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Morphofunctional changes of phytoplankton community during pluvial anomaly in a tropical reservoir

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Abstract

The present study focuses on the structure and function of phytoplankton community during periods of marked changes in hydrological traits, influenced by an atypical climatic event (La Niña) and its impact on Armando Ribeiro Gonçalves Reservoir of Rio Grande do Norte, situated in the Caatinga biome of northeastern Brazil. The main questions addressed were: What are the effects of environmental factors on the temporal variation of Morphologically Based Functional Group (MBFG) of phytoplankton community? How does the composition of cyanobacterial species shift in relation to high and low trends of phytoplankton diversity? The samples were collected monthly during 2008-2009 and analyzed for pH, temperature, electrical conductivity, dissolved oxygen content and the nutrients, such as, nitrate-nitrogen, ammoniacal nitrogen, total nitrogen and orthophosphate. Phytoplankton samples were collected for both qualitative and quantitative analyses to evaluate species richness index and species diversity index. The data was divided into two distinct hydrodynamic periods of instability and stability. The results demonstrate considerable changes in dissolved oxygen content, water transparency and nitrogen nutrients, which directly influenced the MBFG of phytoplankton community in space and time. The instability of reservoir water was caused by heavy rainfall, which exerts atypical external disturbances. The seasonal variation of MBFG demonstrates a change in cyanobacterial composition and their diversity during instability and stability periods. MBFG VII, composed by colonial cyanobacteria with mucilage, was associated with reduced values of electrical conductance and alterations in pH. The predominance of filamentous species with heterocyst (MBFG III) occurs only during the hydrodynamic stability period and did not show significant association with analyzed parameters. The co-dominance of MBGFs III, V and VII along with high species diversity of phytoplankton community occurred during the second hydrodynamic instability period which was associated with the reduction in water temperature. It is concluded that the decrease in cyanobacterial species dominance and the general increase in the diversity of phytoplankton community are influenced by pluvial anomaly. The higher water level during the period of pluvial anomaly resulted in nutrient pulse and the mixing of water column in the reservoir, which determined the MBPG phytoplankton community distribution.

Keywords: hydrodynamism, environmental factors, phytoplankton community, morphofunctional groups.

Alterações morfofuncionais da comunidade fitoplanctônica durante anomalia pluvial em um reservatório tropical

Resumo

O presente estudo centra-se na estrutura e função da comunidade fitoplanctônica nos períodos de alterações marcantes nas características hidrológicas, influenciado por um evento climático atípico (La Niña) e seu impacto sobre o Reservatório: Armando Ribeiro Gonçalves, no Rio Grande do Norte, situado no bioma Caatinga, localizado na Região Nordeste do Brasil. As principais questões abordadas foram: Quais são os efeitos dos fatores ambientais sobre a variação temporal, baseados no grupo funcional da morfologia (GFBM) da comunidade fitoplanctônica? Como seria a composição das espécies de cianobactérias, em relação a varição das tendências de alta e baixa diversidade do fitoplâncton? As amostras foram coletadas mensalmente durante os anos de 2008-2009 e analisadas em relação a: pH, temperatura, condutividade elétrica, teor de oxigênio dissolvido e os nutrientes, tais como, tais como: nitrato, amônio, nitrogênio total e ortofosfato. As amostras de fitoplâncton foram coletadas para análises quantitativas, bem como, qualitativas para avaliar o índice de riqueza e de diversidade das espécies. Os dados foram divididos em dois períodos diferentes: instabilidade e estabilidade. Os resultados demonstraram alterações significativas no teor de oxigênio dissolvido, transparência da água e nutrientes de nitrogênio, que influenciaram diretamente os GFBM da comunidade do fitoplâncton no espaço e no tempo. A instabilidade da água do reservatório foi causada por fortes chuvas, que exerceu perturbações externas atípicas. Os resultados demonstraram alterações significativas no teor de oxigênio dissolvido, transparência da água e nutrientes de nitrogênio, que influenciaram diretamente os grupos morfofuncionais do fitoplâncton no espaço e no tempo. A instabilidade da água do reservatório foi causada por fortes chuvas, que exerceu perturbações externas atípicas. A sucessão sazonal de GFBM demonstrou a mudança na composição da cianobactéria e sua diversidade, durante os períodos de instabilidade e estabilidade. GFBM VII, composto por cianobactéria colonial com mucilagem esteve associado com baixos valores de condutividade elétrica e alterações no pH. A predominância das espécies filamentosas com heterocistos (GFBM III) ocorreu apenas durante o período de estabilidade hidrodinâmica e sem associação significativa com os parâmetros analisados. A codominância de GFBM III, V e VII juntamente com a elevada diversidade das espécies fitoplanctônicas ocorreram durante o segundo período da estabilidade hidrodinâmica e estiveram associadas com a redução da temperatura da água. Conclui-se que a diminuição da dominância de espécies de cianobactérias e o aumento geral na diversidade da comunidade do fitoplâncton são influenciadas pela anomalia pluvial. O nível da água mais elevado durante o período de anomalia pluvial resultou em um pulso de nutrientes e uma mistura da coluna de água no reservatório, que determinou a distribuição da comunidade fitoplanctônica MBPG.

Palavras-chave: hidrodinamismo, fatores ambientais, comunidade de fitoplâncton, grupos morfofuncionais.

1. Introduction

Climatic events, such as, El Niño and La Niña are often responsible for climate variations consisting of surface temperature fluctuations in the Pacific and Atlantic Oceans (Groisman et al., 2005; Marengo and Dias, 2006). These natural phenomena cause worldwide atypical events, such as strong trade winds and high rainfall levels in continental areas, including the southern hemisphere. The effects of climatic variations have a direct influence on phytoplankton community distribution and abundance. The characteristics of light intensity, water temperature, nutrient availability and turbidity may be altered owing to rainfall pattern in certain regions of the world, consequently modifying the phytoplankton production and biomass in a wide range of aquatic ecosystems (Reynolds, 2000; Scheffer, 2004). The El Niño effect and its impact on phytoplankton community composition have been well documented in freshwaters of tropical and subtropical regions of Brazil and Argentina of the Southern hemisphere through cycle of drought polygon and unusual rain fall (Bouvy et al., 2003; Devercelli, 2010).

Climate change triggers El Niño, which impacts extreme weather events and consequent heavy rainfall in continental ecosystems. As a consequence, the water level in the reservoirs increases, reduces resident time, induces mixing regime and nutrient load, (Scheffer, 2004; Winder and Sommer, 2012). This acts as an important natural exogenous or disturbance factor, inducing changes in species composition, forms of life and seasonal succession traits of phytoplankton groups in tropical and temperate environments (Gerten and Adrian, 2000; Devercelli, 2010).

