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Diversity and Dominance in the phytoplankton community during nycthemeral cycles at different thermal patterns in the water body in the semiarid region of Brazil

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ABSTRACT

The vertical distribution of phytoplanktonic species in tropical regions responds quickly to the physicochemical factors of water with ecophysiological changes and biomass. Abiotic factors are responsible for the changes in the dominance of the different groups. The study analyzed the diversity and dominance of the phytoplankton community in a eutrophic reservoir localized in the semiarid region of Brazil. The samplings were conducted in nycthemeral cycles in different thermal regimes along a vertical profile. The biomass was determined by density and specific biovolume. Patterns of richness, diversity and specific dominance index were analyzed. The significant differences between the biotic data were analyzed by the ANOVA two-way and t-test. Similarity matrices were plotted using the Jaccard and Bray-Curtis indices with subsequent data ordination. 33 taxa were identified during the study. Differences in thermal patterns that are occurring in nycthemeral cycles showed changes in the structure of the phytoplankton community. The atelomictic event contributed to changing of the algal structure, especially in biomass, dominance, and diversity that shows significant differences between periods. The lowest diversity reported (< 1.03 bits.L^{-1}) were influenced by monospecific dominance of the cyanobacteria *C. raciborskii*, thus recording greater biomasses, forming blooms throughout the study period. In the tropical eutrophic reservoirs, an algal bloom of cyanobacteria has persisted throughout the year, regardless of variations in the thermal regime, thereby reducing the phytoplankton diversity.

Keywords: Atelomixia, cyanobacteria, daily cycles, eutrophic reservoir, thermal profiles.

Introduction

In aquatic water bodies from tropical regions, especially reservoirs, thermal patterns related to the condition of stratification and interactions between the system of vertical mixing and the availability of light and nutrients, beyond the ecophysiological factors. Among these factors, the presence of structures such as aerotopes, and biotic relationships, as predation and herbivory (Elser & Goldman, 1991; Reynolds, 2006) can interfere at the distribution and structure of phytoplankton in the water column (Tilzer & Goldman, 1978; Kimmel et al., 1990; Calijuri et al., 2002), establishing this way, the advantages of some species.

The physiological needs and responses that lead to changes, such as in diversity, biomass, taxonomic composition, dominance and patterns of vertical distribution of the phytoplanktonic species (Naselli-Flores & Barone 2005; Naselli-Flores et al., 2007; Becker et al., 2008; Tolotti et al., 2010) are rapid, proportionate to the brief life cycle of this group of organisms, where the variations tend to be higher than in the nycthemeral cycles in seasonal scales (MacIntyre & Melack, 1988). Thus, studies such as Becker et al. (2008), Borges et al. (2008), Bittencourt-Oliveira et al. (2012) have been conducted in nycthemeral scale (24 h) in order to understand the important questions about the dynamics of the algal community.

Throughout the studies into the behavior of phytoplankton in short time scale, some researchers have found the emergence of a pattern of differential thermal stratification in the tropical and subtropical systems of Brazil (Becker et al., 2008, 2009; Barbosa et al., 2011), known as atelomixis (Lewis, 1973). This phenomenon is characterized by daytime heating, and pronounced variability in wind speed, followed by nighttime cooling. It is responsible for a complex system and multiple thermoclines (Gunkel & Casallas, 2002), resulting in stratification and destratification in the water column, and characterized for being a driving factor, selecting certain phytoplanktonic species (Reynolds, 1999; Barbosa & Padisák, 2002).

This pattern of diurnal heating followed by a drop in temperature at night is common in the semi-arid region of northeastern Brazil. In this region, the reservoirs are characterized as eutrophic to hypertrophic, with consequent reduction in phytoplankton diversity and high biomass of cyanobacteria, leading to dominance of this group, which in turn, has been represented by one or a few species (Bouvy et al., 2000; Huszar et al., 2000; Chellappa & Costa, 2003; Aragão et al., 2007; Moura et al., 2011; Chellappa et al., 2008; Dantas et al., 2011; Bittencourt-Oliveira et al., 2012, 2014).

