Vol.46, n. 4 : pp. 641-651, December 2003
ISSN 1516-8913 Printed in Brazil

BRAZILIAN ARCHIVES OF
BIOLOGY AND TECHNOLOGY
A N I N T E R N A T I O N A L J O U R N A L

Limnological Characteristics and Seasonal Changes in Density and Diversity of the Phytoplanktonic Community at the Caçó Pond, Maranhão State, Brazil

Maria José Dellamano-Oliveira*, Pedro Américo Cabral Senna and Glória Massae Taniguchi

Universidade Federal de São Carlos; Centro de Ciências Biológicas e da Saúde; Departamento de Ecologia e Biologia Evolutiva; Rodovia Washington Luiz, km 235; 13565-905; C. P. 676; São Carlos - SP - Brazil

ABSTRACT

Seasonal changes of the phytoplanktonic community and limnological abiotic characteristics of Caçó pond (Maranhão State, Brazil) was evaluated from two field researches during the rainy (April 1999) and dry (November 1999) seasons. Measurements of twelve chemical and physical variables and phytoplankton collections were carried out at eight sampling stations. The Chlorophyceae and Cyanobacteria groups were in highest fractions during the rainy and dry seasons, respectively. The limnological abiotic variables showed a homogenous spatial distribution. The cluster analysis, using Bray-Curtis distance, distinguished two major groups, represented by the most common and abundant species in both the periods. The results showed that the climate regime, due to the seasonal changes in pluviosity, was a determinant over the phytoplanktonic community structure at Caçó pond.

Key words: Seasonality, phytoplankton, diversity, tropical region

INTRODUCTION

Ecological studies in tropical regions can be considered recent, particularly for their natural lakes located close to the Equatorial zone. The majority of these works were developed at the Amazon basin, which has been considered one of the tropical areas best studied limnologically (Huszar, 1994). In the Brazilian north-eastern region, the phycological studies are scarce and most the times restricted to species lists. The phytoplankton community knowledge of the Maranhão State is comprised in works by Eskinazi-Leça et al., 1985; Oliveira et al., 1986; Lavôr-Fernandes, 1987, 1988a, 1988b; Barbieri et al., 1989; Pessoa, 1992; Azevedo, 1995; Araújo et al., 1998; Pereira, 1999; Moschini-Carlos and Pompêo, 1999; Araújo et al., 1999; Ericeira, 2000; Araújo, 2000, and three technical reports (Labohidro/UFMA, 1983; 1990; 1994).

The phytoplankton spatial and temporal distribution knowledge is important for an adequate comprehension of the lentic ecosystems structure and functioning. The study of this community is complex due to the multiplicity of factors that influence it (Huszar, 1996). In tropical regions lakes, the environmental variables which regulate seasonal patterns of the phytoplankton are not only light and temperature, since these factors can be considered relatively more constant along the year, other variables assume greater relevancy,

* Author for correspondence

such as the precipitation, the wind and the water level fluctuation, which develop patterns of variations within the nutrient and light availability and are reflected in the phytoplanktonic populations cycle (Espíndola et al., 1996). The interaction of the climatological and hydrological factors and their direct or indirect influence over other environmental variables affect the biological distribution in both vertical and horizontal spatial axis.

The aim of this study is to contribute to the knowledge of the phytoplanktonic community structure at the Caçó pond, in Maranhão State, considering the climatic seasonality in terms of the rainfall quantity along the year.

MATERIALS AND METHODS

The Caçó pond (2º58'S and 43º25'W) is located in the northern region of the Maranhão State at Primeira Cruz county, approximately 100 km from the sea. The region is under sub humid tropical climate, with total rainfall between 1,500 and 1,750 mm/year (Nimer, 1989), essentially controlled by the Intertropical Convergence Zone (ITCZ) seasonal movement above the Atlantic ocean and by the winds regime, which provides a six months rainy period (from January to June), when the ITCZ is located in the south of Equator and a period of six dry months (dry season, from July to December), when the ITCZ is located to the north of Equator.

Two samplings, one in April (rainy period) and another one in November (dry period) of 1999, were performed at eight sampling stations (S1 to S8), following a southwest to north-eastern transect (Fig. 1).

Total monthly rainfall (mm) was obtained at Tutóia and Barreirinhas Meteorological Stations (MA).

Fourteen abiotic limnological variables were analysed in this study. The water temperature (°C), conductivity (µS/cm), pH, dissolved oxygen (mg/l), were obtained with Horiba equipment, model U-10. The water transparency (m) was determined with Secchi disk. The euphotic zone (m) according to Cole (1994). The alkalinity (mEq/l) according to Golterman et al. (1978). The free CO_2 (mg/l) was determined according to Stum and Morgan (1981). The concentrations of the dissolved nutrients (nitrite, nitrate, ammonium, and orthophosphate) were determined by HPLC and the total nutrients (nitrogen = TN and phosphorus = TP) according to Valderrama (1981). Also, total nitrogen and phosphorous ratio (TN:TP) was calculated.

For the quantitative study of the phytoplanktonic community, samples were collected in Van Dorn bottle and transferred to a flask with known volume, preserved in lugol and maintained in a fresh and dark place until the moment of the analysis. The phytoplankton quantification was carried out in a inversed microscopy of Carl Zeiss mark, with a 400x maximum magnification and followed the method of sedimentation in chambers described by Uthermöhl (1958). The count up limit was established by the smallest area method (Bicudo, 1990). The results were expressed in individuals/ml and calculated according to Ros (1979). During transportation of the collected material to the laboratory, the samples concerning to the S4 (surface and middle) and S8 sampling stations of the rainy season and S1 and S8 (middle and bottom) of the dry season were mislead and were not considered.