Hydrodynamic drivers stimulate seasonal changes and are often modified by exogenous disturbances caused by mixing and resuspension of sediments with nutrient pulses (Huszar and Reynolds, 1997). These scenarios are induced by strong seasonal winds and water removal operations in reservoirs that lead to a variety of sudden and unexpected changes in the phytoplankton community. These auto and allogenic factors may induce thermal structure changes in the water column and control the composition, biovolume and functional diversity the phytoplankton community (Hoyer et al., 2009).

Morphologically Based Functional Group (MBFG) system of phytoplankton community was used as an environmental predictor on the basis of functional properties of species (Reynolds, 1988; Reynolds et al., 2002; Kruk et al., 2010). These systems consist of a particular association of species with the measurement of morphological traits, such as, volume, maximum linear dimension, surface area and the presence of mucilage, flagella, aerotopes, heterocysts or siliceous structures. Potentially dominant or co-dominant ecological attributes have been successfully used by many authors to explain the functional distribution of phytoplankton related to different environmental conditions (Whitfield, 2001; Salmaso and Padisák, 2007; Padisák et al., 2009; Rangel et al., 2009). Furthermore, morphological traits of species are essential properties that influence growth rate, resource use efficiency (ex. nutrients, light) and susceptibility to herbivory under different environmental conditions, and can predict the effects of climatic variability over time (Padisák et al., 2003; Salmaso, 2003). These facts are important drivers to efficient management of continental ecosystems (Reynolds et al., 2002).

The present study focuses on the structure and function of phytoplankton community during periods of marked changes in hydrological traits, influenced by an atypical climatic event (La Niña) and its impact on Armando Ribeiro Gonçalves Reservoir of Rio Grande do Norte, situated in the Caatinga biome of northeastern Brazil. The main questions addressed here were: 1) What are the effects of environmental factors on the temporal variation of Morphologically Based Functional Groups (MBFG) of phytoplankton community? 2) How does the composition of cyanobacterial species shift in relation to high and low trends of phytoplankton diversity?

2. Material and Methods

2.1. Study area

The Caatinga biome with distinctive scrub vegetation is located entirely in the Brazilian territory. This biome has been the focus of ecological studies, due to desertification intensified by climatic variations, periodic deforestation and other anthropogenic activities. It occupies an area of 1,037,517.80 km^2, with rainfall ranging between 200 and 700 mm and annual temperatures ranging between 25°C and 27°C. This biome exhibits semiarid tropical climate with high evaporation rates, low humidity, and a large water deficit (Baily, 1979; Leite and Machado, 2010).

This study was conducted in the Armando Ribeiro Gonçalves Reservoir (latitudes 05° 49'25" S and longitudes 36° 51'12" W), the largest reservoir in the State of Rio Grande do Norte, which was constructed on the River Piranhas-Assu, supplying water for 400,000 habitants. Details of the study area have been published (Costa et al., 2006; Chellappa et al., 2009). The sampling site was located at a distance of five meters from the reservoir impoundment, where the depth varied from 12.5 meters during dry season to 22 meters in wet season. The maximum volume of reservoir was 2.4×10^9 m^3, and a depth of 30m was registered during the pluvial anomaly period.

2.2. Samples and analyses

The samples were collected monthly from March, 2008 to June, 2009. This period was influenced by a strong La Niña phenomenon (CPTEC, 2010), which caused hydrodynamic changes in the reservoir. These periods were determined based on rainfall data obtained from the meteorological station of the Agricultural Research Company of Rio Grande do Norte (EMPARN), located in the city of Ipanguaçu, 20 km from the reservoir. Besides the rainfall data (mm), the reservoir water volume (m^3) was also obtained.

The sampling site was established near the slope of the reservoir, where the water residence time was greater. However, during periods of high atypical rainfall, water flew out of the reservoir from this zone, and when renewed, intense physical and chemical, and biological changes were detected during the study period.

Limnological parameters were assessed from water column samples in surface (0-1m) and bottom (9-25m) layers during the study period. During water sample collections the following *in situ* measurements of physical and chemical parameters were recorded: water temperature (°C), concentration of dissolved oxygen (mgL^{-1}), pH, electrical conductance (μScm^{-1}), using a WTW Multi 340i multi-parameter sensor and water transparency (m) with a Secchi disk.

Concentrations of soluble reactive phosphorous (SRP), total phosphorous (TP) and N-nitrite N-NO_2 (Wetzel and Likens, 2000), N-nitrate N-NO_3, N-ammoniacal N-NH_4^+ and total nitrogen (TN) were determined (Golterman et al., 1978). Chlorophyll *a* concentration, after 90% acetone extraction, was determined using a Biochrom Libra S6 spectrophotometer (Marker et al., 1980).

Qualitative analysis of phytoplankton was carried out from samples obtained with a plankton net (20µm mesh), where 50L of water was filtered by an STIHL suction pump and fixed with 4% formaldehyde. Samples for quantitative analyses were collected with a Van Dorn bottle and fixed with Lugol's iodine solution. 1 ml of well sedimented samples were drawn carefully and transferred to Sedwickrafter counting cells and counted randomly, approximately 100 to 200 cells of the counting chamber. Rare species curve was not used because there conceivably small numbers. Rare species were identified after counting, surface and bottom samples were integrated for detailed taxonomic analysis. The taxonomic biomass of the phytoplankton community was analyzed, considering the biovolume of individuals (mm^3L^{-1}). This was calculated as individual volume of the species multiplied by individual density ($ind.mL^{-1}$). Microalgal counts (cells, filaments and colonies) were performed under a binocular microscope using the magnification of x400 (10×40) (Nikon Eclipse E200). Individual volume was based on specific geometric approximations proposed by Hillebrand et al. (1999). Species diversity was obtained using the Shannon-Wiener index (Shannon and Weaver, 1949). The species were inserted into morphofunctional groups according to a recent classification developed by Kruk et al. (2010), based on species morphology as a means of functionally characterizing the phytoplankton community.

2.3. Statistical analyses

Normality and homogeneity of variance were analyzed using the Kolmogorov-Smirnov and Bartlett tests, respectively. Significant differences in environmental variables between the study periods were assessed by analysis of variance (ANOVA) and the Kruskal-Wallis test, with Student-Newman-Keuls (SNK) multiple comparison based on SigmaStat 3.5 software. Principal Component Analysis (PCA) was used to determine which environmental factors (temperature, pH, DO, electrical conductance and nutrients) were associated to the three hydrodynamic periods (FHIP, HSP and SHIP). The ordinations were carried out using the software XLSTAT 7.5.3, at a significance level of $p<0.05$.