Dominance of cyanobacteria and low diversity of phytoplankton frequently occur in tropical reservoirs, and because this, it was necessary to assess the behavior of these algae, in light of any changes in the thermal regime, the present study aims to determine the structure of the algal community in a eutrophic reservoir in northeastern Brazil, at different depths along the nycthemeral cycles, caused by presence or not of atelomixis.

This study tested the hypothesis: 1) the atelomictic process contributes to the increase in biomass and algal dominance, and the consequent reduction in phytoplanktonic diversity in eutrophic reservoirs in the semiarid of Brazil, assuming that: (a) the high algal biomass promoted by the cyanobacteria bloom event, reduces the diversity of algae; (b) the changes in the thermal pattern of the ecosystem influences the algal structure and modifies the diversity and dominance of phytoplanktonic community.

Material and Methods

Study area

The study was conducted in Pedra reservoir (08°29'35"S and 36°56'39"W), in Agreste mesoregion of the state of Pernambuco, Brazil. This region had a tropical rainy climate type BShs' (hot and dry), typical of semi-arid (Albuquerque & Andrade, 2002), with two seasons: March through August (rainy) and September to February (dry). It has a maximum capacity of 2.9 x 10^6 m^3, with an extension of 1.6 km and volume of 2,658 hm^3 (ANA, 2013), and Zmax = 9m (SRH, 2012).

Data collection

Samplings collections were made in two climatic periods: August and December 2012, during nycthemeral cycles with intervals of four hours, beginning at 12AM, considering light (8AM, 12AM and 4PM) and dark periods (8PM, 12PM and 4AM). Water samples were collected with *van Dorn* bottle in the limnetic region, at a fixed point near the dam at four depths: surface (0.1 m), sub-surface (0.5 m), limit of the photic zone, estimated by the calculation proposed by Cole (1994), and aphotic layer (1 m above the sediment).

Vertical profiles with temperature and dissolved oxygen were carried from the surface to the aphotic layer, establishing intervals of 0.5 m to the depth of 5 m, and from this to the aphotic layer, intervals of 1m.

The environmental data were analyzed only for the characterization of the environment. Some abiotic variables were determined in situ: water temperature (°C) and dissolved oxygen ($mg.L^{-1}$) using an oximeter (Schott, HandyLab OX1), the limit of the photic zone estimated by Cole (1994), Zmax using a bathymeter and electrical conductivity with a conductivity meter (HandyLab LF1). Turbidity (NTU) and pH were analyzed *in situ* with a turbidimeter (Hanna Instruments, HI 93703) and a potentiometer (Digimed, DMPH-2), respectively.

Analyses to assess the concentrations of nitrate- NO_3, nitrite- NO_2 (Mackereth et al., 1978), ammonia nitrogen- NH_3^+ (Koroleff, 1976), orthophosphate- PO_4 and total phosphorus-PT (Strickland & Parsons, 1965) were measured at surface, subsurface, limit of the photic zone and aphotic layer in only one sampling collection (12PM), in both nycthemeral cycles.

The thermal patterns were determined from temperature profiles along the water column, and the stratification was considered stable when the average gradient showed a thermocline.

The phytoplankton was identified with the aid of specialized literature for each group of algae analyzing them to the lowest possible taxonomic level under a binocular microscope (Zeiss, Axiovert). The quantitative analysis was based on the counting of up to 400 organisms from the most frequent species (margin of error ≤ 10%) (Lund et al., 1958), using an inverted microscope (Zeiss, Axiovert), method described by Utermöhl (1958).

Thirty individuals of abundant species and 10 of the rare species were measured to calculate the biovolume, following the method described by Sun & Liu (2003). The biomass was determined from the density and specific cell biovolume is expressed in mg.L^{-1} (Wetzel & Likens, 2000).

