DOI: http://dx.doi.org/10.1590/1519-6984.21912

Influence of fish farming in net cages on phytoplankton structure: a case study in a subtropical Brazilian reservoir

Bartozek ECR.[a]*, *Bueno NC.*[a,b] *and Rodrigues LC.*[c]

[a]Programa de Pós-graduação em Recursos Pesqueiros e Engenharia de Pesca, Universidade Estadual do Oeste do Paraná – UNIOESTE, Rua da Faculdade, 645, Jardim Santa Maria, CP 320, CEP 85903-000, Toledo, PR, Brasil
[b]Programa de Pós-graduação em Conservação e Manejo de Recursos Naturais, Universidade Estadual do Oeste do Paraná – UNIOESTE, Rua Universitária, 2069, Jardim Universitário, CEP 85819-110, Cascavel, PR, Brasil
[c]Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura, Universidade Estadual de Maringá – UEM, Av. Colombo, 5790, Bl. H-90, CEP 87020-900, Maringá, PR, Brasil
*e-mail: elaine.bartozek@gmail.com

Received: October 2, 2012 – Accepted: January 8, 2013 – Distributed: February 28, 2014
(With 6 figures)

Abstract

This study investigated the enrichment influence due to fish farming in net cages on the phytoplankton composition, density and diversity in two arms of a subtropical reservoir (Salto Caxias, Paraná). There were no statistically significant differences in the phytoplankton composition and diversity, as well as for concentrations of nutrients among the handled treatment. The density values were higher during the summer. Richness and Shannon diversity values were low during the study period. The equitability values were high during the winter and low in the summer. Variations of phytoplankton community and nutrients were mainly influenced by seasonality. The absence of significant differences between the treatments was probably due to the small number of net cages and fish used, as well as to the hydrodynamics of the studied environments, which are influenced by upstream rivers inflows.

Keywords: phytoplankton, community structure, net cages, hydrodynamics's effect.

Influência do cultivo de peixes em tanques-rede sobre a estrutura do fitoplâncton: estudo de caso em um reservatório subtropical brasileiro

Resumo

Este estudo investigou os efeitos do enriquecimento devido ao cultivo de peixes em tanques-rede sobre a composição, densidade e diversidade fitoplanctônica em dois braços de um reservatório subtropical (Salto Caxias, Paraná). Não foram registradas diferenças significativas para a composição e diversidade fitoplanctônica e para as concentrações de nutrientes entre os tratamentos utilizados. A densidade foi maior durante o verão. Os valores de riqueza de espécies e diversidade de Shannon foram baixos durante todo o período de estudo. A equitabilidade foi elevada no inverno e baixa no verão. As variações da comunidade fitoplanctônica e dos nutrientes parecem ter sido influenciadas principalmente pela sazonalidade. A ausência de diferenças significativas entre os tratamentos, provavelmente se devem ao pequeno número de tanques e peixes utilizados, e à hidrodinâmica dos ambientes estudados, os quais são influenciados pelos influxos dos rios à montante.

Palavras-chave: fitoplâncton, estrutura da comunidade, tanques-rede, efeitos da hidrodinâmica.

1. Introduction

In Brazil, fish cultivation in net cages is a relatively recent activity that started in the 1980s, been introduced in the country, mainly, to generate employment and income, and has been growing substantially in recent years and also receiving governmental incentives (Alves and Baccarin, 2007; Ayrosa et al., 2008).

During intensive cultivation in net cages, large amounts of organic matter, from feedstuffs used in feeding and from fish excreta, are directly released in the aquatic environment (Alves and Baccarin, 2007; Santos et al., 2009). Such activity can increase the concentration of nitrogen and phosphorus in the water column, leading to the eutrophication of the system (Diaz et al., 2001; Figueredo and Giani, 2005; Alves and Baccarin, 2007).

The eutrofization promotes changes in the trophic web and in the balance of aquatic communities, a decrease in phytoplankton diversity and fosters the heavy growth of some species (Crossetti et al., 2008; Borges et al., 2010). As a result of nutrient load, an increase in phytoplankton proliferation, particularly Cyanobacteria, has been recorded and it represents a growing problem in ecosystems such as reservoirs (Borges et al., 2010).

Therefore, phytoplankton community is an important tool in the diagnosis of environmental conditions as it readily responds to impacts on the aquatic environment, resulting in changes in its structure (Diaz et al., 2001; Lachi and Sipaúba-Tavares, 2008). Such changes may be caused by variations in nutrient availability, changes in water retention time and light availability (Kimmel et al., 1990; Nogueira, 2000; Borges et al., 2008; Teixeira de Oliveira et al., 2011).

In tropical and subtropical regions, seasonal changes, mainly the ones related to variations in rainfall, induce physical and chemical changes in water (Figueredo and Giani, 2001) and it can become the main responsible for changes in phytoplankton dynamics (Huszar and Reynolds, 1997). In reservoirs, in addition to seasonal variations in water level, other factors must also be considered, such as the natural nutrients inputs from the affluents associated to the fish cultivation which can accelerate the eutrophication process in the system (Nogueira, 2000; Diaz et al., 2001).

In despite of numerous studies on phytoplankton dynamics in Brazilian reservoirs, studies about the effects of fish cultivation in net cages on this community are still poor. Therefore, this study aimed to evaluate the changes in diversity components of this community according to an experimental cultivation of two species of Siluriformes, silver catfish (*Rhamdia voulezi* Haseman, 1911) and surubim of Iguaçu (*Steindachneridion melanodermatum* Garavello, 2005), in net cages in an arm of Salto Caxias reservoir, Paraná.

We tested the hypotheses that the cultivation system of Siluriformes (i) increases the nutrient concentration in the affected areas, (ii) decreases the taxonomic complexity (composition) of phytoplankton community, (iii) increases the density, and (iv) reduces species richness, evenness and Shannon-Wiener diversity.

2 Material and Methods

The Iguaçu River is formed by the union of Irai and Atuba rivers in Curitiba city, and travels around 1,320 km following its course to debouch on Paraná River, in the city of Foz do Iguaçu (Paraná, 2010). Salto Caxias reservoir (25º 33' S; 53º 30' W) is the last of a series of five large impoundments which regulate the flow of Iguaçu River. The construction of the dam began in 1995 and its operation in 1999 (Copel, 2011). The reservoir is considered a trickle, it has 142 km^2 of surface area and 3,573 km^3 of volume (Comitê Brasileiro de Barragens, 2011). Water residence time is estimated in 32.5 days and shows a dendritic pattern of margin development (Ribeiro et al., 2005).

The region's climate is classified as humid subtropical (Cfa), with well defined seasons along the year. Rainfall is usually well spread throughout the year; however it is fewer in autumn and winter (dry season) than in spring and summer (rainy season). The average annual rainfall is from 1,600 to 1,800 mm and the average annual temperature is 19-20° C (Maak, 2002).

This study was carried out in two side arms located on the right-hand margin of the reservoir's transition region (Figure 1), in the city of Boa Vista da Aparecida, Paraná.