3. Results

3.1. Environmental factors

Hydrological traits of 2008-2009 were an important tool which defined environmental changes and phytoplankton community composition. Different rainfall patterns were observed during the periods of hydrodynamic instability of the present study when compared with the characteristic dry season of the semiarid region of 2003 to 2007 (ANOVA $p<0.05$) (Figure 1a). In this study the sampling period was divided into the following three hydrodynamic periods: the First Hydrodynamic Instability Period (FHIP), Hydrodynamic Stability Period (HSP) and Second Hydrodynamic Instability Period (SHIP), based on the pluvial anomaly registered during 2008-2009. The hydrodynamic instability periods corresponded to the months of March to June, 2008 (FHIP), and February to June, 2009 (SHIP), during which time pluvial anomalies of the region were registered. The hydrodynamic stability period of July, 2008 to January, 2009 (HSP), coincided with the characteristic dry season of the semiarid region during 2003 to 2007.

Water temperature showed a mean difference of 2.32°C during the instability period when compared to the stability period (ANOVA $p<0.05$) (Figure 1b). Water volume of the reservoir during the two periods of hydrodynamic instability were significantly different from the period of stability (ANOVA $p<0.001$). A significant difference was also observed in water volumes between the atypical period and the normal climatic condition (Figure 1c).

Water depth in reservoir varied up to a maximum value of 25.7 m. Water transparency varied from 1.5 m during the stable period to 0.4 m during the turbid condition. The significant difference between instability and stability periods could be readily conceived (ANOVA $p<0.001$). The euphotic zone and the vertical extinction coefficient of light showed no significant difference between the hydroperiods (ANOVA $p<0.005$) (Table 1).

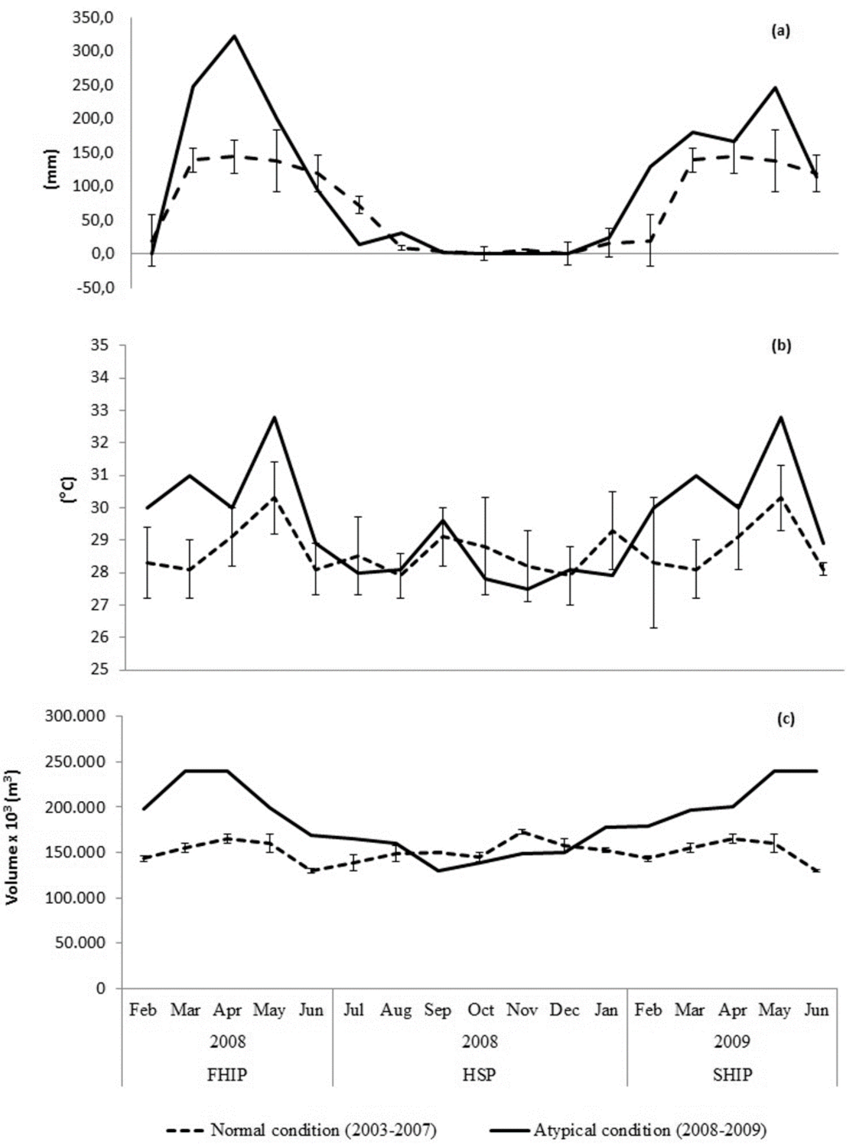

Figure 1. Rainfall (a), water temperature (b) and water volume (c) in the Armando Ribeiro Gonçalves Reservoir during normal pluvial condition (2003-2007) and atypical pluvial condition (2008-2009).

Table 1. Environmental factors, nutrients and chlorophyll *a* during the three hydrodynamic periods of 2008-2009.

		FHIP		HSP		SHIP		One-way ANOVA (*Kruskal Wallis)	P values
		Média	DP	Média	DP	Média	DP		
Water Temperature (°C)	S	28.1	2.3	31.1	1.4	28.5	3.4	*6.282	P<0.05
	B	26.6	1.6	27.2	1.8	28.8	2.8	*6.341	P<0.05
pH	S	7.8	0.6	8.4	0.8	7.4	0.5	3.105	P<0.05
	B	7.3	0.7	8.2	0.8	7.7	0.5	1.866	P 0.19
Electrical Conductance (μScm^{-1})	S	145.0	20.3	187.5	19.7	176.0	32.1	*5.943	P>0.05
	B	178.0	17.3	194.0	12.4	178.0	17.3	*2.466	P 0.29
Dissolvid Oxygen (mgL^{-1})	S	8.3	3.4	7.9	2.6	8.0	2.2	*1.087	P<0.05
	B	7.4	1.9	6.3	1.7	4.6	1.1	3.375	P <0.01
N- NO_3^- (μgL^{-1})	S	210.0	58.9	91.7	20.4	398.0	14.5	1.08	P<0.05
	B	234.0	54.2	130.0	79.5	292.0	30.3	1.68	P 0.23
N- $NO_2^=$ (μgL^{-1})	S	0.0	0.0	0.0	0.0	0.2	0.0	1.02	P 0.60
	B	0.0	0.0	0.0	0.0	0.7	0.0	*4.43	P 0.11
N-NH_4^+ (μgL^{-1})	S	330.4	41.5	212.9	72.6	198.0	26.8	1.08	P<0.005
	B	270.0	21.6	140.0	15.8	120.0	25.8	*3.87	P <0.14
P-PO_4 (μgL^{-1})	S	283.1	21.1	298.1	83.6	207.0	62.0	1.08	P<0.001
	B	217.1	79.4	306.4	74.0	179.7	38.5	3.65	P<0.06
Total Nitrogen (μgL^{-1})	S	1232.0	12.7	1085.0	58.1	728.0	19.0	0.74	P<0.04
	B	1244.0	66.7	670.0	16.9	616.0	77.9	8.74	P<0.001
Total Phosphorus (μgL^{-1})	S	218.0	14.7	230.0	14.1	384.0	11.8	3.41	P<0.07
	B	302.0	55.4	180.0	11.8	394.0	14.0	4.54	P<0.03
Chlorophyll *a* (μgL^{-1})	S	31.5	11.5	62.0	68.3	11.8	12.3	1.44	P<0.05
	B	26.6	11.4	39.5	21.1	15.4	9.6	2.73	P 0.11