Statistical analysis

The species richness (nº species) and Shannon diversity (H' = -Σpi.log pi; where, pi = ni/N, ni = biomass species; N = total sample biomass) (Shannon & Weaver, 1949) were determined, to assess the variations in the composition and structure of the phytoplankton community. The Simpson index (D) was used to assess the dominant species by calculating D = Σni (ni-1)/N(N-1).

Initially, the nycthemeral cycles were characterized based on the different thermal patterns. A two-criteria ANOVA analysis of variance was used per period to verify the significant differences based on data richness, diversity, dominance, and biomass between nycthemeral and depths. The t-test was used to assess the differences between these attributes at each depth between different thermal patterns.

The similarity of composition was analyzed using the matrices of the presence and absence of species, using the Jaccard index for depths, times and periods, and structure of phytoplankton, based on biomass, using data Bray-Curtis. Subsequently, ordination of the data was performed using the non-metric multidimensional scaling (NMDS).

Results

This study revealed differences in thermal patterns that occur in the different nycthemeral cycles in semiarid reservoirs. During the rainy period, it was observed the presence of atelomictic phenomenon, characterized by the alternation of daytime thermal stratification (with thermocline set between depths of 0.5 to 1.5 m) and destratification overnight, with cooling of the water column. While in dry the period, thermal stratification was marked throughout all hours of the cycle, not being registered atelomixis event (Figure 1).

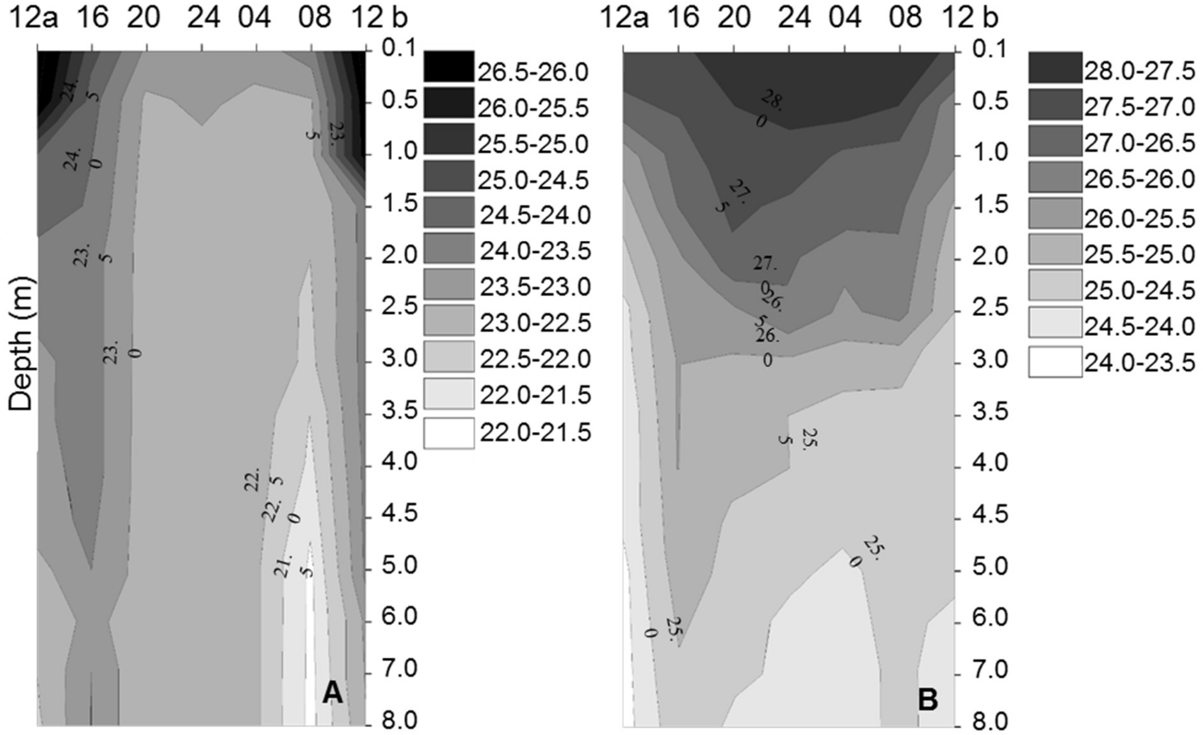

Figure 1. Thermal profile in nycthemeral cycles, (A) atelomictic (rainy season) and (B) non- atelomictic (dry), at different depths (over 8 m of the water column), at the Pedra reservoir, Northeast Brazil. Day interval (24 hours): 12a (12PM = 1st sampling), 4 PM, 8 PM, 24 AM, 4 AM, 8 AM, 12b (12 PM = last sampling).