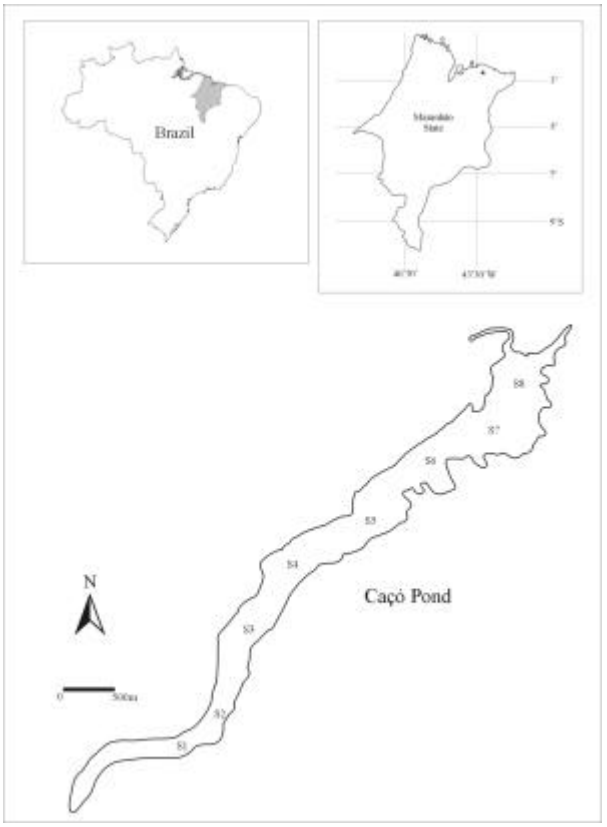

Figure 1 - Map showing the eight sampling stations (S1-S8) at Caçó pond, Maranhão State, Brazil.

The indexes concerning the phytoplanktonic community structure were calculated from the data obtained in the quantitative analysis. For the calculation of the species diversity (H'), the Shannon-Wienner index (Shannon and Wienner, 1963) were used. The equitability or uniformity (J) were evaluated according to Pielou (1975) and the community dominance (D) was estimated through Simpson's (1949) formula. The specific richness was represented as the total number of taxa presented within the samples.

The descriptive statistic analyses (minimum and maximum values and the mean and standard deviation) was used for the abiotic limnological variables. The Bray-Curtis distance (Valentin, 2000), calculated considering the absolute values of the taxa in each sample, was used to verify the similarities among sampling seasons (April and November) in relation to the phytoplanktonic community specific composition. A cluster analysis was carried out from the distance values using UPGMA as clustering method. The cophenetic correlation coefficient (r) was calculated to evaluate the representation of the distance matrix in the dendrogram (Valentin, 2000).

RESULTS

Total monthly rainfall (mm) registered during the studied period is presented in Fig. 2. The total rainfall in 1999 was 1,440 mm, what can be considered a typical year, according to Tutóia and Barreirinhas Meteorological Stations data (MA), for the period from 1965 to 1999.

The minimum and maximum values, means and standard deviations (s) of the abiotic limnological variables are presented in Table 1. The concentrations of the nitrite and orthophosphate nutrients were always below the detection level of the method used.

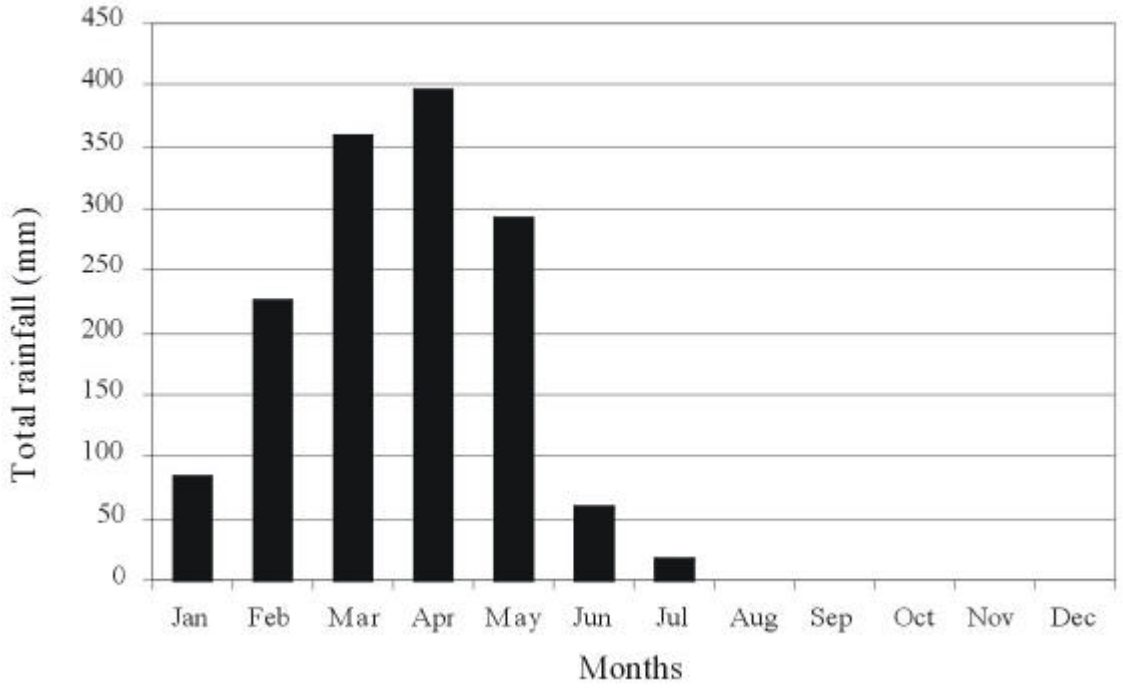

Figure 2- Total monthly rainfall (mm) during 1999 at Caçó pond region, according to Barreirinhas and Tutóia Meteorological Stations data (MA).

