FLORISTIC COMPOSITION AND BIOGEOGRAPHICAL ASPECTS OF THE PHYTOPLANKTON OF AN AMAZONIAN FLOODPLAIN LAKE (LAKE BATATA, PARÁ, BRASIL).

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ABSTRACT: Floristic composition and biogeographical aspects of the phytoplancton of an Amazonian floodplain lake (Lake Batata, Pará, Brazil). The floristic composition and biogeographical aspects of the phytoplankton of a shallow Amazonian floodplain lake (Lake Batata, Pará, Brazil) were analysed and compared to other tropical and subtropical lakes x temperate zone lakes. It was concluded that: 1) the floristic composition of Lake Batata is relatively complex when compared to deep tropical lakes; 2) no significant differences were obtained between the mean numbers of genera of tropical and subtropical lakes x temperate lakes, indicating similar complexities of their floristic compositions; and 3) associations of pantropical genera were demonstrated, the mean number of genera common to Lake Batata and to other tropical and subtropical lakes being significantly higher than the mean number in common with temperate zone lakes.

Key-words: Amazonia, phytoplankton, floristic composition, biogeography, floodplain lake.

RESUMO: Composição florística e aspectos biogeográficos do fitoplancton de um lago de inundação amazonico (Lago Batata, Pará, Brasil). Analisaram-se a composição florística e aspectos biogeográficos do fitoplâncton de um lago de inundação amazônico raso (lago Batata, Pará, Brasil), comparando-o a outros lagos de regiões tropical e subtropical x lagos de região temperada. Concluiu-se que: 1) a composição florística do lago Batata é relativamente complexa, se comparada a lagos tropicais profundos; 2) não foram registradas diferenças significativas entre o número médio de gêneros de lagos tropicais e subtropicais x lagos temperados, indicando complexidades semelhantes de suas composições florísticas; e 3) foram evidenciadas associações de gêneros pantropicais, tendo sido significativamente maior o número médio de gêneros comuns ao lago Batata e a outros lagos tropicais e subtropicais.

Palavras-chave: Amazônia, algas planctônicas, composição florística, biogeografia, lago de inundação.

INTRODUCTION

The science of tropical ecology has been influenced by ideas formulated from temperate ecosystems, which constitute a basis for the majority of hypotheses on the functioning of tropical ecosystems (Welcomme & Berkowitz, 1991). Until recently, a large part of research in the tropics has been carried out by scientists from temperate regions on short visits to low latitudes, carrying their intellectual baggage acquired in the temperate zones. For instance, certain authors have referred to a lower species richness in tropical lakes in general (Lewis, 1978) and in Amazonia in particular (Payne, 1986), than in lakes of the temperate region. In addition, shallow tropical lakes have been considered to have a simpler floristic composition than large tropical lakes (Lewis, 1978). Pantropical associations typified by certain genera have also been pointed out. Other authors, however, have concluded that no correlation exists between richness of species and the latitude in which the lakes are located (Kalff & Watson, 1986), since most algae are cosmopolitan at least at the genus level (Reynolds, 1995), and are adapted as much to lakes of the warm belt as to those of temperate regions (Pollingher & Berman, 1991).

Structural analyses of the phytoplankton community generally have preceded functional analyses, above all in tropical regions where knowledge of these communities is still relatively poor. The analysis presented here is of particular interest since it includes comparisons between wide intervals of latitude, potentially leading to improved comprehension of the factors governing phytoplanktonic community structure.

The phytoplankton of Lake Batata has been studied in different aspects, including the taxonomy of its components (Huszar, in press; Sophia & Huszar, in press; Menezes & Huszar, in press) as well as its structural dynamics (Huszar, 1994; Huszar & Reynolds, in press). The present study complements those preceding, formulating considerations on the floristic composition and on biogeographical aspects of the planktonic algae.

Based on the literature, the following hypotheses were formulated for this work: 1) by reason of being a shallow tropical lake, the composition of the phytoplankton of Lake Batata is simpler than that of deep tropical lakes; 2) by reason of being a tropical lake, the composition of the phytoplankton is simpler than that of temperate lakes; and 3) associations of pantropical genera could be recognized.