A similar pattern to the thermal profiles it was analyzed by dissolved oxygen concentration, the stratified periods was observed, both atelomictic as the non-atelomictic, differences between layers were observed, showing a clinograde profile, which showed destratification along the water column (Figure 2).

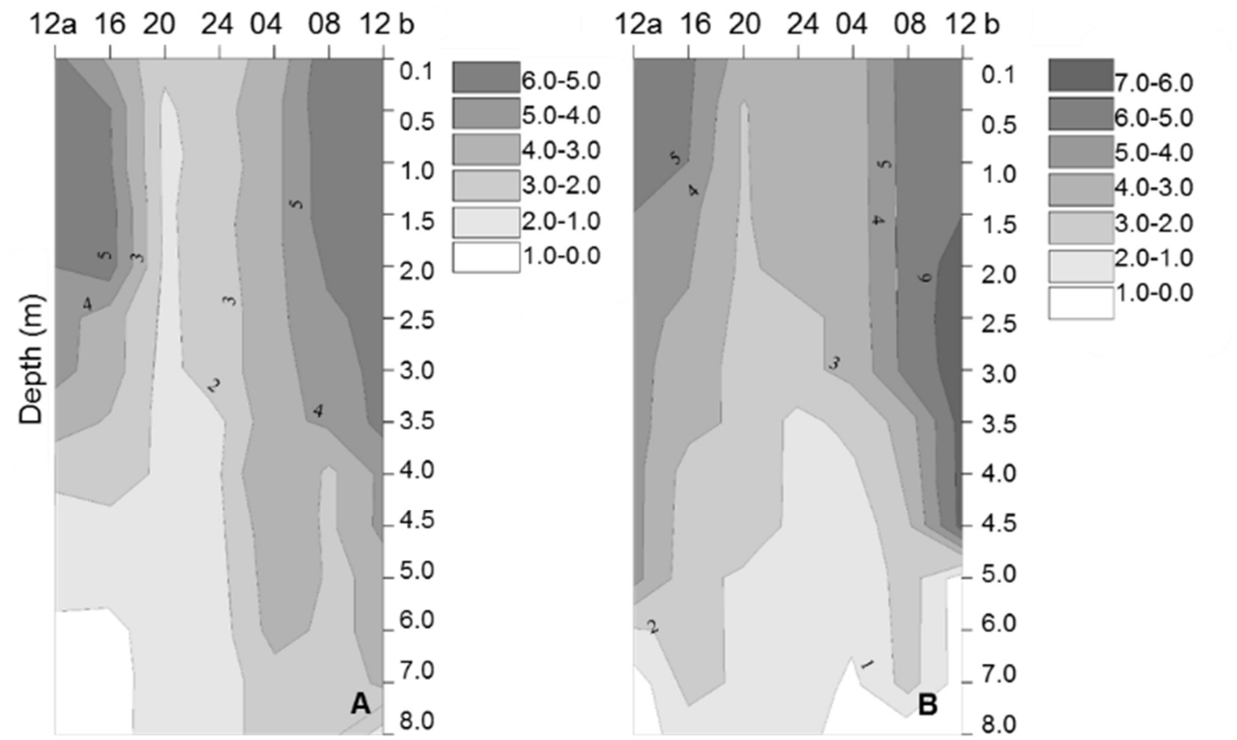

Figure 2. Dissolved oxygen profile in nycthemeral cycles, (A) atelomictic (rainy season) and (B) non-atelomictic (dry), at different depths (over 8 m of the water column), at the Pedra reservoir, Northeast Brazil. Day interval (24 hours): 12a (12PM = 1st sampling), 4 PM, 8 PM, 24 AM, 4 AM, 8 AM, 12b (12 PM = last sampling).

