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A N   I N T E R N A T I O N A L   J O U R N A L

Structure and Dynamics of Phytoplankton Community in the Botafogo Reservoir-Pernambuco-Brazil

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ABSTRACT

The aim of the present study was to investigate the structure and dynamics of the phytoplankton in the Botafogo reservoir-PE-Brazil. Phytoplankton assemblages were identified from current literature and density was estimated using an inverted microscope. Concurrently to the sampling of biotic variables, measurements of abiotic parameters, such as water temperature, dissolved oxygen and pH, were determined using field probes and transparency was determined with a Secchi disk. Total phosphorus and total nitrogen concentrations were determined in laboratory. A total of 24 taxa were identified. Chlorophyta presented the greatest number of species. Species diversity in the reservoir was low throughout the study period. Principal component analysis revealed that Trachelomonas volvocina*,* Chlorella vulgaris*,* Euglena sp. *and* Peridinium gatunense *were directly correlated with oxygen, turbidity and total nitrogen;* Planktosphaeria gelatinosa*, P. gatunense and* Euglena sp. *were directed correlated with total nitrogen; rainfall explained the occurrence of* Monoraphidium arcuatum *and* Chlorella vulgaris.

Key words: Structure, Tropical reservoir, Phytoplankton, Brazil

INTRODUCTION

Reservoirs respond to physical (influx radiation, evaporation, wind, drainage, etc.), chemical (precipitation, sedimentation, etc.) and biological influences from the natural environment. They are also very sensitive to human activities due to their function as collectors and processors of material from anthropogenic activities such as agriculture, animal pasturing, recycling, etc. (Straskraba and Tundisi, 2000). Tropical reservoirs are special aquatic ecosystems in which physical, chemical and biological characteristics are strongly controlled by the input of water from rivers and periodic dewatering (Thornton *et al.*, 1990). The study of the phytoplankton community in reservoirs has attracted much attention from researchers as an indicator of changes in the trophic-dynamic conditions of these ecosystems (De Bernardi, 1984). According to Tundisi (1999), the study of dynamic systems such as reservoirs has contributed greatly to the understanding of basic questions in the field of ecology, such as succession in communities, colonization patterns and pulse effects. Numerous

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studies have shown that the analysis of phytoplankton is fundamental to the biological monitoring of these systems, furnishing basic information regarding the establishment of norms for water quality control (Sant'Anna *et al.*, 1997). Studies on reservoirs have generally dealt with the structural and behavioral composition of the phytoplankton community, with focus on taxonomic surveys and ecological studies. In Brazil, most studies on reservoirs have been carried out in the South and Southeast regions (Calijuri and Dos Santos, 2001; Figueredo and Giani, 2001; Calijuri *et al.*, 2002; Marinho and Huszar, 2002; Henry *et al.*, 2006) and are mainly about seasonal and circadian variations, with only a few addressing short-term periods. Very few work has been developed on reservoirs in the Northeastern region; Chellapa et al. (1990; 1998) and Costa et al. (2006) conducted studies in the state of Rio Grande do Norte; Bouvy et al. (2000), Bouvy et al. (2001), Falcão et al. (2002) and Bouvy et al. (2003) conducted studies in the state of Pernambuco.

Considering the importance of phytoplankton studies in reservoir ecosystems, the aim of the present study was to analyze the phytoplankton community of the Botafogo reservoir (Pernambuco, Brazil), characterizing the structure and biota dynamics as well as interactions with abiotic factors.

MATERIAL AND METHODS

The Botafogo Reservoir is part of the water supply system of the state of Pernambuco, Brazil and is located in the district of Igarassu (07º53'02"S 35º03'32"W (Fig.1). It is important for irrigation and fishing activities. The reservoir has high accumulation capacity ($28.8 \times 10^6 m^3$) and is located in a humid climate region with total annual precipitation greater than 1000mm. There are two well-defined seasons in this region: the rainy season (March to August) and the dry season (September to February).