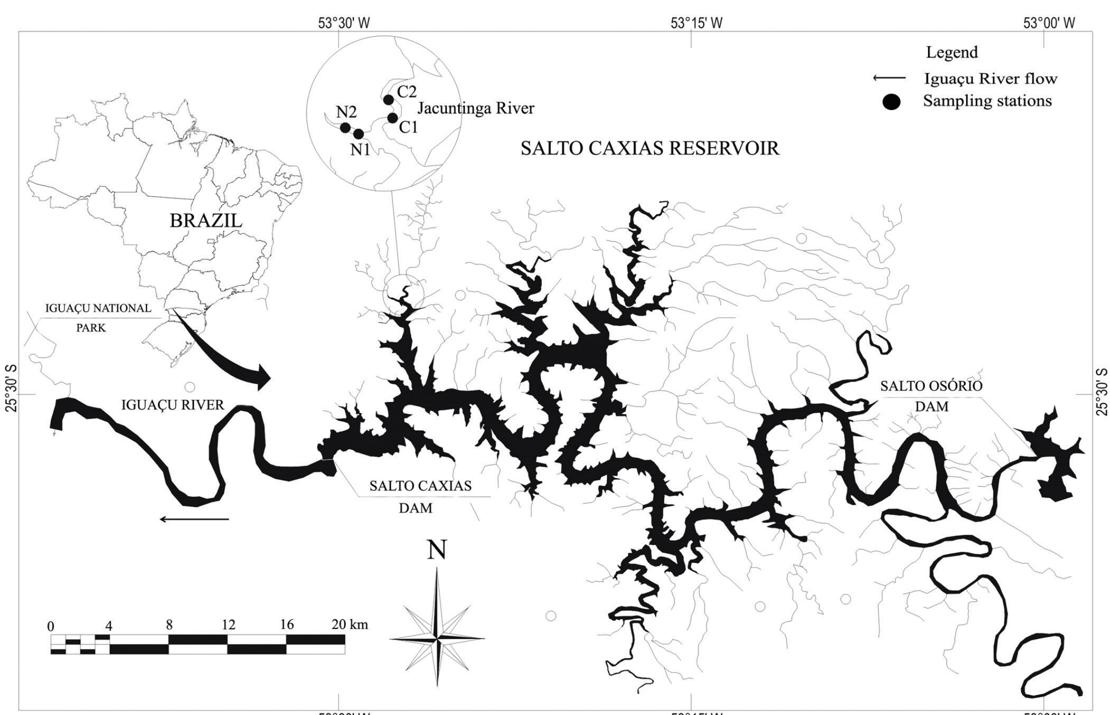

Figure 1. Salto Caxias reservoir with the location of sampling stations. Codes available in Table 1.

The larger arm is comprised by the Jacutinga River and the smaller one by an unnamed stream. The area surrounding the reservoir is dominated by grasslands and small areas of secondary forest (Júlio Júnior et al., 2005) with small rural properties and the predominance of family farming (Lima et al., 2005). Aquatic macrophytes were not observed during the study period.

The net cages (30) were arranged in the smaller arm in three sets of ten a year before the beginning of this experiment. In each 4 m^3 net cage 60 adult fish of the species *Rhamdia voulezi* (silver catfish) and *Steindachneridion melanodermatum* (surubim do Iguaçu) were placed. The second arm, comprised by the Jacutinga River, was considered without influence of the net cages.

The silver catfish is a neotropical species, found from Southeast Mexico to the central region of Argentina (Urbinati and Gonçalves, 2005). Surubim do Iguaçu is an endemic species, restricted to the lower level of Iguaçu River (it appears only downstream of Segredo reservoir) and it is considered at risk of extinction (Feiden et al., 2006). In order to feed the fish, commercial ration of extruded type has been used. Feeding management was established by the technique of supply *ad libidum* and was adjusted by using the method of entire food consumption observation in the first hour after the supply. Fish received food twice a day (morning and afternoon).

Samplings of phytoplankton and abiotic variables were performed in the pelagic zone of the two arms bimonthly from September 2010 to July 2011. Two sampling stations were established beside the net cages (N1 and N2) and 200 m apart from each other; two other stations were established in the cageless arm (C1 and C2) and also 200 m apart from each other. In September 2010 there was no sampling at the station C2.

Environmental variables were obtained simultaneously to the collections of the phytoplankton and included water temperature (T_w) and dissolved oxygen (DO). Euphotic zone (Z_{eu}) was estimated as 2.7 times the extinction depth of Secchi disk (Cole, 1994). The ratio between the euphotic zone and the maximum zone (Z_{eu}:Z_{max}) was estimated by the ratio between the euphotic zone and the maximum depth.

Turbidity (Turb), pH and concentrations of dissolved total phosphorus (P-DTP; Mackereth et al. (1978)), soluble reactive phosphorus (P-SRP; Mackereth et al. (1978)), nitrite (N-NO_2^-; Strickland and Parsons, 1972) and ammonium (N-NH_4^+; Koroleff, 1976) were determined. The sum of the latter two (dissolved inorganic nitrogen - N-DIN) was used for the analyses.

The wind speed values (Win), air temperature (T_a) and precipitation (Pre) were provided by the Meteorological Institute of Paraná (Simepar) and records used were obtained from Salto Caxias station, located in the city of Capitão Leonidas Marques. In statistical and multivariate analyzes the sum of the three days preceding the sampling was used for rainfall.

Samples of phytoplankton community were collected in the subsurface and fixed with 1% acetic lugol solution. In addition, samples were obtained with plankton net with 25 mm aperture, with the purpose of concentrating the material and assisting in taxonomic analysis. These samples were preserved in Transeau solution (Bicudo and Menezes, 2006) and the classification system adopted for class was the Round (1965, 1971) proposed by Bicudo and Menezes (2006). The framing of Cyanobacteria taxa was based on Komárek and Anagnostidis (1989, 1998, 2005).

Phytoplankton density was determined according to the methodology described by Utermöhl (1958), with analysis of samples under inverted microscope. The count of fields was held at random using the criteria of minimum area (100 fields) or until achieving species curve of rarefaction. The phytoplanktonic density was performed according to the American Public Health Association - APHA (1995) and the result, expressed in individuals (cells, coenobium or colonies) per milliliter.

The attributes evaluated for phytoplankton community were composition, species richness (tax number per quantitative sample), density (ind.ml^{-1}), evenness (E; Pielou, 1966) and Shannon-Wiener diversity (bits.$ind.^{-1}$) (*H'*; Shannon and Weaver, 1963). The frequency of species was calculated from the percentage of occurrence in quantitative samples.

Abiotic variables were synthesized using a Principal Components Analysis (PCA) and significant axes were selected according to the Broken Stick criteria (Jackson, 1993). A variance analysis (two-way ANOVA) was applied to test significant differences for the values of nutrients (P-SRP, P-DTP and N-DIN) in different treatments (sampling stations - factor 1) and collection seasons (dry and rainy seasons - factor 2). Assumptions of normality and homoscedasticity of ANOVA were evaluated by Shapiro-Wilk and Levene tests, respectively. When significant differences were identified ($p < 0.05$), the Tukey test was applied *a posteriori*.

To summarize phytoplankton composition data, the Detrended Correspondence Analysis (DCA – Gauch Junior (1986); Jongman et al. (1995)) was used by referring to a table with presence (1) and absence (0) of species in the different stations and sampling seasons. To test for significant differences in species composition between stations and sampling seasons, a variance analysis (two-way ANOVA) was applied from the scores of the two first axes of the DCA, species richness, density, evenness and Shannon diversity.

To assess the influence of abiotic variables on the composition of phytoplankton community, Spearman's Correlation Analysis was performed between the variables with the highest structure coefficient obtained from the PCA, and the values of species richness, density, evenness and Shannon diversity. Correlations considered significant were those where $p < 0.05$. For the variance analysis and Spearman's Correlation the sofware Statistica 7.1 was used (StatSoft Inc., 2005). To estimate the values of species richness, evenness, Shannon diversity and multivariate analysis (PCA and DCA) the software used was Pc-Ord 4.0 (MacCune and Mefford, 1999).