The higher water temperatures were registered in the rainy period. The variation between the sampled periods were only 0.3 ^{o}C. The water transparency varied from 4.5 m to 4.7 m in April and 4.2 m to 4.3 m in November. The euphotic zone comprise the maxim depth of the pond in both sampled period. The environment was well oxygenated, with the dissolved oxygen concentrations varying between 5.3 mg/l and 7.6 mg/l in April and 5.3 mg/l and 7.8 mg/l in November. The pH data obtained suggested an environment with water slightly acid with values always lower than 7.0. The results of conductivity showed a variation from 30 μS/cm to 37 μS/cm in April and from 35 μS/cm to 39 μS/cm in November. The mean alkalinity was higher in April. The same pattern was observed for the free CO_2. Among the dissolved nutrients, ammonium presented greater concentrations in April and nitrate, in November. Total nitrogen and phosphorus ratio suggested that the concentrations of these essential nutrients were limited at the Caçó pond.

The mean value of the phytoplanktonic community total density varied from 1.30 x 10^4 ind/ml in April (rainy period) to 1.39 x 10^4 ind/ml in November (dry period). The Chlorophyceae were best represented in terms of density at the majority of the sampled stations, during the rainy season (Fig. 3), while during the dry season, the best representative were the Cyanobacteria (Fig. 4). The other classes didn't show a clear distribution pattern in relation of the two seasons and sampled stations.

The specific richness and the diversity, equability and dominance indexes of each station and sampled season are presented in Table 2. Considering the seven sampled stations in April, the specific richness was 84 taxa and the diversity index was 4.04 bits/ind. For the eight sampled stations in November, the registered richness was 46 taxa and the diversity index was 3.79 bits/ind. The equitability indexes were higher in November. There was no dominance of any taxa.

The dendrogram resulted from the cluster analysis with the Bray-Curtis distance (Fig. 5) presented two major groups formed by the separation of the rainy season samples in relation of the total samples from the dry season, in an estimated distance of approximately 0.63 (37% of the similarity).

DISCUSSION

Considering the absolute rainfall values presented in Fig. 2, the two studied periods could be characterised as rainy season (April/1999) and dry season (November/1999). Some authors, as Martin (2000), showed that in the tropical Brazil, the rainfalls were controlled by the expansion and retraction of the South and North anticyclones and by the wind changes, which controlled the ITCZ seasonal movements above the Atlantic ocean and determine the rainy season duration. This was observed by Moura and Shukla (1981) in the Brazil's north and north-eastern regions and by Marengo (1992) in the Amazonian region. Therefore, the local climatic seasonality observed through the rainfall values in 1999 could be interpreted as consequence of the ITCZ location over the ocean, in function of the trade winds activity. Regarding the abiotic limnological variables, a homogeneous spatial distribution pattern and high similarity among periods was observed. This resemblance among the two studied periods could be due to the dynamic system which was probably influenced not only by the rainfall differences but also by other characteristics, such as few changes in the temperature along the year and by the activity of trade winds within the region.

The total phytoplankton density values ranged from 1.30 to 1.39 x 10^4 ind/ml during the whole studied period, being slightly higher on the dry season. In general, a homogeneity of the phytoplanktonic classes in relation to the dry and rainy periods were observed. However, considering the eight sampled stations, was observed a spatial heterogeneity with some stations presenting higher density values. The Chlorophyceae class contributed highest to the total phytoplankton density during the rainy season. According to Huszar (1996), a higher contribution of the Chlorophyceae class occurs so much in tropical as in temperate lakes. Lewis (1978), studying a tropical lake in the Philippines, observed that the Chlorophyceae, Cyanobacteria and Dinophyceae classes contributed with higher density values under high luminosity and low nutrient concentrations conditions, which was also observed at Caçó pond. During the dry season, the Cyanobacteria group was the most expressive in number of individuals per sample analysed. According to Reynolds (1984), values over 12 for the N:P ratio indicated the phosphorus as the

limiting nutrient for the phytoplankton growth, facilitating the species which supported a nutrient scarcity in the environment, as it was the case of the Caçó pond. The ability of these organisms (Cyanobacteria) to tolerate extreme environments could explain this fact. Huszar (1994) and Araújo (2000) encountered similar results in their studies about phytoplanktonic communities.

Table 1 - Minimum, maximum and mean values and standard deviation (s) of the abiotic limnological variables at the eight sampling stations in Caçó pond, on both studied periods (April and November 1999).

	April				November			
	Min	**Max**	**Mean**	**s**	**Min**	**Max**	**Mean**	**s**
Water temperature (°C)	28.4	30	29.1	0.31	28.3	29.9	28.8	0.27
Water transparency (m)	4.5	4.7	4.6		4.2	4.3	4.3	
Euphotic zone (m)		Total				Total		
Conductivity (µS/cm)	30	37	35.4	1.47	35	39	35.1	0.57
pH	4.13	6.31	5.0	0.52	4.32	6.31	5.3	0.44
Alkalinity (mEq/l)	0.01	0.08	0.05	0.02	0.03	0.04	0.03	0.01
D. O. (mg/l)	5.33	7.59	6.6	0.51	5.30	7.81	6.7	0.85
Free CO_2 (mg/l)	3.91	16.09	10.67	3.75	4.37	10.22	8.53	1.6
TP (µg/l)	4.32	12.48	8.16	2.29	4.98	7.92	6.5	0.89
TN (µg/l)	205.15	327.13	246.78	30.36	233.85	439.32	288.1	46.58
Ammonium (µg/l)	3.24	148.68	28.37	34.34	2.88	77.58	25.88	24.77
Nitrate (µg/l)	21.7	58.28	34.82	10.10	48.36	106.64	63.4	12.03
TN:TP	19.5	60.3	33.4	12.27	30.3	69.96	45.16	10.36

Table 2 - Specific richness (R), Shannon-Wienner diversity (H') (bits/ind), equitability or uniformity (J) and dominance (D) indexes of the eight sampling stations (S1 to S8), in both studied periods.

