	1.0	-	39.0	29.0	1.0	70.0	9.0	14.0	21.0	35.0
<i>Peridinium</i> sp.2	-	-	19.0	2.0	-	21.0	-	4.0	2.0	-
Total density	123.0	58.0	131.0	207.0	347.0	149.0	133.0	575.0	147.0	432.0
Richness	18	22	22	19	27	19	22	19	22	18

Table 8. Phytoplankton richness (number of taxa) by Class in 10 ponds of Lençóis Maranhenses National Park.

Ponds Class	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Cyanophyceae	5	3	3	4	4	4	5	1	4	3
Chlorophyceae	-	2	1	-	1	1	1	-	-	-
Zygnemaphyceae	9	9	11	8	15	9	10	10	10	10
Bacillariophyceae	3	8	5	4	5	3	4	4	6	4
Euglenophyceae	-	-	-	1	1	-	1	1	-	-
Dinophyceae	1	-	2	2	1	2	1	2	2	1

Table 9. Phytoplankton specific density (ind.mL⁻¹) in the Lagoa Azul pond in nictemeral variation.

Genus/species depth	11:30 am			3:30 pm			9:30 pm			4:20 am		
	0.0 m	0.5 m	1.0 m	0.0 m	0.5 m	1.0 m	0.0 m	0.5 m	1.0 m	0.0 m	0.5 m	1.0 m
Cyanophyceae												
<i>Microcystis</i> sp.	-	-	-	1.0	-	-	-	-	-	-	-	-
<i>Geitlerinema amphibium</i>	-	-	-	1.0	1.0	-	-	-	1.0	-	-	1.0
<i>Phormidium</i> sp.	1.0	-	-	-	1.0	-	1.0	1.0	-	-	-	-
<i>Leptolyngbya</i> sp.	-	-	-	-	1.0	-	-	-	-	-	-	-
Chlorophyceae												
<i>Eutetramorus fottii</i>	13.0	18.0	21.0	22.0	16.0	23.0	13.0	18.0	20.0	13.0	22.0	19.0
<i>Coleastrum</i> sp.	-	2.0	2.0	-	1.0	-	-	1.0	1.0	-	1.0	1.0
<i>Botryococcus</i> sp.	-	1.0	1.0	-	-	-	-	-	-	-	-	-
<i>Kirchneriella</i> sp.	-	-	-	1.0	-	-	-	-	-	-	-	-
Zygnemaphyceae												
<i>Staurastrum leptocladum</i>	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0
<i>Closterium gracile</i>	-	-	1.0	1.0	-	1.0	-	-	-	-	-	1.0
<i>Pleurotaenium minutum</i>	1.0	1.0	-	130.0	1.0	1.0	1.0	-	1.0	1.0	1.0	1.0
<i>Actinotaenium wollei</i>	1.0	-	-	-	-	-	-	1.0	-	-	1.0	-
<i>Micrasterias arcuata</i>	1.0	-	-	-	1.0	-	1.0	-	-	-	-	1.0
<i>Netrium</i> sp.	-	-	-	-	-	-	-	-	-	-	-	1.0
<i>Mougeotia</i> sp.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	13.0
<i>Oedogonium</i> sp.	1.0	-	-	-	-	-	-	-	-	1.0	-	-
<i>Zygonium</i> sp.	-	-	-	-	-	1.0	-	1.0	-	-	1.0	1.0
Bacillariophyceae												
<i>Stauroneis</i> sp.	1.0	-	-	-	1.0	-	-	1.0	1.0	-	-	-
<i>Fragillaria</i> sp.	1.0	-	-	-	-	-	-	-	-	-	-	-
<i>Cocconeis placentula</i>	1.0	-	1.0	-	-	-	-	-	-	-	-	-
<i>Eunotia</i> sp.	-	-	-	1.0	1.0	-	-	-	-	-	-	-
<i>Aulacoseira</i> sp.	-	-	-	1.0	-	-	-	-	-	-	-	-
<i>Navicula</i> sp.	-	-	-	1.0	1.0	-	1.0	1.0	1.0	1.0	-	-
<i>Cyclotella</i> sp.	-	-	-	1.0	-	-	-	-	-	-	-	-
Dinophyceae												
<i>Peridinium</i> sp. 2	1.0	-	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	1.0
Total density	25.0	24.0	29.0	163.0	28.0	29.0	20.0	29.0	28.0	19.0	29.0	41.0
Richness	12	6	8	13	13	7	8	10	9	7	8	11

Eutetramorus fottii, *Cocconeis placentula* and *Peridinium pusillum*, abundant species in the phytoplankton, are typical organisms of initial successional stages, with small biomass, high surface / volume ratio and high rate of renovation (species r - selected) (Reynolds, 1990). But the desmids are considered k - selected species adapted to low nutrient levels (Sophia and Huszar, 1996), presenting low renovation rate and high biomass.

The water acidity is very important in the determination of the algal composition of these ponds (Moschini-Carlos and Pompêo, 2001). Desmidian is characteristic of waters that have low pH (4.0-7.0), low alkalinity, and are poor in nutrients (Margalef, 1983). Most of the species can be found associated with the aquatic macrophytes or the metaphyton; few are truly planktonic organisms, and they frequently vary in size from 9 - 20 µm, presumably because of their low sedimentation rate (Hoek et al., 1997).