3. Results

The highest precipitation levels were registered in summer (December 2010 and January-February 2011), and the lowest levels occurred at the end of autumn (May-June 2011) (Figure 2). In July 2011 occurred high values of precipitation prior to sampling (Table 1), despite of this being a month of drought.

The extension of the euphotic zone achieved almost the whole water column during most part of the season, as depicted from values of Z_{eu}:Z_{max} (Table 1). Air and water temperatures were higher in January and March 2011. Dissolved oxygen values were similar between the stations and sampling periods, with the highest values observed in July 2011, together with the lowest values of air and water temperature. Turbidity was higher in November 2010 in all stations.

The pH showed values close to neutrality during the study period, and the lowest values were observed in

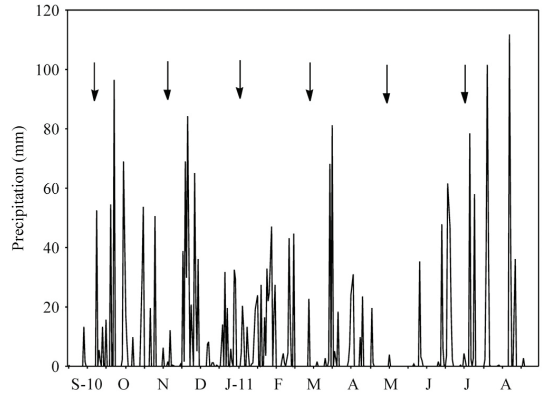

Figure 2. Daily values of precipitation recorded at Salto Caxias reservoir from September 2010 to August 2011. Arrows indicate the dates of collections. Codes available in Table 1.

Table 1. Values of precipitation - Pre (mm); wind speed - Win (m.s^{-1}), depth - Dep (m), euphotic zone - Z_{eu} (m), euphotic zone:maximum zone ratio - Z_{eu}:Z_{max}, air temperature - T_a (°C), water temperature - T_w (°C), dissolved oxygen - DO (mg.l^{-1}), turbidity - Turb (NTU), soluble reactive phosphorus - P-SRP (µg.l^{-1}), dissolved total phosphorus - P-DTP (µg.l^{-1}) and dissolved inorganic nitrogen - N-DIN (µg.l^{-1}) recorded in the four sampling stations in the two arms of Salto Caxias reservoir, from September 2010 to July 2011. Mean values by location and sampling time, and variation coefficient (CV) for the entire period. (N1 and N2: samples stations with net cages; C1 and C2: samples stations without net cages; Sep-September, Nov-November, Jan-January, Mar- March, May, Jul-July).

Stations	Pre	Win	Dep	Z_{eu}	Z_{eu}:Z_{max}	T_a	T_w	DO	Turb	pH	P-SRP	P-DTP	N-DIN
N1													
Sept	0.0	2.7	9.6	9.6	1.0	20.0	23.9	6.7	2.1	7.1	24.2	47.7	23.3
Nov	50.8	2.0	9.9	7.9	0.8	21.1	23.5	6.3	3.1	7.1	8.7	50.4	20.1
Jan	62.2	1.9	9.9	9.9	1.0	24.8	28.2	5.6	0.3	7.3	3.8	35.2	17.6
Mar	0.0	2.9	10.7	9.3	0.9	24.4	28.5	6.3	0.8	7.6	0.5	8.9	33.1
May	0.2	1.7	11.2	8.0	0.7	19.3	24.2	5.9	1.2	7.2	0.5	28.6	46.0
Jul	81.0	2.1	7.8	7.1	0.9	19.4	20.0	7.5	0.0	7.3	3.8	24.7	16.8
N2													
Sept	0.0	2.7	6.5	6.5	1.0	20.0	21.5	6.7	1.7	7.0	25.0	45.5	15.2
Nov	50.8	2.0	4.2	4.2	1.0	21.1	23.9	6.2	2.6	7.1	13.6	58.0	26.6
Jan	62.2	1.9	4.2	4.2	1.0	24.8	28.7	6.5	0.8	7.3	4.6	34.8	21.4
Mar	0.0	2.9	5.2	5.2	1.0	24.4	28.0	5.6	0.4	7.5	2.2	7.9	54.3
May	0.2	1.7	5.5	5.5	1.0	19.3	24.4	6.1	0.9	7.1	1.3	6.9	21.5
Jul	81.0	2.1	5.5	5.5	1.0	19.4	19.7	7.5	0.0	7.2	3.0	2.2	21.7
C1													
Sept	0.0	2.7	10.8	10.8	1.0	20.0	23.3	6.2	2.2	6.2	20.9	62.8	11.1
Nov	50.8	2.0	9.4	8.9	1.0	21.1	24.4	6.2	6.2	7.2	8.7	63.8	21.7
Jan	62.2	1.9	9.4	7.3	0.8	24.8	29.1	7.0	0.7	7.7	4.6	79.9	14.5
Mar	0.0	2.9	10.9	10.9	1.0	24.4	28.1	5.7	0.8	7.0	4.6	12.6	47.8
May	0.2	1.7	10.6	9.2	0.9	19.3	24.0	5.6	1.1	7.3	0.5	54.8	29.6
Jul	81.0	2.1	10.6	7.8	0.7	19.4	20.7	7.4	0.0	7.3	3.8	49.3	30.7
C2													
Nov	50.8	2.0	8.0	8.0	1.0	21.1	24.8	6.3	6.3	7.2	4.6	43.4	21.7
Jan	62.2	1.9	6.3	6.1	1.0	24.8	29.6	6.5	0.4	7.4	4.6	42.9	22.2
Mar	0.0	2.9	4.0	4.0	1.0	24.4	29.0	5.1	1.4	7.1	4.6	53.1	74.7
May	0.2	1.7	5.6	5.6	1.0	19.3	25.2	6.1	0.8	7.1	0.5	26.5	13.4
Jul	81.0	2.1	5.6	4.1	0.7	19.4	20.8	7.4	2.6	6.3	7.0	2.8	16.8
CV (%)	101.4	19.4	32.3	30.5	11.3	10.9	12.7	10.3	108.0	4.8	56.5	107.5	60.2

stations C1 and C2 in September 2010, and C2 in July 2011. N-DIN concentrations were slightly higher in summer, and the largest values were observed in March. Turbidity, P-SRP, rainfall and N-DIN were the abiotic variables with the highest coefficients of variation over the study period.

The two-way ANOVA showed that the nutrients concentration (P-SRP, P-DTP and N-DIN) showed no significant variations between treatments (stations with and without net cages). However, significant differences were found, considering the sampling periods. In March 2011, there were significant differences compared to the level recorded in other months for the P-SRP values ($F = 16.14$, $p = 0.0001$) and N-DIN ($F = 19.77$, $p = 0.0001$). Considering the P-DTP, September 2010 showed significant differences compared to other months ($F = 78.85$, $p = 0.0001$).

The Principal Components Analysis (PCA) explained 50.2% of the total data variability (Figure 3). The score dispersion of places and sampling periods showed a temporal gradient, splitting summer and winter in the diagram,

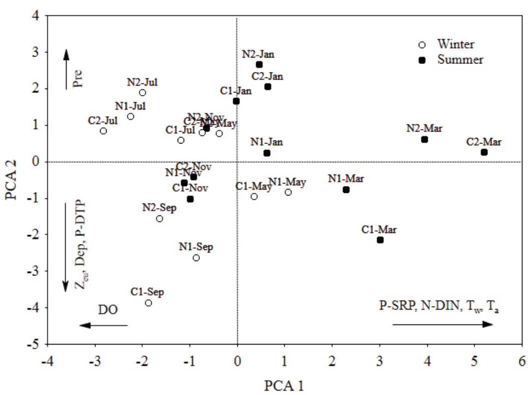

Figure 3. Score dispersion of locations and sampling periods along the first two axes of Principal Components Analysis (PCA), performed for the abiotic variables in the two arms of the Salto Caxias reservoir. Codes available in Table 1.

being November 2010 and May 2011 in the intermediate position. No evident spatial differences were observed.