	R		**H'**		**J'**		**D**	
	April	**November**	**April**	**November**	**April**	**November**	**April**	**November**
S1	54	20	3.40	2.42	0.59	0.81	0.07	0.12
S2	23	22	2.65	2.78	0.59	0.90	0.10	0.09
S3	21	23	2.01	2.39	0.46	0.76	0.17	0.14
S4	47	26	3.47	2.63	0.62	0.81	0.06	0.12
S5	19	25	1.83	3.64	0.43	1.13	0.19	0.11
S6	19	22	2.14	2.50	0.51	0.81	0.14	0.11
S7	20	23	2.03	2.67	0.47	0.85	0.15	0.10
S8		19		2.49		0.85		0.12

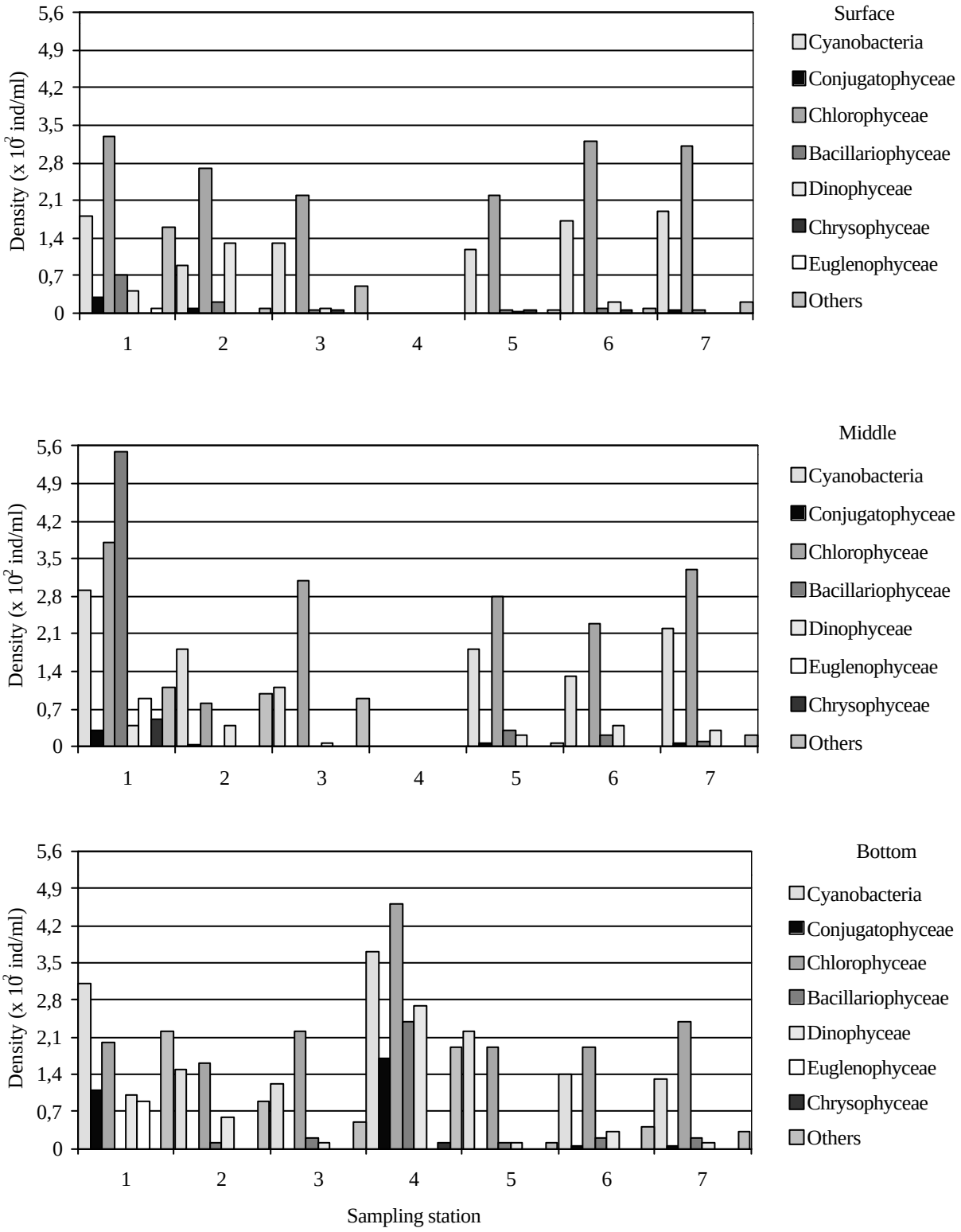

Figure 3 - Vertical and horizontal distributions of the phytoplanktonic classes density (ind x 10^2/ml) in rainy season, at seven sampling stations and in three depths.