Two sampling stations were established in the pelagic zone of the reservoir: Station 1 (7º50'23"S and 35º01'50"W) and Station 2 (7º50'37"S and 35º02'20"W) (Fig.1). Samples for nutrient and biological analysis were collected from the subsurface using a recipient with a large overture. Further samples were collected from the bottom with a Van Dorn bottle. Samplings were carried out for seven consecutive days during both the rainy season (July 2003) and dry season (January 2004), in which six days were used as replicas of the first. Water transparency was determined with a 25-cm diameter Secchi disk. A field probe was used to determine water temperature (T°C), total dissolved solids (TDS mg.L^{-1}), electrical conductivity (μS.cm^{-1}), dissolved oxygen (mg.L^{-1}), turbidity (NTU) and pH. Total nitrogen (μg.NT.L^{-1}) and total phosphorus (μg.PT.L^{-1}) levels were determined using the method described by Valderrama (1981). Samples for taxonomic analyses were preserved in formaldehyde 4% and identification performed using an optical microscope (Zeiss/Axioskop) down to the species level or to the highest possible taxonomic resolution using the relevant literature (Round *et al.*, 1990; Sant'Anna, 1984; Komarék and Foot, 1983; Komárek and Anagnostidis, 1999; Komárek and Anagnostidis, 2005). Aliquots of 100 mL of water were collected daily from the reservoir and preserved in acetic Lugol's solution for the determination of cellular density (Cel.L^{-1}) according to the Utermöhl method (Utermöhl, 1958).

The Diversity Index was calculated using the Shannon and Wiener Index (Shannon and Weaver, 1948), considering:

$$H' = - \Sigma \, pi \, . \, \log_2 pi, \text{ where } pi = Ni / N$$

Ni = number of individuals of each species and **N** = total number of individuals. The results were expressed in bits.cel^{-1}.

Equitability (*J*) was calculated with Shannon and and Wiener index, Shannon and Weaver, 1948. Variance (ANOVA) was calculated for each sampling station, depth and season, with significance set at 5% and using BioEstat 3.0 (Ayres *et al.,* 2003) with significance set at 5% and 1%.

All environmental variables and the abundant species in either sampling unit for the two periods analyzed were considered in the principal component analysis (PCA), using the NTSYS program, version 2.1 for Windows, 2000.
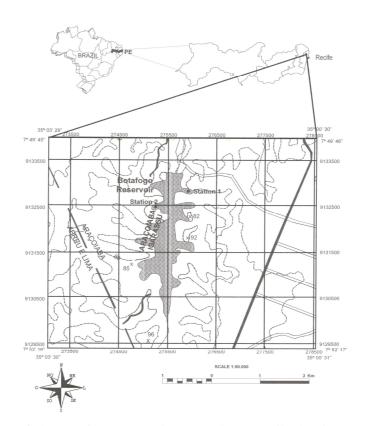
Figure 1 - Map of the Botafogo Reservoir, Pernambuco-Brazil, showing sampling stations.
Source: Technology Institute of Pernambuco.

RESULTS

Limnological variables
Table 1 displays the mean values of the physico-chemical variables at both sampling stations during dry and wet seasons. Significant differences were observed between the two seasons for all abiotic variables (p<0.01), except total phosphorus (p>0.05) (Table 2).

Dissolved oxygen, total nitrogen and turbidity were lower during the dry season (Table 1). Water transparency, water temperature, pH, electric conductivity and total dissolved solids were higher in the dry season, but there were no clear pattern of variation between vertical or horizontal sampling stations. Temperature exhibited differences between depths (p<0.05) at both sampling stations and in both climatic seasons (Tables 1 and 2).

Table 1 - Mean values of the physical and chemical variables of the Botafogo Reservoir, Pernambuco State, Brazil at sampling stations S_1 e S_2 at the subsurface and bottom during the dry and rainy seasons. (S1S): Station 1 Subsurface; (S1B): Station 1 Bottom; (S2S): Station 2 Subsurface; (S2B): Station 2 Bottom.

Variables (Mean values)	Rainy season				Dry season			
	S1S	S1B	S2S	S2B	S1S	S1B	S2S	S2B
Secchi disk (m)▲	0.84	-	0.84	-	1.30	-	1.30	-
Dissolved Oxygen (mg.L⁻¹) ▲	3.51	3.19	3.35	3.20	0.85	0.82	1.20	1.03
Water temperature (°C) ▲	27.30*	26.80	27.00*	26.90	30.00**	29.30	30.40**	29.60
pH▲	6.36	6.20	6.41	6.29	6.60	6.50	6.69**	6.37
Total dissolved solids (mg.L⁻¹) ▲	54.10	55.10	55.10	55.40	58.00	58.20	58.70	58.70
Electric conductivity (µS.cm⁻¹) ▲	54.40	55.30	55.10	55.60	58.30	58.40	58.90	58.90
Turbity (NTU) ▲	18.10	18.40	18.20	20.60	4.70	4.90	4.70	4.40
Total nitrogen (µg.L⁻¹) ▲	3.70	2.71	1.70	2.73	0.36	-	-	-
Total phosphorus (µg.L⁻¹)	111.40*	117.10	112.80	114.20	110.00	117.10	110.00**	117.10

▲Difference between seasonal periods (p<0.01); Difference between depths: *p<0.05, **p<0.01

Table 2 - Results from ANOVA for the assessment of temporal and spatial differences of abiotic variables in the Botafogo Reservoir, Pernambuco State, Brazil.