The first axis of PCA, which explained 32.2% of the data variability, separated the sites according to their time variation. Samplings for the summer period were placed on the right side of the diagram and had positive correlation with the variables P-SRP (0.44), N-DIN (0.44), water temperature (0.39) and air temperature (0.33). Samplings for the winter period were placed on the left side of the diagram and showed negative correlation with the DO (–0.37).

The second axis of PCA explained 20% of the data variability and ordered the samplings on the positive side of the diagram, which were influenced by rainfall (0.39), and on the negative side the samplings influenced by variables Z_{eu} (–0.47), depth (-0.40) and P-DTP (–0.36).

Considering the qualitative and quantitative analyses of phytoplankton, 206 taxa distributed in nine taxonomic groups were registered: Cyanobacteria (65), Bacillariophyceae (59), Zygnemaphyceae (37), Chlorophyceae (31), Oedogoniophyceae (7), Chrysophyceae (4), Cryptophyceae (1) Chlamydophyceae (1) and Dinophyceae (1).

Species richness values were low, with less than 15 species. Higher values of richness were observed in summer. Chlorophyceae (12), Bacillariophyceae (11) and Cyanobacteria (10) had a greater contribution to richness. In March 2011 higher values of richness were recorded, with the greatest contribution of Cyanobacteria (Figure 4a). The most frequent species were *Spicaticribra rudis* (Tremarin, Ludwig, Becker & Torgan) Tuji, Leelahakriengkrai et Peerapornpisal, present in 70% of samples, and *Eutetramorus fottii* (Hindák) Komárek, with a frequency of 65%. The values of richness in January and March 2011 showed significant differences compared to other sampled months ($F = 9.47$; $p = 0.001$).

Phytoplankton density values increased between September 2010 and March 2011, decreasing until the end of the experiment. The highest values of this attribute were observed in March in all sampling stations, with values above 1,300 ind.mL^{-1} (Figure 4b). The groups that have

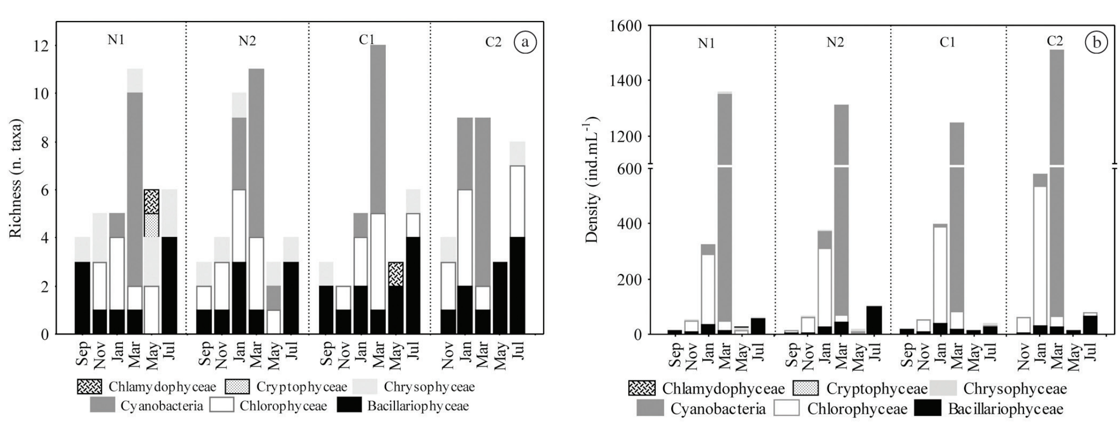

Figure 4. Variation in species richness (a) and phytoplankton density (b) for taxonomic classes observed in the two arms of the Salto Caxias reservoir, from September 2010 to July 2011.

most contributed to the density were Cyanobacteria and Chlorophyceae, especially during summer (November 2010, January and March 2011). According to the ANOVA, January and March showed significant differences for density (F = 216.6; p = 0.0001) compared to other months.

The summer period had the lowest values of evenness, with significant differences compared to the winter period (F = 6.695; p = 0.004), when the largest values were observed (Figure 5). Shannon diversity values were lower than the 2.2 bits.mm^{-3}. We observed an increase pattern over the period of study, however, the lowest values were observed in station C1 in November 2010 and May 2011. The greatest value of *H'* was observed in station C2 in July 2011 (Figure 5). No significant differences were observed for attributes of phytoplankton community between treatments (stations with and without cages), according to the ANOVA.

The two first DCA axes were retained for interpretation and explained 23% of total data variability. The DCA showed a temporal gradient in species composition in the sampled months, and separation between summer and winter (Figure 6). On the first DCA axis, November 2010, January and March 2011 were detailed on the left side of the diagram, and September 2010, May and July 2011, on the right. Cyanobacteria and Chlorophyceae were mainly associated to the summer, while other classes were more representative during the winter. The low score dispersion of species showed spatial similarity in phytoplankton composition (Figure 6b).

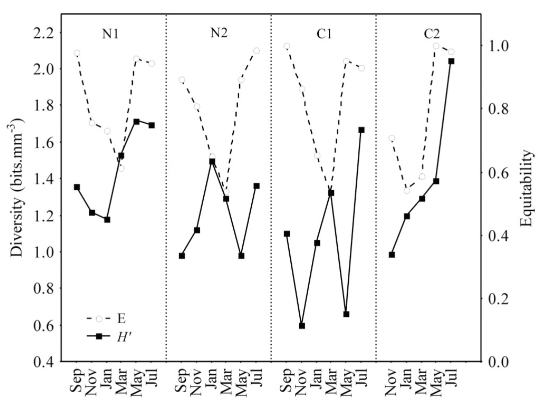

Figure 5. Variation of Shannon-Wiener diversity (*H'*) and evenness (E) of phytoplankton observed in the four sampling stations of the Salto Caxias reservoir, from September 2010 to July 2011. Codes available in Table 1.

The variance analysis showed significant differences for the first DCA axis (F = 156.8; p = 0.0001). The Tukey test showed significant differences between the summer and winter periods. The Spearman's correlations showed that changes in the composition of phytoplankton community in the two arms of Salto Caxias reservoir were related to rainfall, wind, air and water temperature, turbidity, DO, pH, P-DTP, P-SRP and N-DIN (Table 2). The Shannon diversity was not correlated with any of the abiotic variables.

4. Discussion

The nutrients concentrations and other abiotic variables showed only temporal changes, as evidenced by numerical analyzes, with separation between summer and winter periods. The effects of the net cages, primarily, depend on the intensity of the cultivation system, area and depth of the environment, as well as retention time of water (Guo and Li, 2003). We found out that the low retention time of the reservoir (estimated in 32.5 days), associated with the low depth of sampling locations and the inflows of the two upstream rivers, seem to have resulted in low effects of cultivation on the environment assessed.