In both periods oxygen layers were assessed along the water column, especially in the epilimnion (3.8 - 6.6 mg.L^{-1}), especially in daytime hours (8 AM to 4 PM), while the at deeper layer (8m) was recorded hypoxia (0.2 - 2.5 mg.L^{-1}); pH was neutral to alkaline at the two studied periods and all sampling depths (Table 1). Significant differences between depths were recorded only to dissolved oxygen ($F = 12,027.66$; $p < 0.05$). However, among the nycthemeral cycles were observed differences in conductivity ($F = 49.60$; $p < 0.05$) and turbidity ($F = 10,877$; $p < 0.05$), with higher values in the non-atelomictic period (stratified) (Table 1).

Regarding the nutrients, high concentrations of ammonia and total phosphorus were registred, in atelomictic and non- atelomictic periods, with higher values in the deeper layers (NH_3^+: 1891 µg.L^{-1}; TP: 204.8 µg.L^{-1}) and the photic zone (NH_3^+: 1173.61 µg.L^{-1}; TP: 216.3 µg.L^{-1}), respectively, while the orthophosphate values presents higher during the period atelomictic (Table 1).

The phytoplankton community was composed by 33 taxa, distributed in six classes, Chlorophyceae (13 spp.), followed by Cyanophyceae (10 spp.). Twenty two taxa present in both study periods, demonstrating the low turnover of species throughout the study, as well as changes were not observed in composition or in the phytoplankton structure during nycthemeral cycle, and among the depths of the two cycles.

Cyanobacteria was present the largest phytoplankton biomass. In atelomictic period, a reduction in biomass was recorded along the depths and times of samplings, compare with those presented in the period non-atelomictic, the higher biomass was registred in atelomictic period (79.99 mg.L^{-1}), while in the non-atelomictic was 125,470 mg.L^{-1}, these biomasses were recorded at the 12aAM) (Table 2).

Considering a contribution above 5% of phytoplankton biomass, *Cylindrospermopsis raciborskii* (Woloszynska) Seenaya & Subba Raju highlighted in both study periods, while *Geitlerinema amphibium* (Agardh ex Gomont) Anagnostidis occurred only in the non-atelomictic period.

The higher biomasses were *C. raciborskii*, considered the only dominant species in all samples (94% of the biomass in the atelomictic cycle and 87% in the non-atelomictic), followed by *G. amphibium*, *Microcystis* sp., *Planktothrix agardhii* (Gomont) Anagnostidis & Komárek, *Phacus* sp. and *Staurastrum* sp. (Table 2).

It was observed similarity in both the vertical distribution of the total phytoplankton biomass pattern especially *C. raciborskii* in atelomictic and non-atelomictic periods. In atelomictic event, a low vertical heterogeneity was recorded, throughout the cycle, already during the non-atelomictic, more evidenced stratifications were observed in the hypolimnion (Figure 3ab).