Sormus (1996) observed *Pleurotaenium minutum* during its development in ponds and marshes in the periphyton of aquatic plants roots, stones, and sediments, as well as on the plankton and in floating and submerged masses. Most of the planktonic algae in the Lagoa Azul pond, at least during part of its life cycle, compose the periphyton and/or metaphyton community (Moschini-Carlos and Pompêo, 2001).

According to Leentvaar (1997), dune ponds are generally small and shallow, and many disappear in the dry season. The morphometric study showed a high level of variation in the dimensions of ponds in Lençóis Maranhenses National Park. Similarly, the bathymetric maps also indicate great variation in the shape of the ponds.

In the Lençóis Maranhenses, the aquifer fills as a result of the rains and the rise in the water level of the water table. Probably the ponds located in the lowest sites pres-

ent a larger and quicker increase in the level of the water. Over the course of the year, evapotranspiration causes a reduction in the level of the water table. In relation to the hydric regime, the Lençóis Maranhenses ponds can thus be classified as either temporary (ponds that dry up in each annual cycle) or permanent (ponds that never dry) environments during the year.

Ponds with greater length, width, area and volume are formed by the union of two or more ponds - a very common phenomenon in the rainy period, but of short duration (Moschini-Carlos and Pompêo, 2001). The morphometric variations observed during 1998 in the Lagoa Azul pond are due to the annual rainfall regime. In July, at the end of the rainy season, the pond reaches its maximum depth. In the dry season, the pond progressively dries up, reaching a depth of 12 cm. Thus, the phytoplankton and zooplankton richness and density can be explained in part by morphometric variation of the ponds, mainly variations in area and volume alterations. No effect of nutrient concentration on the phytoplanktonic and zooplanktonic abundance was observed, although for 10 ponds, the phytoplankton density showed a linear relation with nitrite ($r = 0.643$, $p = 0.045$).

The annual cycle of precipitation in the region influences the shape, depth and duration of the ponds, which influences their physical, chemical and biological characteristics (Tundisi and Mussara, 1986).

The Lençóis Maranhenses is an environment of extremes, with elevated temperatures, high solar radiation, low levels of nutrients, daily periods of thermal stratification, periods of flooding and drought. Associated with the morphometric variation of the ponds, these are probably the factors responsible by low species richness and reduced densities, mainly of phytoplankton, and the low richness and the dominance of some species and groups of zooplankton.

The temperature of the pond water mass remains elevated throughout the year (Pompêo and Moschini-Carlos, 2001). The daily period of mixture and stratification can be attributed mainly to the lower depth and the constant wind action. A similar situation was observed in some ponds along the coast of the state of Rio de Janeiro (Brazil) (Esteves et al., 1984). According to Panosso et al. (1998), shallow environments are subject to processes of cooling and heating and to the mixing action caused by the wind, which impedes the formation of vertical stratifications of temperature and salinity. Thus, the high oxygen concentration and percentage of saturation observed in the ponds reflect the daily mixture process.

The low chloride concentrations typical of freshwater ($< 100 \mu\text{g.L}^{-1}$ of chloride, according Redeke, 1948) can be attributed to the fact that the ponds were mostly formed by rainwater and are located far from the ocean. The distance from the ocean plays an important role that results in the

variation of the ocean spray and precipitation (Leentvaar, 1997). Thus, the greater distance of the ponds from the ocean is probably responsible for the smaller influence of the salinity of the ocean on these water bodies. Planktonic composition is typical of freshwater environments.

Phosphorus and nitrogen concentrations were also low. The small quantity of dissolved nutrients observed in the ponds probably limits phytoplankton growth, since the algae biomass is low. Phytoplankton primary productivity measured in the Lagoa Azul pond in 1998 (Moschini-Carlos and Pompêo, 2001) ranged from 0.25 to 14.7 $\text{mgC/m}^3/\text{h}$, and phytoplankton density was also low.

Electrical conductivity was low in all the ponds studied, unlike some dune ponds in New Zealand (Cassie and Freeman, 1980). In the tropics, the values of electrical conductivity are more related to the geochemical nature of the land, which vary with the rainfall regime and trophic state (Pérez, 1992).

The Lençóis Maranhenses ponds are acid and the pH values showed little variation, as was also observed by Moschini-Carlos and Pompêo (2001) in the Lagoa Azul pond. However, Espíndola et al. (1998) and Rietzler et al. (1998), studying ponds in the same region of the Lagoa Azul pond, observed a greater variation in the pH; their measurements were taken at the outer edge of the dune, in the restinga region.

The zooplankton community observed is composed of many neotropical endemic species, also observed by Rocha et al. (1998). Few species found in the Lençóis Maranhenses have wide geographical distribution.

The dominance of rotifers in density and in richness is very common in ponds, lakes, reservoirs and rivers of Brazil (Rocha et al., 1995; Nogueira and Matsumura-Tundisi, 1996). This is probably due to the short life cycle of these organisms, adapted to unstable environments. Rotifers reach maturity earlier and have higher replacement rates than microcrustaceans, which allows them to establish themselves in systems where conditions of physical instability prevail.

The close proximity of the small and shallow ponds to one another in sand dunes is probably the reason for the similarity of the physical and chemical variables of the water. In relation to the zooplankton community, however, the richness of the species varies considerably with respect to their rates of colonization, mainly in young ecosystems (Jenkins and Buikema-Jr., 1998), as observed in these ponds.

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