Variables	Depths								Season				Periods	
	Rainy				Dry									
	Station 1		Station 2		Station 1		Station 2		Rainy		Dry			
	F	p	F	p	F	p	F	p	F	p	F	P	F	p
Dissolved oxygen	1.99	0.184	0.65	0.436	0.00	0.947	0.14	0.717	0.27	0.611	0.63	0.436	148.01	0.000
Water temperature	8.24	0.014	7.66	0.017	36.48	0.000	50.94	0.000	0.15	0.703	5.53	0.027	542.93	0.000
pH	2.20	0.164	3.00	0.109	1.29	0.278	10.11	0.008	1.04	0.318	0.14	0.713	17.58	0.000
Total dissolved solids	1.18	0.299	0.18	0.675	0.22	0.646	0.00	1.000	1.30	0.265	2.42	0.132	103.31	0.000
Eletric condutivity	1.18	0.299	0.43	0.522	0.00	0.962	0.00	0.972	0.77	0.389	2.69	0.113	118.99	0.000
Turbity	0.09	0.773	1.11	0.313	0.93	0.355	0.81	0.385	0.91	0.349	1.40	0.247	525.22	0.000
Secchi disk	-	-	-	-	-	-	-	-	0.12	0.739	0.01	0.912	127.76	0.000
Total nitrogen	1.68	0.219	3.47	0.087	1.74	0.212	*	*	4.04	0.055	1.65	0.211	94.70	0.000
Total phosphorus	6.00	0.031	0.27	0.611	2.88	0.115	15.00	0.002	0.14	0.712	0.00	1.000	0.05	0.823

Legends: * : Data missing, - : Analysis not applied.

Species Composition

Twenty four taxa were identified in the Botafogo Reservoir from the following divisions: Chlorophyta (*Chlorella vulgaris* Beijerinck, *Eudorina elegans* Ehrenberg, *Golenkinia radiata* Chodat, *Kirchneriella lunaris* (Kirchner) Möbius, *Monoraphidium arcuatum* (Korshikov) Bourelly, *Planktosphaeria gelatinosa* G. M. Smith*, Sphaerocystis planctonica* (Korshikov) Bourelly, *Staurastrum leptocladum* Nordstedt, *Staurastrum paradoxum* Meyen*, Tetraedrum victorae* Wolosynka), Cyanophyta (*Aphanocapsa* sp., *Chroococcus limneticus* Lemmermann, *Chroococcus minutus* Kützing, *Chroococcus turgidus* Kützing, *Geitlerinema amphibium* (Agardh ex Gomont) Anagnostidis, *Merismopedia punctata* Meyen, *Microcystis aeruginosa* (Kützing) Kützing, *Microcystis incerta* (Lemmermann) Emend. Starmach and *Oscillatoria* sp.), Euglenophyta (*Euglena* sp. and *Trachelomonas volvocina* (Ehrenberg), Bacillariophyta (*Aulacoseira granulata* (Ehrenberg) Simonsen, Dinophyta (*Peridinium gatunense* Nygaard) and Chrysophyta (*Mallomonas* sp.).

Density

Total density varied from 4.96 x 10^4 cel.L^{-1} (Station 2 Bottom - Dry season) to 47.75 x 10^4 cel.L^{-1} (Station 1 Subsurface - Rainy season).

Higher densities of Euglenophyta and Chlorophyta were observed in detriment to the Cyanophyta. Among the Euglenophyta, *Trachelomonas volvocina* was responsible for 82% and 24% of the total density of algal species in the rainy and dry seasons, respectively. In the rainy season, *T. volvocina* density varied according to depth, with higher density found at the subsurface. The highest densities of these algae coincided with higher rainfall periods (Fig. 2). *Peridinium gatunense* and *Chlorella vulgaris* presented high densities during the rainy season and *Planktosphaeria gelatinosa* presented high densities during the rainy season only at the subsurface of Station 2. During the dry season, *T. volvocina* density was higher at the subsurface at both samplings stations (Fig. 2).
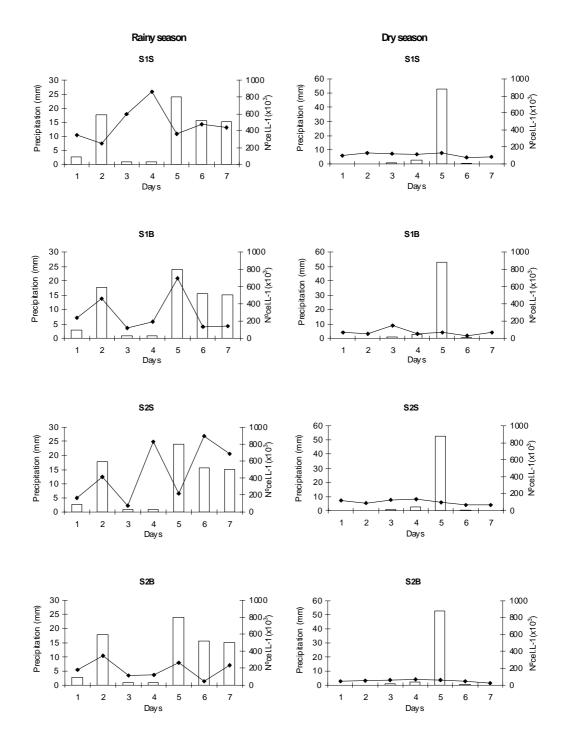
Rainy season