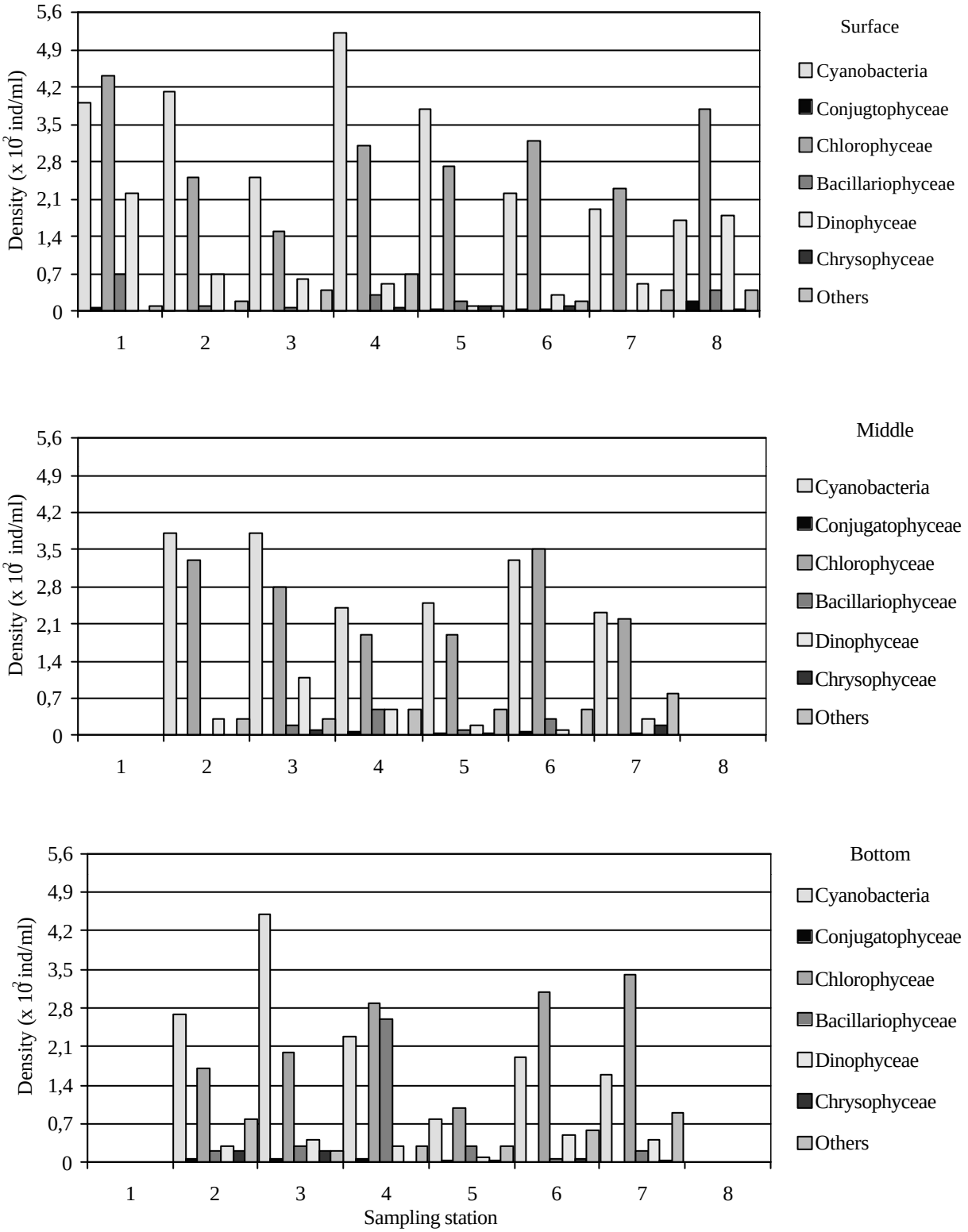

Figure 4 - Vertical and horizontal distributions of the phytoplanktonic classes density (ind x 10^2/ml) in dry season, at eight sampling stations and in three depths.