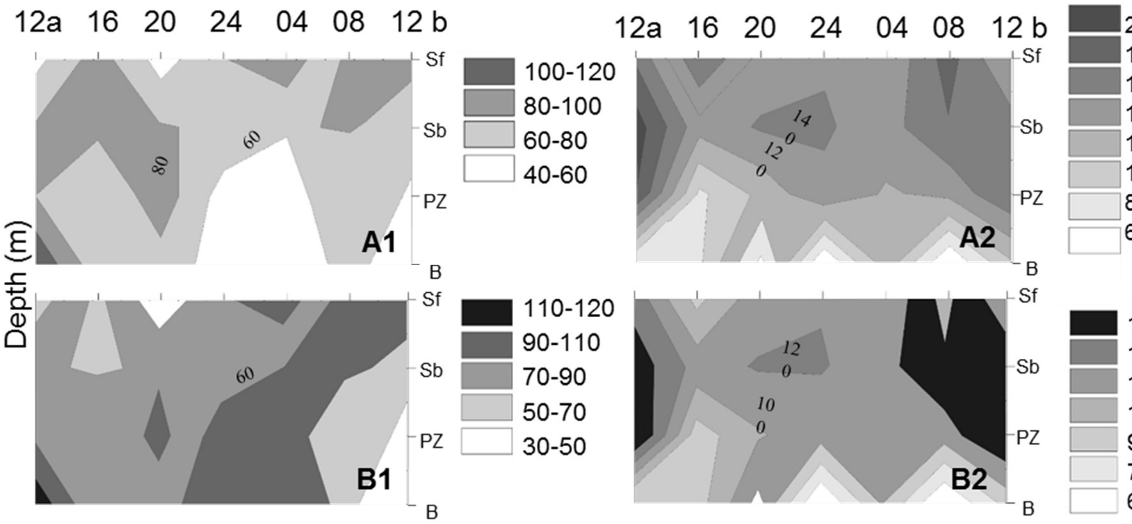

Figure 3. Depth-time diagrams of Phytoplankton. A. total biomass (mg.L^{-1}); A1. in the atelomictic period; A2. in the atelomictic period; B. Biomass *Cylindrospermopsis raciborskii*; B1. in the atelomictic period; B2. in the atelomictic period, during a 24-hour cycle, at different depths (surface, subsurface, photic zone and bottom) at the Pedra reservoir, Northeast Brazil. Day interval (24 hours): 12a (12PM = 1st sampling), 4 PM, 8 PM, 24 AM, 4 AM, 8 AM, 12b (12 PM = last sampling).

Lower diversity was observed throughout the study. The diversity index of the phytoplanktonic community was represented by values less than 1.03 bits.L^{-1}. Significant differences were observed between the hours ($p < 0.01$), and between the atelomictic and non-atelomictic periods (stratified) ($p < 0.01$), with the lowest index observed in the atelomictic period (0.38-0.60 bits.L^{-1}) (Table 2). The index of species dominance it was observed a variation between 0.73 to 0.93 along the samplings. Unlike the diversity index, there was an increase in species dominance during the atelomictic period (0.89-0.93), with significant differences between periods ($p < 0.01$) (Table 2).

Based on the richness, it was observed a high similarity between the periods and samplings depths. The ordination of non-metric multidimensional scaling (NMDS) (stress, 0.3) showed a single group without the formation of defined groups (Figure 4a). Whereas based in the biomass data, it was observed a formation of two distinct groups corresponding to the atelomictic and non-atelomictic periods. The NMDS ordination showed a seasonal trend in the 1st axis (stress, 0.1) (Figure 4b).

Table 1. Means of physical and chemical variables of the Pedra reservoir, in Pernambuco State, during the atelomictic (August 2012) and non-atelomictic (December 2012) periods along the vertical gradient. Conductivity (µS.cm^{-1}); D.O (Dissolved Oxygen). *(Sf-Surface, Sb-Subsurface, PZ-photic zone and B-bottom).

Thermal pattern/	**Atelomictic period**				**Non-atelomictic period**			
abiotic variable	**Sf**	**Sb**	**PZ**	**B**	**Sf**	**Sb**	**PZ**	**B**
Conductivity	209	220	220	243	261	258	258	249
D.O (mg.L^{-1})	4.16	4.33	4.37	1.35	4.83	4.7	4.48	0.81
pH	8.16	8.22	8.1	7.34	8.99	8.83	8.42	8.07
Turbidity	96.58	90.57	87.85	66.43	114.28	110.71	103.14	83.71
NO_3 (µg.L^{-1})	19.2	32.6	15.0	1.3	0.4	2.8	6.54	0.98
NO_2 (µg.L^{-1})	2.3	2.6	2.6	2.6	2.1	2.1	2.1	2.1
NH_3^+ (µg.L^{-1})	423.4	348.7	441.5	1,891.6	132.1	196.5	1,173.61	122.7
TP (µg.L^{-1})	157.4	142.4	134.9	204.8	144.2	182.8	216.3	162.2
PO_4 (µg.L^{-1})	113.2	94.1	98.9	130.8	21.6	18.7	47.55	21.62