MATERIAL AND METHODS

Lake Batata (56°14' and 56°21'W, 1°25' and 1°35'S) is located on the right bank of the Trombetas River, near Porto Trombetas, Municipality of Oriximiná, Pará State, Brazil (Fig. 1). It is a clear-water, lateral dam lake (Panosso, 1993), area about 29.5 km^2 water surface at low-water stage, and permanently connected to the Trombetas River. Depending on the amplitude of the flood pulse, the river waters may encroach over the dike separating river and lake. The regional climate is *Am* of Köppen - humid tropical monsoon (Brasil, 1994).

About 20 km southwest of Lake Batata is a bauxite mine developed by the company Mineração Rio do Norte S.A. From 1979 to 1989, bauxite tailings resulting from ore processing were dumped into the western part of the lake, settling over about 30% of the total area during the high water stage (Roland & Esteves, 1993) and about 20% during low water (Panosso, 1993).

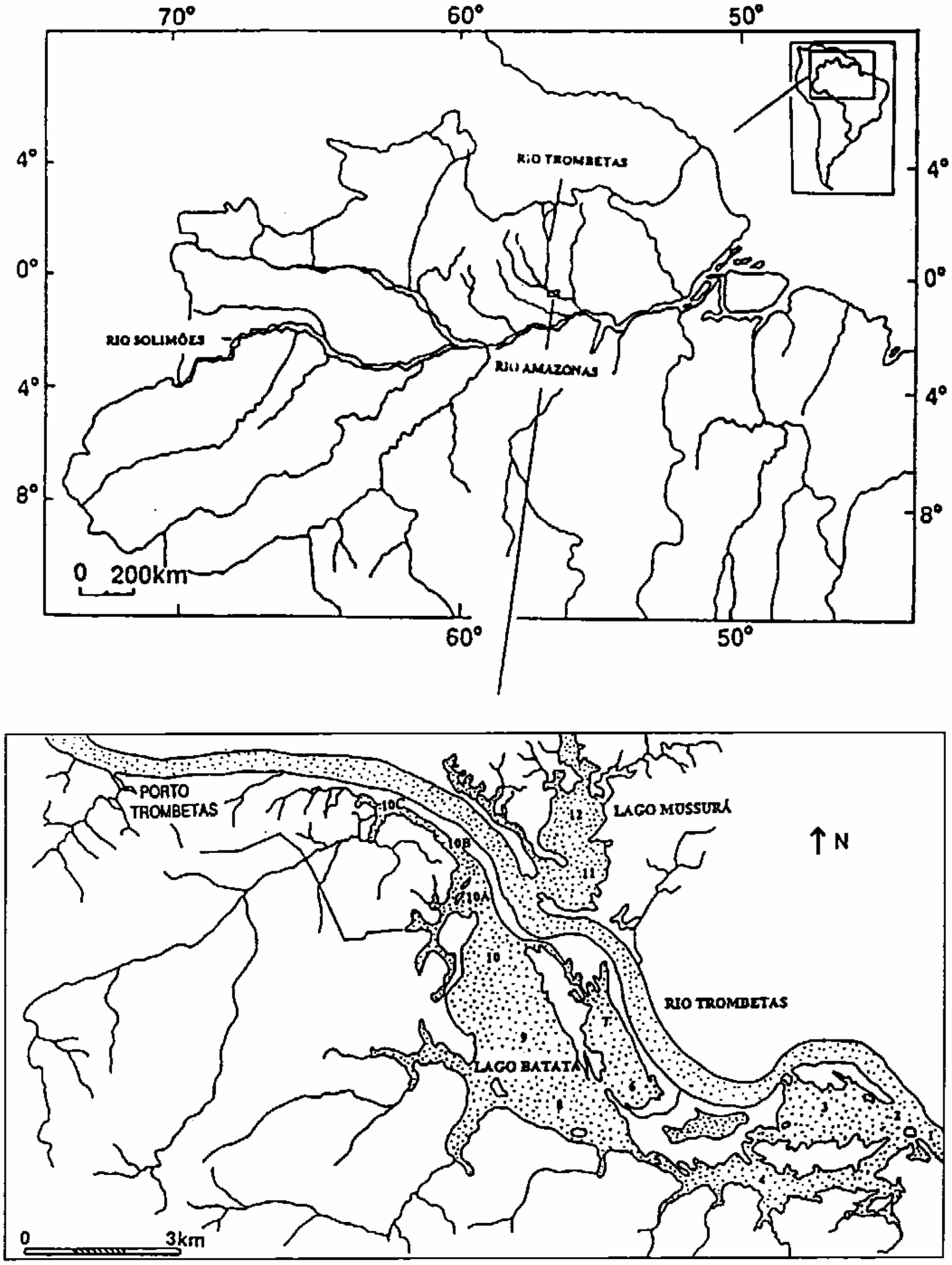

Figure 1. Localization of study area (upper map) and of sampling stations in Lake Batata

The waters of this lake are characterised by low values of electrical conductivity, pH, alkalinity and soluble reactive phosphate content (Tab. 1). According to Huszar (1994) the phytoplankton biomass is dominated by microplanktonic desmids (50-200μm) for six months of the year (low water and filling stages) and by cryptophyceans and nanoplanktonic diatoms during the rest of the year (high water and drawdown stages).

The study of the phytoplankton community was based on 116 samples collected weekly from 04/09/88 to 05/10/89 (58 weeks), including the four periods of the Trombetas River hydrological cycle (drawdown, low water, filling and high water). The samples were collected by passing a flask along the subsurface (ca. 0.1 m) of the lake at two points: one in the natural area (Sta. 8) and the other in the area impacted by the sediment covered by bauxite tailings (Sta. 10). The samples were fixed in acetic lugol's (Vollenweider, 1974) and the algal populations quantified by the method of Utermöhl (1958). For the comparisons between Lake Batata and other tropical and subtropical lakes, and between Lake Batata and temperate lakes, only the floristic composition and not the biomass of the phytoplankton population was considered.