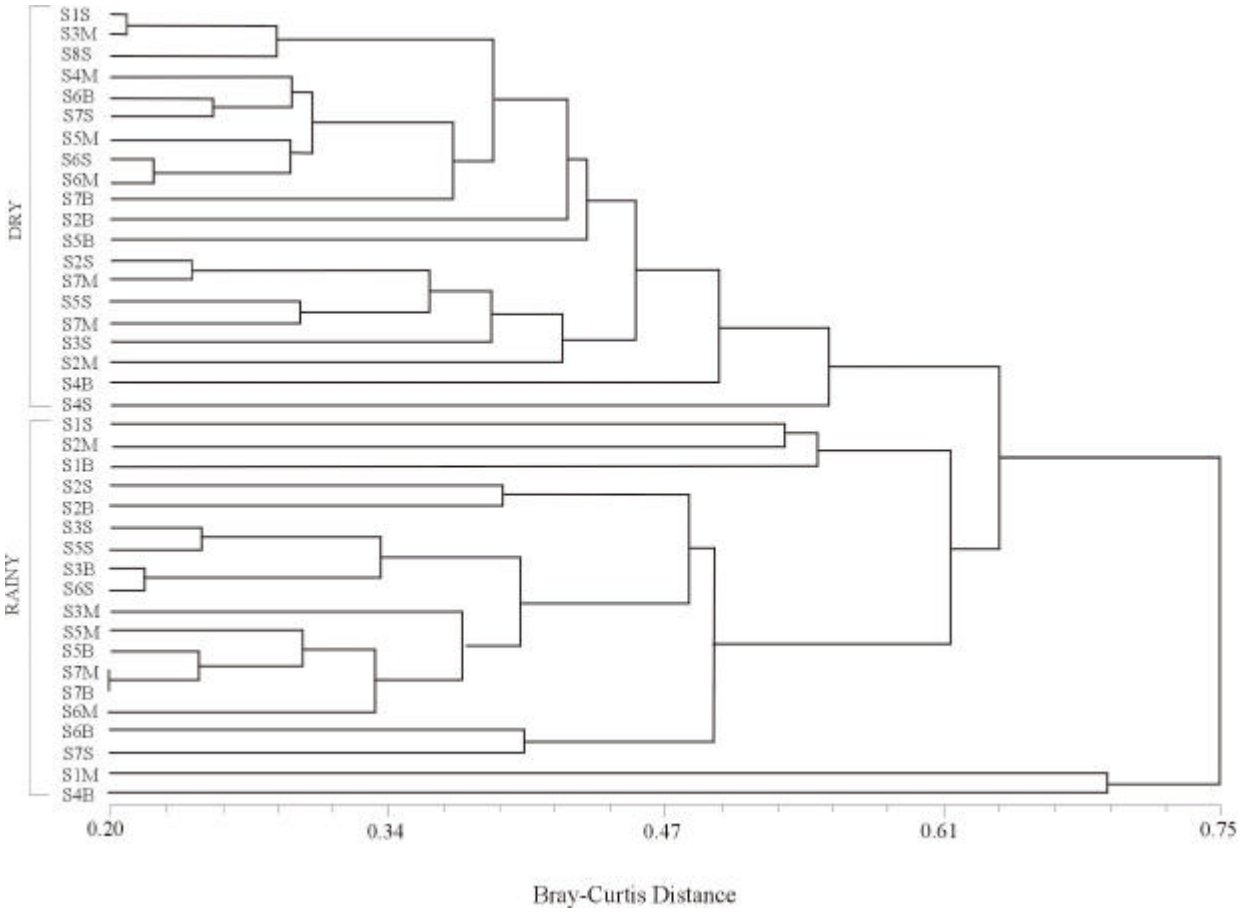

Figure 5 - Dissimilarity dendrogram as a result from the application of the Bray-Curtis distance, using UPGMA as clustering method, between the eight sampled stations and the three depths, in rainy and dry seasons. (r = 0.80)

The vertical distribution of the total phytoplanktonic density at Caçó pond did not present a clear pattern. However, in the rainy season, higher values were observed, occurring from the intermediate stratum of the water column (middle and bottom). Stratified vertical profiles are common and generally the lower algal densities are registered on the bottom and the higher ones on the intermediate stratum. The light availability and the water column instability, probably, were the determinant factors of the phytoplankton distribution in the different stratum of the water column, since the majority of the species found at Caçó pond are known to be not regulators of their fluctuation and concerned 90% of the species registered. Harris and Smith (1977) commented that the light availability, because of its exponential attenuation with the deepness within the aquatic environment, is the determinant factor for the phytoplankton vertical allocation. This characteristic imposes a strong verticality over the phytoplankton, so that discontinuous vertical distributions are expected and occur commonly. Thus, much planktonic associations are found randomly disperse through light gradients (Reynolds, 1992).

The cluster analysis, considering the taxa densities in each sampling station in both periods, displayed two great groups. The first group was composed by species which were most common and abundant on the rainy season, mainly Chlorophyceae class (*Didymocystis* sp., *Monoraphidium* cf. *minutum* and *Monoraphidium* sp.) representatives and the second group was represented, mainly by the Cyanobacteria class (*Aphanothece comasii*, *Aphanothece* cf. *conglomerata*, *Aphanothece* sp., *Chroococcus minimus* and *Chroococcus* cf. *sonorensis*). These

genera are common in natural lakes plankton and widely scattered around the world. The differences in the rainfall amount between the two collection seasons, as the water column instability, contributed to these two great groups separation. According to Tundisi (1990), the vertical mixture promotes changes in the phytoplankton specific composition. As a result, the variety of life forms encountered in the phytoplanktonic community are seen as being adaptable to an unstable and turbulent environment, to the periodical stresses occurrence associated with nutrient availability and to the vertical mixture. These factors represent the higher selective pressures in which the phytoplankton is exposed (Margalef, 1978).

According to Harris (1986), the species composition and abundance changes would be associated randomly and controlled by external factors, while to Reynolds (1984), these changes would be consequence of external interventions (allogenics) or of the organism activities, which would result in progressive changes in the environment (autogenics). The phytoplanktonic species composition and abundance reorganisation, as a result of the environmental (allogenic) and of the community (autogenic) interactions were called by Hutchinson (1967) as "seasonal succession" and have been used to the phytoplankton temporal variability. Considering that, for the Caçó pond, the changes in the density and abundance of the species have occurred possibly due to the rainfall quantity (allogenic factor) and the sample collections were carried out in only one day, in both periods, such changes maybe cannot be characterised as a successional process.

The species diversity can be considered high at Caçó pond. According to the Intermediate Disturbance Hypothesis, formulated by Connell (1978), the high diversity must be related to disturbances of intermediate frequencies or intensities, however must be based in sampling scales close to the algae generation time, regularly done, through several years (Sommer et al., 1993). In Brazil, few water bodies were studied along many years and the Caçó pond is not an exception. Higher species diversity index (H') were registered in April, coinciding with the higher rainfall values, which, probably, caused the algal suspension of the sediment and the periphyton removal, increasing the specific richness as well as the possibility to collect a higher number of species than during the dry season. According to Lewis (1978), the disappearance of species in lakes is just apparent, due to the probability diminution of registering them in periods of low densities. Rainy period presented a low uniformity in equitability index due to the higher density values of the Chlorophyceae class. Considering the dominance index, no taxon were dominant at the Caçó pond.