FHIP= First Hydrodynamic Instability Period; HSP= Hydrodynamic Stability Period; SHIP= Second Hydrodynamic Instability Period; S= Surface; B=Botton. * for dominant/co-dominant species (biovolume > $30mm^3L^{-1}$).

Water temperature exhibited higher homogeneity over the vertical profile during the SHIP. Lower pH values were registered during the hydrodynamic instability periods, with significant differences when compared to the period of stability (ANOVA p<0.01). Electrical conductance showed higher values during the hydrodynamic stability period, coinciding with the months preceding reservoir outflow. The dissolved oxygen concentration in the surface waters varied between 7.9 mgL^{-1} to 8.3 mgL^{-1}, without any significant difference between the hydroperiods (ANOVA p>0.05). However, the dissolved oxygen in the bottom waters varied between 4.6 mgL^{-1} to 7.4 mgL^{-1}, with significant difference between the hydroperiods (ANOVA p<0.01) (Table 1).

Suspension of sediment, provoked by the mixing of water during periods of instability, favored the elevated concentrations of nitrate along the entire vertical profile. Significantly lower homogeneous concentrations of nutrients were observed during the stability period (ANOVA p<0.05). Concentrations of N-nitrite N-NO_2 were different (0.0 μgL^{-1} in SHIP, with a variation of 0.2 to 0.7 in the water column. N-ammoniacal N-NH_4^+ was significantly higher in FHIP (ANOVA p<0.01). Orthophosphate levels were high, with mean values between 207 ±62 μgL^{-1} during the second hydrodynamic instability period and 298.1.1±83.6μgL^{-1} during the stability period, with significant differences in relation to each period (ANOVA p<0.005) (Table 1).

Mean concentrations of total nitrogen were significantly reduced over the study periods with minimum and maximum values ranging between 728.0 μgL^{-1} to 1232.0 μgL^{-1} (ANOVA p<0.05). On the other hand, total phosphorous concentrations were higher in the second hydrodynamic instability period, exhibiting homogeneity along the water column (ANOVA p<0.001) (Table 1).

3.2. Phytoplankton community: composition, diversity and morphofunctional groups (MBFG)

A total of 53 taxa of phytoplankton were identified during the study period: 17 taxa during the first hydrodynamic instability period, 26 taxa during the stability period and 32 taxa in the second hydrodynamic instability period (Table 2). The class with the highest frequency of occurrence during the study was Cyanobacteria (27 taxa), followed by Chlorophyceae (12 taxa) and Bacillariophyceae (8 taxa). The remaining algal classes were Euglenophyceae, Dinophyceae and Xanthophyceae (6 taxa). The taxa recorded during the study period were grouped according to their MBFG (Table 2). Species

Table 2. Characteristics of Morphology Based Functional Groups (MBFG), taxa recorded during the three hydrodynamic periods and Phytoplankton Diversity (Bits.s^{-1}).

MBFG	Morphology	Taxa		
		FHIP	**HSP**	**SHIP**
I	Small organisms with elevated S/V ratio.	*Staurastrum leptocladum* Nordstedt; *Synechococcus* sp. Nägeli; ***Merismopedia punctata*** Meyen	*Staurastrum leptocladum* Nordstedt; *Synechococcus* sp Nägeli.	**Staurastrum leptocladum* Nordstedt; *Trachydiscus verrucosus* H.Ettl.; *Synechococcus sp*. Nägeli
III	Long filaments	*Komvophoron minutum* (Skuja) Anagnostidis et Komárek; *Planktothrix agardhii* (Gomont) Anagnostidis et Komárek;	**Anabaena circinalis* (Rabenhorst) Bornet et Flahault; *Anabaena solitaria* f. *planktonica* (Brunnthaler) Komárek; **Cylindrospermopsis raciborskii* (Woloszynska) Seennayya & Subba Raju; **Geitlerinema splendidum* (Greville ex Gomont) Anagnostidis; *Komvophoron minutum* (Skuja) Anagnostidis et Komárek; *Lyngbya* sp. C. Agardh ex Gomont; *Planktolingbya limnetica* (Lemmermann) Komárková-Legnerová et Cronberg; **Planktothrix agardhii* (Gomont) Anagnostidis et Komárek; *Pseudophormidium batrachospermi* (Starmach) Anagnostidis et Komárek; **Oscillatoria* sp. Vaucher ex Gomont; *Rivularia* sp. (Roth) C. Agardh ex Bornet et Flahault	*Anabaena circinalis* (Rabenhorst) Bornet et Flahault; *Anabaena solitaria* f. *planktonica* (Brunnthaler) Komárek; *Cylindrospermopsis raciborskii* (Woloszynska) Seennayya & Subba Raju; *Geitlerinema splendidum* (Greville ex Gomont) Anagnostidis; **Komvophoron minutum* (Skuja) Anagnostidis et Komárek *Planktothrix agardhii* (Gomont) Anagnostidis et Komárek; *Planktothrix mougeotii* (Bory ex Gomont) Anagnostidis et Komárek; *Pseudanabaena limnetica* (Lermmermann) Komárek; *Oscillatoria* sp. Vaucher ex Gomont
IV	Mid-sized organisms with no specialized characteristics.	*Raphidiopsis curvata* Fritsch	*Sphaerocavum* sp. Azevedo & Sant`Ana; *Phormidium richardsii* Drouet	*Raphidiopsis curvata* Fritsch; *Spirulina* sp Turpin ex Gomont; *Sphaerocavum* sp. Azevedo & Sant`Ana; *Cylindrocapsa geminella*; *Phormidium richardsii* Drouet; *Glaucospira laxissima* West
V	Mid-sized and large unicellular flagellates.	*Peridinium gatunense* Nygaard; *Volvox aureus* Ehrenberg; *Chlamydomonas globosa* Snow		*Phacus* sp; **Volvox aureus* Ehrenberg
VI	Non-flagellate organisms with siliceous exoskeleton.	*Aulacoseira granulata* (Ehrenb) Simonsen	*Asterionella formosa*; *Frustulia rhomboides* Ehrenberg; *Navicula* sp. Ehrenberg; *Synedra ulna* (Nitzsch) Ehrenberg	**Aulacoseira granulata* (Ehrenb.) Simonsen; *Frustulia rhomboides* Ehrenberg; *Navicula* sp.; *Synedra ulna* (Nitzsch) Ehrenberg;
VII	Colonies with mucilage.	*Chrococcus turgidus* (Kütz.) Nag; **Microcystis aeruginosa* (Kützing) Kützing; **Microcystis panniformis* Komárek et al; **Microcystis protocystis* Crow; *Oocystis lacustris* Chodat; **Snowella lacustris* (Chodat) Komárek	*Chrococcus turgidus* (Kütz.) Nag; *Microcystis aeruginosa* (Kützing) Kützing; *Microcystis panniformis* Komárek et al; *Microcystis protocystis* Crow; *Oocystis lacustris* Chodat;	*Aphanocapsa delicatissima* West & West; *Asterococcus* sp.; **Coelosphaerium kuetzingianum* Nägeli ; *Chrococcus turgidus* (Kütz.) Nag; *Eucapsis* sp.; *Microcystis aeruginosa* (Kutzing) Kutzing; **Snowella lacustris* (Chodat) Komárek
Total Biovolume		52.7 mm^3L^{-1}	45.3 mm^3L^{-1}	85.3 mm^3L^{-1}
Phytoplankton Diversity		1.03	1.12	3.99