The level of knowledge of the phytoplankton varies between lakes, among other aspects, as a function of the method of analysis and collection and of the taxonomic literature used (Pollingher & Berman, 1991). Generally, complete species tabulations are unavailable for comparison. In the comparisons made in the present study, only articles with complete tabulations, produced by methods of collection (non-selective) and of quantification (Utermöhl, 1958) similar to those adopted here were used.

In order to compare floristic complexity between shallow and deep tropical lakes, the maximum, minimum and mean numbers of species were analysed, considering each week and the total found for the 58 weeks of the study at Stations 8 and 10 of Lake Batata, with data from tropical and subtropical lakes sampled for about one year, weekly (Lake Lanao, Philippines, Lewis, 1978), biweekly (Los Matadores Lake, Argentina, García de Emiliani, 1980; Monte Alegre Lake, São Paulo, Brazil, Silva, 1995) and every 20 days (Lake Naivasha, Kenya, Kalff & Watson, 1986). The only other periodic work on the phytoplankton of an Amazonian lake is that of Schmidt & Uherkóvich (1973) for Castanho Lake, where collections were made monthly with a plankton net, which made comparisons impossible.

Table 1. Means and standard deviation of some abiotic variables and attributes of the phytoplankton of the areas studied.

Variables	Mean and standard deviation	No. samples
Secchi disk (m)	1,2 1± 0,15	40
Electrical conductivity (μS.cm^{-1})	9,9 ± 1,9	102
Water temperature (0C)	29,6 ± 4,6	102
pH	5,7 ± 0,3	102
Alkalinity (mEq.l^{-1})	0.05 ± 0,03	102
Soluble reactive phosphorus (μg.l^{-1})	5,1 ± 3,41	102
Nitrate (μg.l^{-1})	34,1 ± 42,3	102
Biovolume (mm3.l^{-1})	2,34 ± 2,95	116
Diversity (bits.ind.$^{-1}$)	3,55 ± 1,19	116

In order to compare the floristic composition of tropical and subtropical lakes with that of temperate lakes, and in an attempt to determine individual associations of pantropical genera, the mean of genera common to Lake Batata and seven tropical and subtropical lakes was contrasted with the mean of genera common to Lake Batata and to seven temperate lakes. The comparison was made at the generic level because 1) superposition of species may incur larger errors because of greater uncertainty as to identifications when data of many researchers are compared; and 2) the available lists from works with collection and processing methods similar to the present study are less complete at the specific than the generic level. For purposes of establishing whether the differences between means are statistically significant, Student's T Test was used.