Thus it could be concluded, that the climatologic factor, conditioned by the seasonal ITCZ movement, providing two distinct periods, in terms of pluviosity, was determinant over the dynamic and the structure of the Caçó pond's phytoplanktonic community.

ACKNOWLEDGEMENTS

The authors are grateful to the equip of the research project "Utilização de marcadores limnológicos e sedimentológicos na bacia da lagoa do Caçó (Norte do Maranhão)" and to the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), for the field works viability. The first and third authors received financial support from Conselho Nacional de Pesquisa Científica e Tecnológica (CNPq) (processes 130687/1999-5 and 146515/99-4, respectively).

RESUMO

Mudanças sazonais na comunidade fitoplanctônica e nas características limnológicas abióticas da lagoa do Caçó, Estado do Maranhão, Brasil, foram avaliadas a partir de duas coletas, nos períodos de chuva (Abril/1999) e seca (Novembro/1999). Medidas de quatorze variáveis físicas e químicas e coletas do fitoplâncton foram realizadas em oito estações de amostragem. Quantitativamente, os grupos Chlorophyceae e Cyanobacteria apresentaram maior contribuição nos períodos de chuva e seca, respectivamente. As variáveis limnológicas abióticas mostraram uma distribuição espacial homogênea em relação aos dois períodos amostrados. A análise de agrupamento a partir da distância de Bray-Curtis para comunidade fitoplanctônica distinguiu dois grandes grupos (estação seca e chuvosa), representados pelas espécies mais comuns e abundantes em ambos períodos. Os resultados deste estudo permitiram concluir que o regime climatológico foi

determinante sobre a dinâmica e a estrutura da comunidade fitoplanctônica da lagoa do Caçó.

REFERENCES

Araújo, A. (1999), Contribuição ao conhecimento das desmídias de hábito filamentoso do Parque Nacional dos Lençóis Maranhenses - MA. In: *Anais do VII Congresso Brasileiro de Limnologia*. 274 pp.

Araújo, A. (2000), *A comunidade fitoplanctônica de um sistema lacustre em curto período de tempo (estações seca e chuvosa) - no Parque Nacional dos Lençóis Maranhenses, Maranhão*. Dissertação (Mestrado em Ciências da Engenharia Ambiental) - CRHEA, Universidade de São Paulo, São Carlos.

Araújo, A.; Pessoa, C. D.; Correia, M. and Ibañez, M. S. R. (1998), Fitoplâncton de rede do rio Itapecuru, Maranhão, Brasil: uma contribuição ao conhecimento. *Boletim do Labohidro*, **11**, EDUFMA.

Azevedo, A. C. G. (1995), *Diatomáceas (Bacillariophyceae) epífitas em Bostrychia montagne dos manguezais de Parna açu - ilha de São Luís - estado do Maranhão*. Monografia de graduação - UFMA. 99 pp.

Barbieri, R.; Ibanez, M. S. R.; Aranha, F. J.; Correia, M. M. F.; Reid, J. W. and Turner, P. (1989), Plâncton, produção primária e alguns fatores físico-químicos de dois lagos da baixada Maranhense. *Rev. Bras. Biol.*, **43** : (2), 399-408.

Bicudo, C. E. M. (1990), Considerações sobre metodologias de contagem de algas do perifíton. *Acta Limnologica Brasiliensia*, **3**, 459-475.

Cole, G. (1994), *Textbook of limnology*. 2nd ed. Saint Louis : The C.V. Mosby. 283 pp.

Connell, J. H. (1978), Diversity in tropical rain forests and coral reefs. *Science*, **199**, 1302-1310.

Ericeira, J. E. (2000), *Fitoplâncton dos rios Pindaré, Mearim e Itapecuru (Maranhão, Brasil)*: aspectos taxonômicos e ecológicos. Monografia de graduação, UFMA. 36 pp.

Eskinazi-Leça, E.; Gusmão, L. M. O.and Silva, M. G. G. (1985), Microfitoplâncton da Baia do capim (Estado do Maranhão-Brasil). In: *Anais da VIII Reunião Nordestina de Botânica*. pp. 57-81.

Espíndola, E. G.; Matsumura-Tundisi, T.; Moreno, I. D. (1996), Estrutura da comunidade fitoplanctônica da lagoa Albuquerque (Pantanal Matogrossense), Mato Grosso do Sul, Brasil. *Acta Limnol. Brasil.*, **8**, 13-27.

Golterman, H. L.; Clymo, R. S.; Ohnstad, M. A. M. (1978), *Methods for chemical analysis of freshwaters*. Oxford : Blackweell Scientific Publications. 213 pp. (IBP Handbook, n. 8).

Harris, G. P. (1986), *Phytoplankton ecology, structure, function and fluctuation*. London: Chapman and Hall. 384 pp.

Harris, G. and Smith, R. H. (1977), Observations of small scale spatial patterns of phytoplankton populations. *Limnol. and Oceanogr.*, **22**, 887-899.

Hastenrath, S. and Heller, L. (1977), Dynamics of climatic hazards in Northeast Brazil. *Quart. J. Roy. Meteor. Soc.*, **103**, 77-92.

Huszar, V. L. M. (1994), *Fitoplâncton de um lago Amazônico impactado por rejeito de bauxita (lago Batata, Pará, Brasil)*: estrutura da comunidade, flutuações espaciais e temporais. Tese (Doutorado em Ciências) - PPG-ERN, Universidade Federal de São Carlos, São Carlos.

Huszar, V. L. M. (1996), Planktonic algae, other than desmids, of three Amazonian systems (Lake Batata, Lake Mussará and Trombetas River), Pará, Brazil. *Amazoniana*, **14** : (1/2), 37-73.