FHIP= First Hydrodynamic Instability Period; HSP= Hydrodynamic Stability Period; SHIP= Second Hydrodynamic Instability Period; S-Surface; V-Volume). * for dominant/co-dominant species (biovolume > 30mm^3L^{-1}).

distribution and diversity demonstrated a different pattern between the three hydroperiods. In the FHIP, diversity showed a lower value (H=1.03) and predominance of mucilaginous colonial species (MBFG VII), especially *Microcystis aeruginosa* (Kutzing) Kutzing.

The diversity during the hydrodynamic stability period was 1.12. During the two first months of this period (July and August, 2008) a wide occurrence of MBFG I, VI and VII was observed. However, most of the time, the predominance of filamentous cyanobacteria (MBFG III) was conceivable with the coexistence of the following species: *Planktothrix agardhii* (Gomont) Anagnostidis et Komárek, *Cylindrospermopsis raciborskii* (Woloszynska) Seenayya & Subba Raju, *Geitlerinema splendidum (*Greville ex Gomont*) Anagnostidis and Anabaena circinali*s (Rabenhorst) Bornet et Flahault, which accumulated a biovolume of 28mm^{3}L^{-1}.

The diversity index was significantly higher during the second hydrodynamic instability period (H= 3.99), with predominance of unicellular flagellates (MBFG V), represented mainly by *Volvox aureus* Ehrenberg and the significant occurrence of filamentous species (MBFG III), such as *Komvophoron minutum* (Skuja) Anagnostidis et Komárek, in addition to colonial species (MBFG VII) represented by Chlorophyceae *Coelosphaerium kuetzingianum* Nägeli and *Snowella lacustris* (Chodat) Komárek (F).

3.3. Analysis of MBFG of phytoplankton x environmental factors

The principal component analysis (PCA) applied to the environmental factors, such as, water temperature, concentration of dissolved oxygen, electrical conductance and pH, explained 79.04% of data variability in the first two axes. The first axis (46.45%) separated the study periods. The period of hydrodynamic stability showed no significant association with the variables analyzed. However, the period of the first hydrodynamic instability (FHIP) was ranked in the first position of the first axis and was associated with low values of electrical conductance and pH. The second instability period (SHIP) was associated to reduction of water temperature, and commanded the positive side of axis 2 (32.59%) (Figure 2a).

The principal component analysis (PCA) applied to the inorganic nutrients explained 72.75% of data variability in the first two axes. The first axis (43.88%) separated the study periods, isolating SHIP in the negative side of the axis, which was associated to the elevated values of total phosphorus. FHIP was on the positive side of the first axis and was associated to the high values of N-ammoniacal N-NH$_4^+$. The hydrodynamic stability period (HSP) was not significantly associated with the nutrients analyzed (Figure 2b).

The hydrodynamic changes in the reservoir caused by pluvial anomaly changed the environmental factors, consequently leading to changes in the structure of MBFGs. The FHIP resulted in occurrence of low diversity of species with the dominance of MBFG VII (cyanobacterial colonies with mucilage). During HSP there was predominance of filamentous species with heterocyst, comprising MBFG III. During SHIP there was an increase in the diversity of species with the codominance of MBGFs III, V and VII. However, there was a lower incidence of colonial and filamentous cyanobacteria and an increase of Clorophyceae, especially *Volvox aureus*.

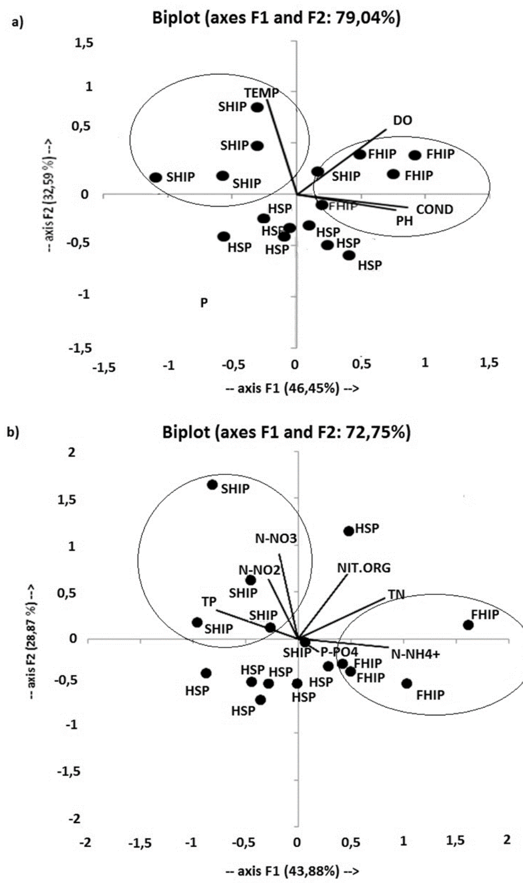

Figure 2. First and second axis of Principal Component Analysis (PCA) illustrating the influence of hidrodynamic periods on (a) environmental factors (temp=temperature; DO=dissolved oxygen; cond=electrical conductance and pH. (b) nutrients (N-NO$_2^=$; N-NO$_3^-$, N-NH$_4^+$; org. nit.= organic nitrogen; TN= total nitrogen. (FHIP=First Hydrodynamic Instability Period; HSP= Hydrodynamic Stability Period; SHIP= Second Hydrodynamic Instability Period).