RESULTS AND DISCUSSION

Lewis (1978) considered the phytoplankton composition of shallow tropical lakes, such as Lake George studied by Ganf (1974) as much simpler than that of deeper lakes such as Lake Lanao which he studied, or the 15 lakes of Java, Sumatra and Bali studied by Ruttner (1952). Additionally, the Amazonian flood-plain lakes were considered by Payne (1986) as not being particularly species-rich and being quite similar to the lakes of Southeast Asia already mentioned. When large tropical lakes are compared, Lake Batata as well as those listed in Table 2, except for Lake Lanao, they are relatively shallow. However, the data reveal considerable floristic complexity within them, each having a total of more than 100 species, of which 49 to 71 may occur in a single sample.

The minimum and maximum numbers of species per sample fluctuated much more in Lake Batata (0 to 49) than in the other tropical and subtropical lakes compared, even in systems subject to periodic inundation such as Los Matadores Lake in the floodplain of the Paraná River, Argentina (García de Emiliani, 1980). This fact and the null values found reflected the extreme conditions of the lotic phase of Lake Batata, which made recording organisms by the method used for quantifying populations impossible.

The matter and energy pulse imposed on Lake Batata was reflected in the species richness of the phytoplankton community in each of the phases of the hydrological cycle. Greater species richness, principally of Chlorophyta (Chlorophyceae and Zygnemaphyceae) could be demonstrated in the periods of lesser influence of the Trombetas River — low water and filling stage — than in those of greater influence — high water and drawdown (Tab. 3).

Biogeographical aspects could be considered by analysing the superposition of floristic composition between tropical and temperate lakes. The data obtained (Tab. 4) indicate the lack of a significant difference ($p=0.01$) between the mean number of genera in tropical and subtropical lakes (54.5), and in temperate lakes (36.6). This contrasts with the results obtained by Lewis (1978), who compared Lake Lanao to ten temperate and ten tropical lakes and concluded that tropical lakes are less rich than temperate ones. The data from the temperate and tropical lakes compared in the present study were collected periodically during at least one year in the decades from 1970 to 1990.

The tropical lakes compared by Lewis (1978) were sampled only once and, only some of the temperate lakes were periodically studied, with data published during the decades from 1930 to 1970. Collections made during only one season and possibly with less rigor in identification may explain the differences found by that author.

Table 2. Variation in maximum, minimum and mean of species (sp) by collection interval in Lake Batata and in four tropical and subtropical lakes of Ásia, Africa and South America.
(Cy=Cyanophyta; Chl.=Chlorophyta; Eu=Eugle-nophyta; Ra=Raphidophyta; Ba=Bacillariophyta; Chr.=Chrysophyta; Xa= Xanthophyta; Cr.=Cryptophyta; Di.=Dinophyta).

	L.Lanao[1] (sp/week.)				L.Matadores[2] (sp/biweekly)				L.MonteAlegre[3] (sp/biweekly)				L.Naivasha[4] (sp/20 days)				L.Batata (sp/week)			
	Máx.	Mín.	Méd.	Tot	Máx.	Mín.	Méd.	Tot	Máx.	Mín.	Méd.	Tot	Máx.	Mín.	Méd.	Tot	Máx.	Mín.	Méd.	Tot
Cy.	10	5	8	12	5	0	3	7	8	3	5	13	18	4	12	24	8	0	4	17
Chl	30	24	27	44	24	8	17	56	37	17	27	60	28	16	26	59	48	0	16	99
Eu.	3	0	1	4	19	2	8	27	1	7	2	14	4	0	1	6	2	0	0	4
Ra.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	2
Ba.	3	1	2	4	15	4	8	22	5	2	3	11	8	4	6	14	7	0	3	13
Chr	1	1	1	1	3	12	4	5	0	3	6	7	0	4	6	15	6	0	2	19
Xa.	0	0	0	0	2	0	1	2	2	1	1	3	1	0	0	1	1	0	0	3
Cr.	2	2	2	2	5	2	4	5	4	2	4	4	8	5	7	9	4	0	2	8
Di.	3	0	2	3	1	0	1	1	4	1	2	4	3	1	2	7	3	0	1	7
Tot	51	36	43	70	59	25	41	124	61	37	49	115	71	37	58	136	49	0	26	172

Lewis (1978)[1];García de Emiliani (1980)[2]; Silva (1995)[3]; Kalff & Watson (1986)[4]

Tabela 3. Variation in species richness of total phytoplankton and of major taxa in the different stages of the hydrological cycle of Lake Batata.