Hutchinson, G. E. (1967), *A treatise on Limnology. II: Introduction to lake biology and limnoplankton*. New York : John Willey and Sons. 1115 pp.

Labohidro/UFMA (1983), O plâncton da região estuarina de Coqueiros (Maranhão). São Luis, Relatório Técnico. 22 pp.

Labohidro/UFMA (1990), Relatório Técnico das atividades desenvolvidas na área de influência do Consórcio ALUMAR, na Ilha de São Luís - MA. Subprojeto plâncton. São Luís. 43 pp.

Labohidro/UFMA (1994), Estudo do plâncton (fito e zooplâncton) e de fatores físicos e químicos na região estuarina dos rios Anil e bacanga. São Luís, Relatório técnico. 88 pp.

Lavôr-Fernandes, G. (1987), Contribuição ao estudo das diatomáceas (Bacillariophyceae) da lagoa da Jansen (São Luís - MA). *Cad. Pesq.*, **3** : (2), 34-52.

Lavôr-Fernandes, G. (1988a), Microfitoplâncton no estuário do Rio Paciência, Paço do Lumiar, Maranhão. *Bol. Lab. Hidrob.*, **8**, 23-44.

Lavôr-Fernandes, G. (1988b), Microfitoplâncton da baía de São marcos (São Luís, Maranhão, Brasil). *Gayana*, **45** : (1-4), 265-274.

Lewis, W. M. (1978a), A compositional, phytogeographical and elementary structural analysis of the phytoplankton in a tropical lake: lake Lanao, Philipines. *J. Ecol.*, **66**, 213-226.

Lund, J. G. and Talling, J. F. (1957), Water analysis: some revised methods for limnologists. Ambleside: *Freshwater Biol. Assoc.* 120 pp.

Marengo, J. (1992), Interanual variability of surface climate in the Amazon basin. *Int. J. Climatol.*, **12**, 853-863.

Margalef, R. (1978), *Ecologia*. Omega. 951 pp.

Martin, L. (2000), Porque ter escolhido a lagoa do Caçó. In: Workshop do Projeto Maranhão, Rio de Janeiro. *Resumos*... Rio de Janeiro. pp. 4.

Moschini-Carlos, V. and Pompêo, M. L. M. (1999), Dinâmica do fitoplâncton em lagoa de dunas (Parque Nacional dos Lençóis Maranhenses). In: *Anais do VII Congresso Brasileiro de Limnologia*. 445 pp.

Moura, A. D. and Sukla, J. (1981), On the dynamics of drought in Northeast Brazil: observations, theory and numerical experiments with a general circulation model. *J. Atmos. Sci*., **33**, 2533-2675.

Nimer, E. (1989), *Climatologia do Brasil*. Rio de Janeiro : IBGE. 421 pp.

Oliveira, D. B. F.; Eskinazi-Leça, E. and Köening, M. L. (1986), Microfitoplâncton da Baía de Mangunça (Estado do Maranhão- Brasil). *Bol. Tec. EMPARN*, **15**, 30.

Pereira, D. F. (1999), Caracterização física e química das lagoas dos Lençóis Maranhenses, Brasil. Monografia de graduação - UFMA. 13 pp.

Pessoa, C. R. D. (1992), *Diatomoflórula (Bacillariophyceae - Pennales) da Fazenda Camaroneira de Perizes, município de Rosário, Estado do Maranhão, Brasil*. Monografia de graduação, UFMA. 56 pp.

Pielou, E. C. (1975), *Ecological Diversity*. New York, Wiley-Interscience. 165 pp.

Reynolds, C. S. (1984), Phytoplankton periodicity: the interations of form, function and environmental variability. *Freshwater Biology*, **14**, 111-142.

Reynolds, C. S. (1992), Dynamics, selection and composition of phytoplankton in relation to vertical structure in lakes. *Verh. Internat. Verein. Theorest. Ang. Limnol.*, **35**, 13-31.

Ros, J. (1979), *Práctica de ecologia*. Barcelona: Omega, 181 pp.

Shannon, C. E.; Wienner, W. (1963), *The mathematical theory of communication*. Urbana: University of Illinois. 173 pp.

Simpson, E. H. (1949), Measurement of diversity. *Nature*, **163**, 688.

Sommer, U.; Padisák, J.; Reynolds, C. S. and Juhász-Nagy, P. (1993), Hutchinson's heritage: the diversity-disturbance relationship in phytoplankton. *Hidrobiol*., **249**, 1-7.

Stum, W. and Morgan, J. (1981), *Aquatic chemistry. An introduction emphazing chemical equilibria in natural waters*. Wiley-Interscience publication: John Wiley and Sons. New York. 799 pp.

Tundisi, J. G. (1990), Distribuição espacial, sequência temporal e ciclo sazonal do fitoplâncton em represas: fatores limitantes e controladores. *Rev. Bras. Biol.*, **50** : (4), 937-955.

Utermöhl, H. (1958), Zur Vervolkomnung der quantitativen phytoplankton: methodic. *Internat. Verein. Theorest. Ang. Limnol. Mitteil*., **9**, 1-38.

Valderrama, J. C. (1981), The simultaneous analysis of total nitrogen and phosphorus in natural waters. *Marine Chemistry*, **10**, 109-122.

Valentini, J. L. (2000), *Ecologia numérica: uma introdução à análise multivariada de dados ecológicos*. Rio de Janeiro: Interciência. 117 pp.

Received: January 21, 2002;
Revised: June 04, 2002;
Accepted: October 31, 2002.