4. Discussion

Armando Ribeiro Gonçalves Reservoir has a long history of cyanobacterial blooms and sometimes with toxin producing events associated with shallow lake tropical ecosystems characteristics (Costa et al., 2006). The present study has documented seasonal changes in quantitative and qualitative features of phytoplankton community in the same tropical reservoir during pluvial anomaly associated with La Niña. Rainfall is the main environmental driver which modifies the morphofunctional structure of the phytoplankton community on a temporal basis, during stable to unstable periods of an annual cycle.

The mechanisms involved in the structure of species and processes are strongly influenced by autogenic (re-suspension of sediment nutrients, competition and coexistence interactions, herbivore abundance) and allogenic forces (rainfall indices, renewal of the water body). These favor the phytoplankton community changes for better adapted species to the prevailing environmental condition. The morphofunctional groups in the Armando Ribeiro Gonçalves Reservoir (MBFG VII → MBFG III → MBFG III/V/VII) during the First Hydrodynamic Instability Period (FHIP), Hydrodynamic Stability Period (HSP) and Second Hydrodynamic Instability Period (SHIP), respectively, demonstrate that the short time interval between one water outflow and another may trigger a series of alterations in the physical, chemical and biological characteristics of the system. The pluvial anomaly registered in the present study is a regional response to Global climatic change and represent a single extreme event which corresponds clearly to the hypothesis of Whitfield (2001). Phytoplankton community composition of the Armando Ribeiro Gonçalves Reservoir in its annual cycle of 2008-2009 registered high diversity in the second hydrodynamic instability (SHIP) event compatible to the hypothesis proposed earlier by Reynolds (1988), Reynolds et al. (1993), Sommer et al. (1993). Water renewal is a regional adaptive strategy aligned to the globally elaborated functional morphology and the adaptive strategies proposed for freshwater phytoplankton community.

The dominance of filamentous cyanobacterial species (MBFG III) along with frequent bloom events in colonial species (MBFG VII) was reported previously (Chellappa et al., 2009). A similar result was found in the present study during the FHIP and SHIP. Thus the transition is marked by diverse changes in reservoir environment with qualitative and quantitative response in the phytoplankton community. The neutral to alkaline pH, lower electrical conductance and high concentration of ammoniacal nitrogen stimulated the cyanobacteria of MBFG VII. Although the principal component analysis did not associate the period of hydrodynamic stability to any environmental factor, it could be observed that during this period the water temperature was higher, which could have favored the dominance of MBFG III.

In the first months of HSP, the alkaline pH and marked thermal heterogeneity initiated changes characterized from MBFG VII to MBFG III. This coincided with greater thermal homogeneity between November, 2008 until early February, 2009. The maximum growth rate of cyanobacteria in eutrophized lakes is often found in temperatures above 28°C, which is generally higher than the optimum temperature observed for green algae or diatoms (Kardinaal and Visser, 2005). Heterogeneity and higher surface water temperature favor the establishment of species such as *Microcystis* sp., which exhibit high light requirements, not dominating in limiting conditions of this resource, as occurs after an instability event (Huisman et al., 1999). Several cyanobacterial species have an efficient carbon concentration mechanism making them potential competitors at high pH values, a common characteristic of eutrophized lakes (Shapiro, 1990). The stable period of the present study reveals mostly cyanobacterial dominance with an alkaline pH and this characteristic is lost during the unstable periods, when there was a shift in preference to other phytoplankton. However, soluble reactive phosphorous concentrations showed similar trend during the FHIP and SHP. It could therefore be inferred that this nutrient does not establish a definite pattern of influence on MBFG VII and MBFG III dominance.

The lower concentration of ammoniacal nitrogen during HSP justifies the changes of colonial cyanobacteria, such as *Microcystis* sp. (MBFG VII) to filaments with heterocyst, *Anabaena circinalis* and *Aphanizomenon flos-aquae* (MBFG III), with subsequent prevalence of filamentous species without heterocyst, *Planktothrix agardhii* and *Geitlerinema splendidum*, when there is an increase in ammoniacal nitrogen concentrations. These results correspond well with the experimental studies of Blomqvist et al. (1994), who hypothesized that the nitrogen nutrient could explain the dominance of filamentous cyanobacteria, where species that do not fix nitrogen are favored in higher concentrations of ammoniacal nitrogen. This phenomenon was also demonstrated by Klemer (1976) for species of *Planktothrix* sp.

Water residence time in the Armando Ribeiro Gonçalves Reservoir until the beginning of 2008 was approximately four years. Therefore, reservoir outflow during the FHIP was not sufficient to cause significant phytoplankton community changes, as compared to the normal hydrocondition observed in Cruzeta reservoir (Chellappa et al., 2008) and in ARG reservoir (Chellappa et al., 2009) of Rio Grande do Norte. The results of similar nature have been described at El Gerdal Reservoir in the southwest of Spain (Hoyer et al., 2009). The present study indicates the cyanobacterial species dominance immediately after a long period without water renewal and phytoplankton community changes affecting diversity when an external disturbance occurred. The dominance and diversity trends are similar to the findings in shallow tropical hypereutrophicated freshwater ecosystems (Crossetti et al., 2008).

Stress-tolerant species belonging to MBFG III and MBFG VII, which occur in the FHIP and HSP, may be classified into the three functional phytoplankton categories (C-S-R strategists) of Reynolds (1997), acting successfully during disturbance events and remaining in the system during stable conditions. The present study revels that phytoplankton communities in disturbance events result directly in biomass reduction and that stress limits the growth rate, leading to the dominance of tolerant species.

An increase in phytoplankton community diversity occurs during the SHIP, where the elevated biomass of potentially toxic cyanobacteria (MBFG III) is replaced by non-toxic species, represented primarily by *Volvox aureus* (MBFG V), *Aulacoseira granulata* (MBFG VI) and *Coelosphaerium Kuetzingianum* (MBFG VII). This marked structural change in morphofunctional groups between the end of HSP and onset of the SHIP can be considered as a consequence of intermediate disturbance caused by the short water residence time in the reservoir, and could be correlated with low concentrations of soluble reactive phosphorous and elevated nitrate concentrations in the water column. The intermediate disturbance hypothesis predicts that the diversity of local species is maximized during an intermediate-level event (Reynolds et al., 1993; Bongers et al., 2009).