Dry season

Figure 2 - Precipitation and total density of phytoplankton, in the sampling stations, at the rainy (and dry seasons, in the Botafogo reservoir-PE. (S1S): Station 1 Subsurface; (S1B): Station 1 Bottom; (S2S): Station 2 Subsurface; (S2B): Station 2 Bottom.

Specific Diversity and Equitability
Species diversity was consistently low at all sampling stations (Table 3) and during both the rainy and dry seasons, indicating that the phytoplankton community was formed by a relatively small number of species, among which one or two species exhibited high densities. During the rainy season, *T. volvocina* was the dominant species, whereas in the dry season, *P. gelatinosa* and *S. planctonica* were also encountered at high densities.

Equitability was low in the rainy season, with values under 0.5 (exception for the bottom of Station 2, which was 0.62). Thus, the number of individuals was not well distributed among the different species. During the dry period, equitability values were above 0.5, indicating a more even distribution of individuals among the different species (Table 3).

Table 3 - Specific diversity index and equitability values, in the sampling stations at the rainy and dry seasons, in the Botafogo Reservoir-PE. (S1S): Station 1 Subsurface; (S1B): Station 1 Bottom; (S2S): Station 2 Subsurface; (S2B): Station 2 Bottom.

Sampling Date	Specific Diversity (bits.cel.$^{-1}$)				Equitability			
Rainy Season (Days)	**S1S**	**S1B**	**S2S**	**S2B**	**S1S**	**S1B**	**S2S**	**S2B**
07/07/03	0.288	0.545	0.455	0.788	0.109	0.207	0.172	0.299
07/08/03	0.436	0.341	0.417	0.506	0.165	0.129	0.158	0.192
07/09/03	0.491	0.631	1.143	0.779	0.186	0.239	0.433	0.295
07/10/03	0.426	0.826	0.763	0.837	0.161	0.313	0.289	0.317
07/11/03	0.976	0.647	1.031	0.775	0.370	0.245	0.391	0.294
07/12/03	0.581	0.832	0.594	1.631	0.220	0.315	0.225	0.618
07/13/03	0.657	0.889	1.090	0.643	0.249	0.337	0.413	0.243
Dry Season	**S1S**	**S1B**	**S2S**	**S2B**	**S1S**	**S1B**	**S2S**	**S2B**
01/12/04	1.637	1.673	1.611	1.597	0.522	0.534	0.514	0.509
01/13/04	1.745	1.484	1.562	1.690	0.557	0.473	0.498	0.539
01/14/04	1.709	1.001	1.688	1.253	0.545	0.319	0.538	0.400
01/15/04	1.841	1.740	1.759	1.870	0.587	0.555	0.561	0.596
01/16/04	1.661	1.696	1.724	1.794	0.530	0.541	0.550	0.572
01/17/04	1.734	1.768	1.601	1.897	0.553	0.564	0.511	0.605
01/18/04	1.964	1.979	1.852	1.797	0.626	0.631	0.591	0.573

In the principal component analysis, the eigenvalues from the axes 1 and 2 explained 54.52% of data variability. Figure 3 displays the spatial projection of variables. Component 1 explained 43.01% of the data variance, demonstrating that the presence of *T. volvocina*, *Chlorella vulgaris*, *Euglena* sp. and *P. gatunense* was directly correlated with oxygen, turbidity, total nitrogen and was inversely correlated with water temperature, total dissolved solids, conductivity, transparency and pH. Component 2 explained 11.51% of the variation, indicating that the presence of *P. gelatinosa, P. gatunense* and *Euglena* sp. was directly related to total nitrogen and inversely correlated with rainfall. Rainfall explained the occurrence of *Monoraphidium arcuatum* and *C. vulgaris*.
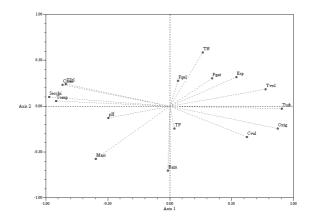