Division/Stage	Drowdown	Low water	Filling	High water
Cyanophyta	13	15	12	10
Chlorophyta	49	80	73	25
Euglenophyta.	02	02	01	01
Raphidophyta	02	01	02	01
Bacillariophyta	08	11	07	05
Chrysophyta	13	10	14	07
Xanthophyta	0	0	02	0
Cryptophyta	04	05	07	06
Dinophyta	03	05	04	03
Total	94	129	122	58

Tabela 4. Total number of genera of tropical and subtropical lakes and of temperate lakes, and comparison between the number of genera in common with Lake Batata and other tropical and subtropical lakes, with the number of genera in common with Lake Batata and temperate, with the respective percentage.

	No.Gen.	Gen.common w/.Batata L.	% Gen.common w/ Batata L.
TROPICAL AND SUBTROPICAL			
Lanao (Philippines)[1]	43	33	77
Lago Valencia (Venezuela)[2]	51	37	72
Naivasha (Kenya)[3]	81	45	56
Oloiden (Kenya)[3]	49	44	90
Matadores (Argentina)[4]	66	40	61
Infernão (Brazil)[5]	50	32	64
Monte.Alegre (Brazil)[6]	61	50	82
Paranoá (Brazil)[7]	35	28	80
Mean	54,5	38,6	72,7
TEMPERATE LAKES			
Ontario (Canada)[8]	48	23	48
Erie (Canada)[8]	19	10	53
Huron (Canada)[8]	42	25	59
Superior (Canada)[8]	33	20	60
Michigan (Canada)[8]	35	22	63
Vilá (Spain)[9]	32	25	76
Banyoles (Spain)[10]	47	26	55
Mean	36,6	21,6	59,1

(1-Lewis,1978; 2-Lewis & Riehl,1982; 3-Kalff & Watson,1986; 4-Garcia de Emiliani,1980; 5-Dias,1991; 6-Silva,1995; 7- Branco, 1991; 8-Munawar & Munawar,1986; 9-Garcia de Emiliani,1973; 10-Planas,1973)

Kalff & Watson (1986), in comparing two African tropical lakes with other temperate and tropical ones concluded that no correlation existed between species richness and latitude as previously suggested by Lewis (1978). According to those authors, this is not surprising, because the water temperature as well as the incident radiation differ little, at least in the summer months, between temperate and tropical lakes, especially if one takes into account the short generation time of algae (<10^5-10^6 seconds, Reynolds, 1992).

In spite of some variation in rigor in generating the lists, an approximate superposition indicated that Lake Batata has on average 38.6 genera (72.7%) in common with other tropical and subtropical lakes, and 21.6 genera (59.1%) in common with temperate lakes, independently of their morphometry, physical and chemical conditions, etc. Lewis (1978) recorded a similarity of 79% between the genera of Lake Lanao and other tropical lakes, and only 45% between that lake and temperate lakes. This led him to conclude that the phytoplankton genera of Lake Lanao belong to pantropical associations, typified by many genera common to those environments. The data from the present study confirmed Lewis' conclusions, since significant differences ($p=0.01$) were observed between the mean number of genera common to Lake Batata and tropical and subtropical lakes x the mean number of genera common to Lake Batata and temperate lakes. This indicated, then, more pantropicality than cosmopolitanism of the phytoplanktonic genera.

CONCLUSIONS

The floristic composition of Lake Batata, considered at species level, is relatively complex when compared to deep tropical lakes. No significant differences were recorded between the mean number of genera of tropical and subtropical lakes x temperate lakes, indicating a similar degree of complexity of their floristic compositions. Associations of pantropical genera were evident, the mean number of genera common to Lake Batata and to other tropical and subtropical lakes being significantly greater than between Lake Batata and temperate lakes.

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