Plankton Ecology Group model was used intensely to predict how temporal dynamics of freshwater plankton community was affected in different ecosystems of the world including tropical ecosystems. Furthermore, it was suggested that annual precipitation in tropics may reset the seasonal variations of plankton community in favour of species ability to adapt to variable environments (Domis et al., 2013).

One of the significant effects of climate change is the occurrence of pluvial anomaly in tropics, which triggered altered water levels of the reservoir, and consequently stimulated increased nutrient pulse, similar to the results of highly variable flow regime with abrupt changes found in the dammed water course of Southern Brazil (Zanon et. al., 2013).

This study has focused on the importance of unusual rainfall event, the single extreme event in the semiarid Caatinga region of Brazil, which caused environmental modifications with a marked influence on phytoplankton community structure. It is concluded that the decrease in cyanobacterial species dominance and the general increase in the diversity of phytoplankton community are influenced by pluvial anomaly. Such event might be considered as a positive adaptation to demonstrate how the temperature change and pluvial anomaly at regional levels result in greater species diversity and consequent low dominance of potentially toxic cyanobacteria in the study reservoir. The higher water level during the period of pluvial anomaly resulted in nutrient pulse and the mixing of water column in the reservoir, which determined the MBPG phytoplankton community distribution.

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References

BAILY, HP., 1979. Semi-arid climate: their definition and distribution. In HALL, AE., CANNELL, GH. and LAWTON, HW. (Eds). *Agriculture in semiarid environments*. Berlin: Springer. p. 73-97. Ecological Studies, no. 34.

BLOMQVIST, P., PETTERSSON, A., and HYENSTRAND, P., 1994. Ammonium-nitrogen: a key regulatory factor causing dominance of non-nitrogen-fixing cyanobacteria in aquatic systems. *Archiv für Hydrobiologie*, vol. 132, no. 2, p. 141-164.

BONGERS, F., POORTER, L., HAWTHORNE, WD. and SHEIL, D., 2009. The intermediate disturbance hypothesis applies to tropical forests, but disturbance contributes little to tree diversity. *Ecology Letters*, vol. 12, no. 8, p. 798-805. http://dx.doi.org/10.1111/j.1461-0248.2009.01329.x. PMid:19473218.

BOUVY, M., NASCIMENTO, SM., MOLICA, RJR., FERREIRA, A., HUSZAR, V. and AZEVEDO, SMFO., 2003. Limnological features in Tapacurá reservoir (northeast Brazil) during a severe drought. *Hydrobiologia*, vol. 493, no. 1-3, p. 115-130. http://dx.doi.org/10.1023/A:1025405817350.

CHELLAPPA, NT., BORBA, JA. and ROCHA, O., 2008. Phytoplankton community and physical-chemical characteristics of water in the public reservoir of Cruzeta, RN Brasil. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 68, no. 3, p. 477-494. http://dx.doi.org/10.1590/S1519-69842008000300004.

CHELLAPPA, NT., CÂMARA, FRA. and ROCHA, O., 2009. Phytoplankton community: indicator of water quality in the Armando Ribeiro Gonçalves reservoir and Pataxó channel, Rio Grande do Norte, Brazil. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 69, no. 2, p. 241-251. http://dx.doi.org/10.1590/S1519-69842009000200003. PMid:19675924.

COSTA, IAS., AZEVEDO, SMFO., SENNA, PAC., BERNARDO, RR., COSTA, SM. and CHELLAPPA, NT., 2006. Occurrence of toxin-producing cyanobacteria blooms in a Brazilian semiarid reservoir. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 66, no. 1B, p. 211-219. http://dx.doi.org/10.1590/S1519-69842006000200005. PMid:16710515.

Centro de Previsão de Tempo e Estudos Climáticos – CPTEC. Instituto Nacional de Pesquisas Espaciais – INPE, 2010. *Centro de Previsão de Tempo e Estudos Climáticos*. Available from: <http://www.cptec.inpe.br>. Access in: 05 Maio 2010.

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

DEVERCELLI, M., 2010. Changes in phytoplankton morpho-functional groups induced by extreme hydroclimatic events in the Middle Paraná River (Argentina). *Hydrobiologia*, vol. 639, no. 1, p. 5-19. http://dx.doi.org/10.1007/s10750-009-0020-6.

DOMIS, LNS., ELSER, JJ., GSELL, AS., HUSZAR, VLM., IBELINGS, BW., JEPPESEN, E., KOSTEN, S., MOOIJ, WM., ROLAND, F., SOMMER, U., DONK, EV., WINDER, M. and LÜRLING, M., 2013. Plankton dynamics under different climatic conditions in space and time. *Freshwater Biology*, vol. 58, no. 3, p. 463-482. http://dx.doi.org/10.1111/fwb.12053.

GERTEN, D. and ADRIAN, R., 2000. Climate-driven changes in spring plankton dynamics and the sensitivity of shallow polymitic lakes to the North Atlantic Oscillation. *Limnology and Oceanography*, vol. 45, no. 5, p. 1058-1066. http://dx.doi.org/10.4319/lo.2000.45.5.1058.

GOLTERMAN, HL., CLYMO, RS. and OHNSTAD, MAM., 1978. *Methods for physical and chemical analysis of fresh waters*. Oxford: Blackwell Scientific Publications. 213 p. IBP Handbook, no. 8.

GROISMAN, PY., KNIGHT, RW., EASTERLING, DR., KARL, TR., HEGERL, GC. and RAZUVAEV, VN., 2005. Trends in intense precipitation in the climate Record. *Journal of Climate*, vol. 18, no. 9, p. 1326-1350. http://dx.doi.org/10.1175/JCLI3339.1.

HILLEBRAND, H., DÜRSELEN, CD., KIRSCHTEL, D., POLLINGER, U. and ZOHARY, T., 1999. Biovolume calculation for pelagic and benthic microalgae. *Journal of Phycology*, vol. 35, no. 2, p. 403-424. http://dx.doi.org/10.1046/j.1529-8817.1999.3520403.x.

HOYER, AB., MORENO-OSTROS, E., VIDAL, J., BLANCO, JM., PALOMINO-TORRES, RL., BASANTA, A., ESCOT, C. and RUEDA, FJ., 2009. The influence of external perturbations on the functional composition of phytoplankton in a Mediterranean reservoir. *Hydrobiologia*, vol. 636, no. 1, p. 49-64. http://dx.doi.org/10.1007/s10750-009-9934-2.

HUISMAN, J., JONKER, RR., ZONNEVELD, C. and WEISSING, FJ., 1999. Competition for light between phytoplankton species: experimental tests of mechanistic theory. *Ecology*, vol. 80, no. 1, p. 211-222. http://dx.doi.org/10.1890/0012-9658(1999)080[0211:CFLBPS]2.0.CO;2.