In addition to the environment hydrodynamics, characterized by high flow, the size of the cultivation system seems to have assumed relevance, since in the present study few net cages were used. Despite the nutrients had no significant increase in the arm influenced by cultivation, other studies on the impacts of fish farming have demonstrated changes in their concentrations, such as those conducted by Guo and Li (2003) and Guo et al. (2009), who found

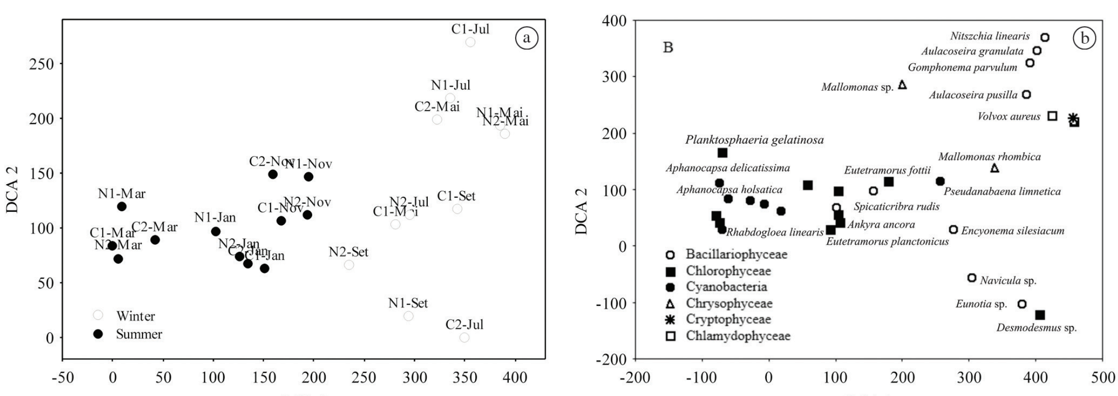

Figure 6. Score dispersion of locations and sampling peeriods (a) and of phytoplankton species (b) along the first two DCA axes. Codes and abbreviations are present in Table 1.

Table 2. Relevant results of Spearman's correlations for the two arms of the Salto Caxias reservoir, from September 2010 to July 2011. Codes available in Table 1.

Attributes/variables	Pre	Win	T_a	T_w	DO	Turb	pH	P-SRP	P-DTP	N-DIN
Bacillariophyceae density	0.48	-	0.87	0.72	-	–0.62	-	-	-	-
Chlorophyceae density	-	-	0.87	0.72	-	-	-	-	-	-
Cyanobacteria density	-	-	0.70	0.80	-	-	0.46	-	-	-
Chrysophyceae density	-	-	–0.41	–0.53	-	-	-	-	-	-
Chlamydophyceae density	-	–0.45	–0.45	-	-	-	-	-	–0.47	-
Total density	-	-	0.81	0.57	-	-	0.43	-	-	-
Bacillariophyceae richness	0.53	-	-	-	0.63	-	-	-	-	-
Chlorophyceae richness	-	-	0.71	0.50	-	-	-	-	-	-
Cyanobacteria richness	-	-	0.68	0.79	-	-	0.47	-	-	-
Chrysophyceae richness	-	-	-	–0.63	0.50	-	-	-	-	-
Chlamydophyceae richness	-	–0.45	–0.45	-	-	-	-	-	–0.47	-
Total richness	-	-	0.60	-	-	-	-	0.49	-	0.49
Evenness	-	-	–0.83	–0.72	-	-	–0.42	–0.46	-	–0.46

an increase of phosphorus and nitrogen from cultivation in net cages in a bay of Lake Niushanhu, China.

Borges et al. (2010), in experiment with tilapia (*Oreochromis niloticus* L.) in net cages in an arm of Rosana reservoir, observed an increase in the concentration of total nitrogen and ammonium after the installation of the net cages, and also found strong influence of the reservoir hydrodynamics on the cultivation system.

Indeed, the hydrodynamic has been pointed out by several authors (Diaz et al., 2001; Silva et al. 2005; Araripe et al., 2006; Alves and Baccarin, 2007; Nogueira et al. 2010) as driving the changes to the abiotic variables. Thus, the fish cultivation can cause eutrophication of the system, especially in environments with low time of water renewal (Araripe et al., 2006). In addition, narrow and shallow environments, as in the case of the two studied arms, associated with the inflows of the upstream rivers and the reservoir operation, have reduced water retention time and, as a consequence, the nutrients were exported downstream (Kennedy and Walker, 1990).

Seasonal changes in the composition and density of phytoplankton seem to mainly have been influenced by natural climatic changes, such as temperature. Cyanobacteria and Chlorophyceae were associated to the summer due to the higher values of temperature and high availability of nutrients. Bacillariophyceae was probably favored by lower temperatures and mixing patterns. Phytoplankton composition can also be determined by the mixing patterns, already reported by other authors (Crossetti and Bicudo, 2005; Tundisi, 1990; Moura et al., 2007).

Cyanobacteria was probably favored by high temperatures, as also verified by Chu et al. (2007), Degefu et al. (2011) and Kosten et al. (2012). In spite of Cyanobacteria being a common component of the phytoplankton, it represents one of the main contributor to the biomass and diversity in aquatic ecosystems, especially in eutrophic waters (Sant'Anna et al., 2006a; Borges et al., 2008) and several species are potential toxin producers (Komárek, 2003; Calijuri et al., 2006).

Bacillariophyceae was primarily represented by centered diatoms and typical potamoplanktonic, such as *Aulacoseira granulata* (Ehrenberg) Simonsen, *A. muzzanensis* (Meister) Krammer and *Spicaticribra rudis*, probably in response to the lower temperatures and water flow from the two evaluated arms, since diatoms are adapted do turbulent environments due to the their high sedimentation rate (Tundisi, 1990; Pérez et al., 1999; Train and Rodrigues, 2004; Silva et al., 2005).

The low values of species richness and density recorded during the study period, with significant seasonal differences, were probably influenced by the short water retention (Train et al., 2005; Brasil and Huszar, 2011). The variations in the number of species between summer and winter may be a result of the reduced depth of the studied environments, whereas shallow environments are more likely to suffer environmental changes, for example, the changes caused by rain (Kimmel et al., 1990; Tundisi, 1990; Padisák, 1993; Straskraba, 1998).

The highest values of Bacillariophyceae richness and density observed in July 2011 were probably favored by lower temperatures. Several authors have reported that diatoms occur mostly in lower temperatures (Huszar and Caraco, 1998; Silva et al., 2005). Additionally, local precipitation in the day preceding the sampling date may also explain the major contribution of this group, and the presence of *Pinnularia* and *Eunotia*, which are typically periphytic. Silva et al. (2005) and Rodrigues et al. (2005) also observed predominance of Bacillariophyceae in Salto Caxias reservoir during the winter in response to low temperatures.

The high contribution of the Chlorophyceae and Cyanobacteria to richness and density in the summer was positively related to air temperature and water temperature. Chlorophyceae and Cyanobacteria are widely distributed and have usually been associated to greater availability of nutrients and light and high temperature conditions (Huszar et al., 2000; Komárek, 2003; Sant'Anna et al., 2006b; Lachi and Sipaúba-Tavares, 2008). In addition, some studies have observed an increase in phytoplankton density and biomass due to the selective consumption of the zooplankton and consequent dominance of Cyanobacteria (Degans and Meester, 2002; Kozak and Goldin, 2004; Borges et al., 2010).

Cyanobacteria and Chlorophyceae were particularly represented by Chroococcales and Chlorococcales, respectively, especially colonial nanoplanktonics, that presented high surface/volume ratio, which increases the absorption of nutrients allowing adaptive advantages (Lopes et al., 2005; Dantas et al., 2008; Brasil and Huszar, 2011).