Figure 3 - Order of the principal components in Axes 1 and Axes 2. Tvol: *T. volvocina,* P.gat: *Peridinium. gatunense*, Pgel.: *P. gelatinosa,* Marc*.: M. arcuatum,* Cvul*.: C. vulgaris,* Esp.: *Euglena* sp., Cond.: Condutivity, Oxig.: Dissoved Oxygen, Temp.: Water Temperature, Turb.: Turbity, TDS: Total Dissolved Solids, Rain.: Rainy, TN: Total Nitrogen, TP: Total Phosphorus, Secchi: Secchi disk.

DISCUSSION

In the Botafogo Reservoir, a significant presence of the Chlorophyta was determined during both the rainy and dry seasons, which was in agreement with results frequently reported for other reservoirs (Ramirez and Diaz 1994; Falcão *et al.*, 2002 and Tucci and Sant'Anna, 2003). The predominance of Chlorophyta could be attributed to the alkaline pH, as many Chlorococcales species seemed to prefer shallow waters with low transparency, such as in eutrophic lacustrine ecosystems that have been altered through anthropogenic activities (Sant'Anna and Martins, 1982). Although the Botafogo Reservoir did not reach alkaline pH values, the other environmental conditions cited by these authors were in fact encountered during the monitoring period, principally during the dry season when diversity was higher.

The high total density of algae observed during the rainy season (with a major contribution by *T. volvocina*) is related to the increased turbidity of the water during the period. Temporal variations in phytoplankton densities in tropical lakes are mainly controlled by the availability of nutrients and below-subsurface radiation (Esteves, 1998). These factors are, in turn, influenced by both external (wind, rain and incident radiation) and internal conditions (turbulence, stratification and mixing of the water column, as well as decomposition rates).

Characteristics observed in the Botafogo Reservoir seemed to indicate that the phytoplankton community was in an early successional stage. The association between the presence of *T. volvocina* and oxygen observed in the present study agreed with results found by John et al. (2002)*,* who observed the presence of this species principally in ecosystems with low oxygen concentrations.

The positive correlation of *T. volvocina* and *C. vulgaris* with total nitrogen corroborated observations by Pômpeo (1996), who suggested that nitrogen was the main limiting factor to phytoplankton primary productivity in the reservoir of Lobo-SP. The relationship between turbidity and *T. volvocina* and *C. vulgaris,* as indicated by PCA, did not seem to be a limiting factor in the distribution of these species, as both was mobile: *T. volvocina* possesses flagella; and Wetzel (1993) observed that chlorophytes such as

C. vulgaris had drops of oil encrusted on their mucilaginous girdles, which gave them buoyancy. The higher microalgae diversity observed during the rainy season, mainly within the Chlorophyta division, was associated with low pH levels, with a consequent increase in dissolved CO_2. It was also associated with the human activities near the reservoir. As the Botafogo reservoir is situated in an area with an intense sugar cane mono-culture, the hypertrophic state observed is certainly a direct reflection of these activities in the reservoir floodplain.

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RESUMO

O objetivo do presente estudo foi investigar a estrutura e dinâmica do fitoplâncton no reservatório de Botafogo-PE-Brasil. A comunidade fitoplanctônica foi identificada com literatura atualizada e a densidade estimada usando microscópio invertido. Concomitantemente as coletas das variáveis bióticas, foram medidos alguns parâmetros abióticos como temperatura da água, oxigênio dissolvido, condutividade e pH usando sondas de campo e transparência com disco de Secchi. Concentrações de fósforo total e nitrogênio total foram determinados em laboratório. Vinte e quatro táxons foram identificados tendo Chlorophyta apresentado maior número de espécie. A diversidade de espécie no reservatório foi baixa durante todo o período de estudo. A análise de componentes principais mostrou que *Trachelomonas volvocina*, *Chlorella vulgaris*, *Euglena* sp. e *Peridinium gatunense* esteve diretamente correlacionada com oxigênio dissolvido, turbidez e nitrogênio total. *P. gelatinosa*, *Peridinim gatunense* e *Euglena* sp. estiveram diretamente relacionada com nitrogênio total; a chuva explicou a ocorrência de *Monoraphidium arcuatum* e *Chlorella vulgaris*.

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