HUSZAR, VLM. and REYNOLDS, CS., 1997. Phytoplankton periodicity and sequences of dominance in an Amazonian flood-plain (Lago Batata, Pará, Brazil): responses to gradual environmental change. *Hydrobiologia*, vol. 346, no. 1-3, p. 169-181. http://dx.doi.org/10.1023/A:1002926318409.

KARDINAAL, WEA. and VISSER, PM., 2005. Dinamics of Cyanobacterial toxins: Sources of variability in microcystin concentrations. In HUISSMAN, J., HANS, CPM. and VISSER, PM. (Eds). *Harmful cyanobacteria*. Netherlands: Springer. p. 41-64.

KLEMER, AR., 1976. The vertical distribution of *Oscillatoria agardhii var. isothrix. Archiv für Hydrobiologie*, vol. 78, p. 343-362.

KRUK, C., HUSZAR, VLM., PEETERS, ETHM., BONILLA, S., COSTA, L., LURLING, M., REYNOLDS, CS. and SCHEFFER, M., 2010. A morphological classification capturing functional variation in phytoplankton. *Freshwater Biology*, vol. 55, no. 3, p. 614-627. http://dx.doi.org/10.1111/j.1365-2427.2009.02298.x.

LEITE, AVL. and MACHADO, IC., 2010. Reproductive biology of woody species in Caatinga, a dry forest of northeastern Brazil. *Journal of Arid Environments*, vol. 74, no. 11, p. 1374-1380. http://dx.doi.org/10.1016/j.jaridenv.2010.05.029.

MARENGO, JA. and DIAS, PLS., 2006. Mudanças climáticas globais e seus impactos nos recursos hídricos. In REBOUÇAS, AC., BRAGA, B. and TUNDISI, JG. (Eds.). *Águas doces no Brasil: capital ecológico, uso e conservação.* (Ed.) São Paulo: Escrituras Editora. p. 26-48.

MARKER, AFH., NUSCH, EA., RAI, H. and RIEMANN, B., 1980. The measurements of photosynthetic pigments in freshwater and standardization of methods: conclusions and recommendations. *Archiv für Hydrobiologie*, vol. 14, supplement, p. 91-106.

PADISÁK, J., CROSSETTI, LO. and NASELI-FLORES, L., 2009. Use and misuse in application of the phytoplankton functional classification: a critical review with updates. *Hydrobiologia*, vol. 621, no. 1, p. 1-19. http://dx.doi.org/10.1007/s10750-008-9645-0.

PADISÁK, J., BORICS, G., FEHÉR, G., GRIGORSZKY, I., OLDAL, I., SCHMIDT, A. and ZÁMBÓNÉ-DOMA, Z., 2003. Dominant species, functional assemblages and frequency of equilibrium phases in late summer phytoplankton assemblages in Hungarian small shallow lakes. *Hydrobiologia*, vol. 502, no. 1-3, p. 157-168. http://dx.doi.org/10.1023/B:HYDR.0000004278.10887.40.

RANGEL, LM., SILVA, LHL., ARCIFA, MS. and PERTICARRARI, A., 2009. Driving forces of the diel distribution of phytoplankton functional groups in a shallow tropical lake (Lake Monte Alegre, Southeast Brazil). *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 69, no. 1, p. 75-85. http://dx.doi.org/10.1590/S1519-69842009000100009. PMid:19347148.

REYNOLDS, CS., 1988. Functional morphology and the adaptative strategies of freshwater phytoplankton. In SANDGREN, CD. (Ed.). *Growth and reproductive strategies of freshwater phytoplankton*. Cambridge: Cambridge University Press. p. 388-433.

REYNOLDS, CS., 1997. *Vegetation processes in the pelagic: a model for ecosystem theory*. Oldendorf: Ecology Institute. 372 p.

REYNOLDS, CS., 2000. Hydroecology of river plankton: the role of variability in channel flow. *Hydrological Processes*, vol. 4, no. 16-17, p. 3129-3132.

REYNOLDS, CS., PADISÁK, J. and SOMMER, U., 1993. Intermediate disturbance in the ecology of phytoplankton and the maintenance of species diversity: a synthesis. *Hydrobiologia*, vol. 249, no. 1-3, p. 183-188. http://dx.doi.org/10.1007/BF00008853.

SOMMER, U., PADISAK, J., REYNOLDS, CS. and JUHASZ-NAGY, P., 1993. Hutchinson's heritage: the diversity-disturbance relationship in phytoplankton. *Developments in Hydrobiology*, vol. 249, no. 1-3, p. 1-7. http://dx.doi.org/10.1007/BF00008837.

REYNOLDS, CS., HUSZAR, VLM., KRUK, C., NASSELI-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.

SALMASO, N. and PADISÁK, J., 2007. Morpho-functional groups and phytoplankton development in two deep lakes (Lake Garda, Italy and Lake Stechlin, Germany). *Hydrobiologia*, vol. 578, no. 1, p. 97-112. http://dx.doi.org/10.1007/s10750-006-0437-0.

SALMASO, N., 2003. Life strategies, dominance patterns and mechanisms promoting species coexistence in phytoplankton communities along complex environmental gradients. *Hydrobiologia*, vol. 502, no. 1-3, p. 13-36. http://dx.doi.org/10.1023/B:HYDR.0000004267.64870.85.

SCHEFFER, M., 2004. *Ecology of shallow lakes*. Amsterdam: Kluwer Academic Press. 357 p.

SHANNON, CE. and WEAVER, W., 1949. *The mathematic theory of communication*. Urbana: University of Illinois Press. 117 p.

SHAPIRO, J., 1990. Current beliefs regarding dominance by blue-greens: the case for the importance of CO2 and pH. *Verhandlungen - Internationale Vereinigung für Theoretische und Angewandte Limnologie*, vol. 24, p. 38-54.

WETZEL, RG. and LIKENS, GE., 2000. *Limnological analyses*. 3rd ed. New York: Springer. 429 p.

WHITFIELD, J., 2001. All creatures great and small. *Nature*, vol. 413, no. 6854, p. 342-344. http://dx.doi.org/10.1038/35096683. PMid:11574846.

WINDER, M. and SOMMER, U., 2012. Phytoplankton response to a changing climate. *Hydrobiologia*, vol. 698, no. 1, p. 5-16. http://dx.doi.org/10.1007/s10750-012-1149-2.

ZANON, JE., SIMÕES, NR. and RODRIGUES, L., 2013. Effects of recurrent disturbances on the periphyton community downstream of a dammed watercourse. *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 73, no. 2, p. 253-258. http://dx.doi.org/10.1590/S1519-69842013000200005. PMid:23917552.