The low Shannon diversity values and absence of significant differences in the treatments and sampling periods, can be associated to the low values of species richness. Despite the higher density of Cyanobacteria in March 2011, mainly *Aphanocapsa delicatissima* West & West and *A. holsatica* Cronberg & Komárek, there was no decrease in diversity, because in that month the highest values of richness were observed. In higher temperature and high water transparency periods there is the predominance of the picoplankton (Reynolds et al., 2002). Thus, although evenness has decreased until March 2011, diversity has increased due to an increase in the number of species. However, it is worth emphasizing that the decrease in diversity associated with a high proliferation of Cyanobacteria has been frequently mentioned in literature (Padisák, 1993; Borics et al., 2000; Figueredo and Giani, 2001; Sant'Anna et al., 2006b).

The lowest values of Shannon diversity observed in November 2010 and May 2011 in station C1 were probably related to greater depth of this site and lower wind speed in these months. The regimen of mixing water influences directly the phytoplankton structure (Padisák, 1993), as that can affect the availability of nutrients in the water column (Lopes et al., 2005). The decrease in diversity observed in September 2010, May and July 2011 in station N2, and in November 2010 in C1, is a result of the decrease in the number of species and evenness, as observed by Padisák (1993).

Our results did not confirm the hypothesis of changes in the concentration of nutrients for the sites influenced by net cages and on the attributes of the phytoplankton community (composition, richness, density, evenness and Shannon diversity). The hydrodynamics of the two studied arms associated with the seasonal variations probably were key factors in structuring the phytoplankton and the abiotic variables. Although the release of nutrients has not significantly affected the study area, Diaz et al. (2001) points out that systems present a support capacity and that from this point the environment conditions may be compromised.

It's necessary to investigate the impacts of fish waste, considering the intensive farming with a greater number of net cages, especially in high temperatures, when the fish metabolism is increased (Araripe et al., 2006; Borges et al., 2010). In addition, the adjacent areas from the farming should be monitored as well, to verify the real effects on diversity of aquatic biota (Marengoni, 2006; Borges et al., 2010).

Acknowledgments - The authors would like to thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES for funding the Masters Degree of the first author and Drª Iraúza Arroteia Fonseca for her valuable help in the identification of Cyanobacteria taxa.

References

ALVES, RCP. and BACCARIN, AE.,2007. Efeito da produção de peixes em tanques-rede sobre sedimentação de material em suspensão e de nutrientes no córrego da Arribada (UHE Nova Avanhandava, baixo rio Tiête, SP). In NOGUEIRA, M.G., HENRY, R. and JORCIN, A. (Eds.). *Ecologia de Reservatórios*: impactos potenciais, ações de manejo e sistemas em cascata. São Carlos: Rima. p. 329-347.

American Public Health Association - APHA,1995. *Standard methods for the examination of water and wasterwater* 19th ed. Washington: APHA.

ARARIPE, MNBA., SEGUNDO, LFF., LOPES, JB. and ARARIPE, HGA., 2006. Efeito do cultivo de peixes em tanques rede sobre o aporte de fósforo para o ambiente. Revista Científica de Produção Animal, vol. 8, no. 2, p. 56-65.

AYROSA, DMMR., FURLANETO, FPB. and AYROSA, LMS., 2008. Regularização de projetos de piscicultura no estado de São Paulo. Revista Tecnologia & Inovação Agropecuária, vol. 1, no. 1, p. 33-41.

BICUDO, CEM. and MENEZES, M.,2006. *Gêneros de Algas de Águas continentais do Brasil:* chave para identificação e descrições. São Carlos: Rima.

BORGES, PAF., TRAIN, S., DIAS, JD. and BONECKER, CC., 2010. Effects of fish farming on plankton structure in a Brazilian tropical reservoir. Hydrobiologia, vol. 649, no. 1, p. 279-291. http://dx.doi.org/10.1007/s10750-010-0271-2.

BORGES, PAF., TRAIN, S. and RODRIGUES, LC., 2008. Estrutura do fitoplâncton, em um curto período de tempo, em um braço do reservatório de Rosana (ribeirão do Corvo, Paraná, Brasil). Acta Scientiarum Biological Science, vol. 30, no. 1, p. 57-65.

BORICS, G., GRIGORSZKY, I., SZABÓ, S. and PADISÁK, J., 2000. Phytoplankton associations in a small hypertrophic fishpond in East Hungary during a change from bottom-up to top-down control. Hydrobiologia, vol. 424, p. 79-90. http://dx.doi.org/10.1023/A:1003948827254.

BRASIL, J. and HUSZAR, VLM., 2011. O papel dos traços funcionais na ecologia do fitoplâncton continental. Oecologia Australis, vol. 15, no. 4, p. 799-834. http://dx.doi.org/10.4257/oeco.2011.1504.04.

CALIJURI, MC., ALVES, MAS. and SANTOS, ACA.,2006. *Cianobactérias e cianotoxinas em águas continentais*. São Carlos: Rima.

CHU, Z., JIN, X., IWAMI, N. and INAMORI, Y., 2007. The effect of temperature on growth characteristics and competitions of *Microcystis aeruginosa* and *Oscillatoria mougeotii* in a shallow, eutrophic lake simulator system. Hydrobiologia, vol. 581, p. 217-223. http://dx.doi.org/10.1007/s10750-006-0506-4.

COLE, GA.,1994. *Text book of limnology.* Illinois: Waveland Press Inc.

COMITÊ BRASILEIRO DE BARRAGENS,2011. *Usina Hidrelétrica de Salto Caxias*. Available from: <http://www.cbdb.org.br/site/bdados.asp?str_cod=264>. Access in: 17 Oct 2011.

Companhia Paranaense De Energia - COPEL,2011. *Usina Governador José Richa*. Available from: <http://www.copel.com/hpcopel/root/nivel2.jsp?endereco=%2Fhpcopel%2Froot%2Fpagcopel2.nsf%2F044b34faa7cc1143032570bd0059aa29%2F9bdc37f6b8c44b810325741200587db7>. Access in: 17 Oct 2011.

CROSSETTI, LO. and BICUDO, CEM., 2005. Structural and functional phytoplankton responses to nutrient impoverishment in mesocosms placed in a shallow eutrophic reservoir (Garças Pond), São Paulo, Brazil. Hydrobiologia, vol. 541, p. 71-85. http://dx.doi.org/10.1007/s10750-004-4668-7.

CROSSETTI, LO., BICUDO, DC., BICUDO, CEM. and BINI, LM., 2008. Phytoplankton biodiversity changes in a shallow tropical reservoir during the hypereutrophication process. *Brazilian Journal of Biology*, vol. 68, no. 4, p. 1061-1067. PMid, vol. 19197476. http://dx.doi.org/10.1590/S1519-69842008000500013.

DANTAS, EW., MOURA, AN., BITTENCOURT-OLIVEIRA, MC., ARRUDA NETO, JDTA. and CAVALCANTI, ADC., 2008. Temporal variation of the phytoplankton community at short sampling intervals in the Munduaú reservoir, Northeastern Brazil. Acta Botanica Brasilica, vol. 22, no. 4, p. 970-982. http://dx.doi.org/10.1590/S0102-33062008000400008.

DEGANS, H. and MEESTER, LD., 2002. Top-down control of natural phyto and bacterioplankton prey communities by Daphnia magna by the natural zooplankton community of the hypertrophic Lake Blankaart. Hydrobiologia, vol. 479, p. 39-49. http://dx.doi.org/10.1023/A:1021002128426.

DEGEFU, F., MENGISTU, S. and SCHAGERL, M., 2011. Influence of fish cage farming on water quality and plankton in fish ponds: A case study in the Rift Valley and North Shoa reservoirs, Ethiopia. Aquaculture (Amsterdam, Netherlands), vol. 316, p. 129-135. http://dx.doi.org/10.1016/j.aquaculture.2011.03.010.

DIAZ, MM, TEMPORETTI, P.F. and PEDROZO, F.L., 2001. Response of phytoplankton to enrichment from Cage fish farm waste in Alicura reservoir (Patagônia, Argentina). Lakes and Reservoirs: Research and Management, vol. 6, p. 151-158. http://dx.doi.org/10.1046/j.1440-1770.2001.00136.x.

FEIDEN, A., HAYASHI, C., BOSCOLO, WR. and REIDEL, A., 2006. Desenvolvimento de larvas de *Steindachneridion* sp. em diferentes condições de refúgio e luminosidade. Pesquisa Agropecuaria Brasileira, vol. 41, no. 1, p. 133-137. http://dx.doi.org/10.1590/S0100-204X2006000100018.

FIGUEREDO, CC. and GIANI, A., 2001. Seasonal variation in the diversity and species richness of phytoplankton in a tropical eutrophic reservoir. Hydrobiologia, vol. 445, p. 165-174. http://dx.doi.org/10.1023/A:1017513731393.

-., 2005. Ecological interactions between Nile Tilapia (*Oreochromis niloticus*, L.) and the phytoplankton community of the Furnas reservoir (Brazil). Freshwater Biology, vol. 50, p. 1394-1403.

GAUCH JUNIOR, HG.,1986. *Multivariate analysis in community ecology.* Cambridge: Cambridge University Press. Cambridge studies in ecology.

GUO, L. and LI, Z., 2003. Effects of nitrogen and phosphorus from fish cage-culture on the communities of a shallow lake in middle Yangtze River basin of China. Aquaculture (Amsterdam, Netherlands), vol. 226, p. 201-212. http://dx.doi.org/10.1016/S0044-8486(03)00478-2.

GUO, L., LI, Z., XIE, P. and NI, L., 2009. Assessment effects of cage culture on nitrogen and phosphorus dynamics in relation to fallowing in a shallow lake in China. Aquaculture International, vol. 17, p. 229-241. http://dx.doi.org/10.1007/s10499-008-9195-5.

HUSZAR, VLM. and CARACO, NF., 1998. The relationship between phytoplankton composition and physical-chemical variables: a comparison of taxonomic and morphological-functional descriptors in six temperate lakes. Freshwater Biology, vol. 40, p. 679-696. http://dx.doi.org/10.1046/j.1365-2427.1998.00369.x.

HUSZAR, VLM. and REYNOLDS, CS., 1997. Phytoplankton periodicity and sequences of dominance in an Amazonian flood-plain lake (Lago Batata, Pará, Brazil): responses to gradual environmental changes. Hydrobiologia, vol. 346, p. 169-181. http://dx.doi.org/10.1023/A:1002926318409.

HUSZAR, VLM., SILVA, LHS., MARINHO, M., DOMINGOS, P. and SANT'ANNA, CL., 2000. Cyanoprokaryote assemblages in eight productive tropical Brazilian waters. Hydrobiologia, vol. 424, p. 67-77. http://dx.doi.org/10.1023/A:1003996710416.

JACKSON, DA., 1993. Stopping rules in the principal components analysis: a comparison of heuristical and statistical approaches. Ecology, vol. 74, p. 2204-2214. http://dx.doi.org/10.2307/1939574.

JÚLIO JÚNIOR, HF., THOMAZ, SM., AGOSTINHO, AA. and LATINI, JD.,2005. Distribuição e caracterização dos reservatórios. In RODRIGUES, L., THOMAZ, S.M., AGOSTINHO, A.A. and GOMES, LC. *Biocenoses em reservatórios: padrões espaciais e temporais.* Rima, São Carlos: 1-16.

JONGMAN, RHG., TER BRAAK, CJF. and VAN TONGEREN, OFR.,1995. *Data analysis in communit and landscape ecology (reprinted 1996).* Cambridge University Press, Cambridge.

KENNEDY, RH. and WALKER, WW.,1990. Reservoir nutrient dynamics. In THORNTON, K.W., KIMMEL, B.L. and PAYNE, FE. *Reservoir limnology: ecological perspectives.* John Wiley & Sons, New York: 109-131.

KIMMEL, BL., LIND, OT. and PAULSON, LJ.,1990. Reservoir primary production. In THORNTON, K.W., KIMMEL, B.L. and PAYNE, FE. (Eds.). *Reservoir limnology: ecological perspectives.* Somerset: John Wiley & Sons, Inc. p. 133-194.

KOMÁREK, J.,2003. Coccoid and colonial Cyanobacteria. In WEHR, J.D. and SHEATH, RG. (Eds.). *Freshwater algae of North America: ecology and classification.* Academic Press. p. 59-116.

KOMÁREK, J. and ANAGNOSTIDIS, K., 1989. Modern approach to the classification system of Cyanophytes. 4 - Nostocales. Algological Studies, vol. 56, p. 247-345.

-.,1998. Cyanoprokaryota. 1. Teil Chroococcales. In ETTL, H., GÄRTNER, G., HEYNIG, H. and MÖLLENHAUER, D. (Eds.). *Sübwasserflora von Mitteleuropa.* Gustav Fischer Verlag. p. 1-548.

-.,2005. Cyanoprokaryota. 2. Teil Oscillatoriales. In BÜDEL, B., GÄRTNER, G., KRIENITZ, L. and SCHAGERL, M. (Eds.). *Sübwasserflora von Mitteleuropa.* München: Elsevier GmbH. p. 1-759.

KOROLEFF, K.,1976. Determination of ammonia. In GRASSHOFF, K. and KREMLING, E. (Eds.). *Methods of Seawater Analysis.* Winhein: Verlag Chemie.

KOSTEN, S., HUSZAR, VLM., CARES, E., COSTA, LS., VAN DONK, E., HANSSON, L., JEPPESENK, E., KRUK, C., LACEROT, G., MAZZEO, N., MEESTER, L., MOSS, B., LÜRLING, M., NÖGES, T., ROMO, S. and SCHEFFER, M., 2012. Warmer climates boost cyanobacterial dominance in shallow lakes. Global Change Biology, vol. 18, p. 118-126. http://dx.doi.org/10.1111/j.1365-2486.2011.02488.x.

KOZAK, A. and GOLDIN, R., 2004. Zooplankton versus phyto and bacterioplankton in the Maltanski reservoir (Poland) during an extensive biomanipulation experiment. Journal of Plankton Research, vol. 26, p. 37-48. http://dx.doi.org/10.1093/plankt/fbh006.

LACHI, GB. and SIPAÚBA-TAVARES, LH., 2008. Qualidade da água e composição fitoplanctônica de um viveiro de piscicultura utilizado para fins de pesca esportiva e irrigação. Boletim do Instituto de Pesca, vol. 34, no. 1, p. 29-38.

LIMA, JF., ALVES, LR., KARPINSKI, C., PIACENTI, CA. and PIFFER, M., 2005. A região de Salto Caxias no Sudoeste paranaense: elementos para uma política de desenvolvimento econômico microrregional. Revista Paranaense de Desenvolvimento, vol. 108, p. 87-111.

LOPES, MRM., BICUDO, CEM. and FERRAGUT, C., 2005. Short term spatial and temporal variation of phytoplankton in a shallow tropical oligotrophic reservoir, southeast Brazil. Hydrobiologia, vol. 542, p. 235-247. http://dx.doi.org/10.1007/s10750-004-8332-z.

MAACK, R.,2002. *Geografia física do Estado do Paraná*. 3. ed. Rio de Janeiro: Livraria José Olympio. 438 p.

MACKERETH, JFH., HERON, J. and TALLING, JF.,1978. *Water analysis:* some revised methods for limnologists. Freshwater Biological Association. n. 36. 121 p.

MACCUNE, B. and MEFFORD, M.J., 1999. PC-ORD. *Multivariate analysis of ecological data, version 4.0*. Gleneden Blach: MjM Software Design.

MARENGONI, NG., 2006. Produção de tilápia do Nilo *Oreochromis niloticus* (linhagem chitralada), cultivada em tanques-rede, sob diferentes densidades de estocagem. Arquivos de Zootecnia, vol. 55, p. 127-138.

MOURA, AN., BITTENCOURT-OLIVEIRA, MC., DANTAS, EW. and ARRUDA NETO, JDTA., 2007. Phytoplanktonic associations: a tool to understanding dominance events in a tropical Brazilian reservoir. Acta Botanica Brasilica, vol. 21, no. 3, p. 641-648.

NOGUEIRA, MG., 2000. Phytoplankton composition, dominance and abundance as indicators of environmental compartmentalization in Jurumirim Reservoir (Paranapanema River), São Paulo, Brazil. Hydrobiologia, vol. 431, p. 115-128. http://dx.doi.org/10.1023/A:1003769408757.

NOGUEIRA, MG., FERRAREZE, M., MOREIRA, ML. and GOUVÊA, RM., 2010. Phytoplankton assemblages in a reservoir cascade of a large tropical-subtropical river (SE, Brazil). *Brazilian Journal of Biology*, vol. 70, no. 3, p. 781-793. PMid, vol. 21085783. http://dx.doi.org/10.1590/S1519-69842010000400009.

PADISÁK, J., 1993. The influence of different disturbance frequencies on the species richness, diversity and equitability of phytoplankton in shallow lakes. Hidrobiologia, vol. 249, p. 135-156. http://dx.doi.org/10.1007/BF00008850.

PARANÁ. Secretaria de Estado do Meio Ambiente e Recursos Hídricos - SEMA, 2010. *Bacias hidrográficas do Paraná: série histórica.* Curitiba: SEMA. 140 p.

PÉREZ, MC., BONILLA, S. and MARTÍNEZ, G., 1999. Phytoplankton community of a polymictic reservoir, La Plata River basin, Uruguay. *Revista Brasileira de Biologia* =. Brazilian Journal of Biology, vol. 59, no. 4, p. 535-541.

PIELOU, E.C., 1966. The measurement of diversity in different types of biological collection. *Journal of Theoretical Biology*, no. 13, p. 131-144. PMid:5961533.

REYNOLDS, CS., HUSZAR, V., KRUK, C., NASELLI-FLORES, L. and MELO, S., 2002. Towards a functional classification of the freshwater phytoplankton. Journal of Plankton Research, vol. 24, no. 5, p. 417-428. http://dx.doi.org/10.1093/plankt/24.5.417.

RIBEIRO, LHL., BRANDIMARTE, AL. and KISHI, RT., 2005. Formation of the Salto Caxias Reservoir (PR) – an approach on the eutrophication process. Acta Limnologica Brasiliensia, vol. 17, no. 2, p. 155-165.

RODRIGUES, LC., TRAIN, S., PIVATO, BM., BOVO, VM., BORGES, PAF. and JATI, S.,2005. Assembléias fitoplanctônicas de trinta reservatórios do estado do Paraná. In RODRIGUES, L., THOMAZ, S.M., AGOSTINHO, A.A. and GOMES, LC. *Biocenoses em reservatórios: padrões espaciais e temporais.* São Carlos: RiMa. p. 57-72.

ROUND, FE.,1965. *The biology of the algae.* London: Edward Arnold (publishers) Ltda.

-., 1971. The taxonomy of the Chlorophyta, 2. British Phycological Journal, vol. 6, p. 235-264. http://dx.doi.org/10.1080/00071617100650261.

SANTOS, RM., ROCHA, G., ROCHA, O. and WISNIEWSKI, MJS., 2009. Influence of net cage fish cultures on the diversity of the zooplankton community in the Furnas hydroelectric reservoir, Areado, MG, Brazil. Aquaculture and Research, vol. 40, p. 753-761. http://dx.doi.org/10.1111/j.1365-2109.2008.02148.x.

SANT'ANNA, CL., AZEVEDO, MTP., AGUJARO, LF., CARVALHO, MC., CARVALHO, LR. and SOUZA, RCR.,2006a. *Manual ilustrado para identificação e contagem de cianobactérias planctônicas de águas continentais brasileiras.* Rio de Janeiro: Interciência. 58 p.

SANT'ANNA, CL., GENTIL, RC. and SILVA, D.,2006b. Comunidade fitoplanctônica de pesqueiros da região metropolitana de São Paulo. In ESTEVES, K.E. and SANT'ANNA, CL. (Orgs.). *Pesqueiros sob uma visão integrada de meio ambiente, saúde pública e manejo*. São Carlos: RiMa. p. 49-62.

SHANNON, CE. and WEAVER, W.,1963. *The mathematical theory of communication*. Illinois: University Press, Urbana.

SILVA, CA., TRAIN, S. and RODRIGUES, LC., 2005. Phytoplankton assemblages in a Brazilian subtropical cascading reservoir system. Hydrobiologia, vol. 537, p. 99-109. http://dx.doi.org/10.1007/s10750-004-2552-0.

STATSOFT INC,2005. *Statistica (data analisys software system) version 7.1*. Available from: <www.statsoft.inc>.

STRASKRABA, M.,1998. Limnological differences between deep valley reservoirs and deep lakes. International Review of Hydrobiology, vol. 83, no. special issue, p. 1-12.

STRICKLAND, JDH. and PARSONS, TR.,1972. *A pratical handbook of sea water analysis.* Ottawa: Fisheries Research Board of Canada. 310 p.

TEIXEIRA DE OLIVEIRA, M., ROCHA, O. and PERET, A.C., 2011. Structure of phytoplankton community in the Cachoeira Dourada reservoir (GO/MG), Brazil. *Brazilian Journal of Biology*, vol. 71, no. 3, p. 587-600. PMid:21881782.

TRAIN, S. and RODRIGUES, LC.,2004. Phytoplanktonic Assemblages. In AGOSTINHO, A.A., THOMAZ, S.M. and HAHN, NS. (Org.). *The Upper Paraná River and its floodplain*: physical aspects, ecology and conservation. Leiden: Backhuys. p. 103-124.

TRAIN, S., JATI, S., RODRIGUES, LC. and PIVATO, BM.,2005. Distribuição espacial e temporal do fitoplâncton em três reservatórios da bacia do rio Paraná. In RODRIGUES, L., THOMAZ, S.M., AGOSTINHO, A.A. and GOMES, LC. *Biocenoses em reservatórios:* padrões espaciais e temporais. São Carlos: RiMa. p. 73-85.

TUNDISI, JG., 1990. Distribuição espacial, sequência temporal e ciclo sazonal do fitoplâncton em represas: fatores limitantes e controladores. *Revista Brasileira de Biologia* =. Brazilian Journal of Biology, vol. 50, no. 4, p. 937-955.

URBINATI, EC. and GONÇALVES, FD.,2005. Jundiá (*Rhamdia quelen*). In BALDISSEROTO, B. and GOMES, LC. *Espécies nativas para piscicultura no Brasil.* Santa Maria: Editora UFSM. 470 p.

UTERMÖHL, H., 1958. Zur Vervollkommnung der quantitativen phytoplankton-methodic. Mitteilungen Internationale Vereinigung für Theoretische und Angewandte Limnologie, vol. 9, p. 1-38.