Table 2. Biomass (mg.L^{-1}), diversity (bits.L^{-1}) and dominance of the phytoplankton community of the Pedra reservoir, in Pernambuco State, in nycthemeral scale (4h intervals) during the atelomictic (August 2012) and non-atelomictic (December 2012) periods. Day interval (24 hours): a = 1st and b = last sampling; + = taxa with biomass < 0.01 mg.L^{-1}.

Family/Species	**Biomass (mg.L^{-1})**													
	Atelomictic period							**Non-atelomictic period**						
	12a AM	**4 PM**	**8 PM**	**24 PM**	**4 AM**	**8 AM**	**12b AM**	**12a AM**	**4 PM**	**8 PM**	**24 PM**	**4 AM**	**8 AM**	**12b AM**
Cyanophyceae														
Aphanocapsa delicatissima	+	+		+	0.04		0.01	+		+	+	0.01	+	0.02
Chroococcus minutus	0.02	0.04	0.04	0.03	0.04	0.04	0.03	0.11	0.05	0.14	0.15	0.07	0.10	0.03
Cylindrospermopsis raciborskii	79.99	71.75	70.07	60.28	58.75	63.53	52.73	125.47	81.99	113.87	97.26	104.95	107.86	117.44
Dolichospermum sp.									0.57					
Geitlerinema amphibium	1.24	0.97	0.94	1.39	0.98	0.94	1.48	12.11	5.50	10.06	11.97	10.68	9.56	7.00
Merismopedia glauca									0.02	0.11				
Merismopedia tenuissima	0.37	0.42	0.32	0.22	0.36	0.51	0.42	0.32	0.22	0.12	0.15	0.42	0.18	0.25
Microcystis sp.	0.59	0.51	0.56	0.22	0.19	0.34	0.19	3.09	0.65	2.37	1.98	1.81	2.83	2.05
Planktothrix agardhii	0.84	0.77	1.53	0.71	0.52	0.72	0.51	0.83	0.79	0.92	0.81	1.17	0.77	1.07
Sphaerospermopsis aphanizomenoides	0.25	0.25												
Chlorophyceae														
Actinastrum sp.		0.12	0.08	0.09	0.12	0.08	0.07	0.11		0.08	0.11			
Ankistrodesmus sp.	0.13	0.39	0.14	0.05	0.03	0.12	0.05	0.12		0.10			0.10	
Chlorella vulgaris								0.04			0.01		0.04	
Closterium sp.	0.09	0.13	0.10	0.09	0.11	+	0.07			0.11			0.04	
Coelastrum sp.			0.05		0.04								0.10	
Crucigenia fenestrata	+	0.02	0.02	0.01	0.04	+	0.02	0.08	0.05	0.02	0.02	0.02	0.03	0.04
Golenkinia radiata												+		+
Kirchneriella sp.	+	+	+	+	+	+			+	+				+
Monoraphidium arcuatum	0.06	0.14	0.19	0.09	0.13	0.13	0.11	0.71	0.37	0.65	0.44	0.60	0.62	0.62
Monoraphidium contortum	0.03													
Monoraphidium griffithii						0.03	0.01				0.06			
Scenedesmus sp.	0.14	0.02	0.15	0.12		0.14		0.14	0.17			0.16		0.22
Staurastrum sp.								2.32		1.39		1.82	2.65	1.55
Bacillariophyceae														
Aulacoseira granulata										0.01				
Cyclotella meneghiniana								0.23						
Nitzschia palea	0.02									0.03				
Surirella sp.									0.01		0.10			
Ulnaria ulna	0.09	0.09	0.09	0.09		0.09	0.08	0.19	0.7	0.25	0.12	0.27	0.20	0.18
Euglenophyceae														
Euglena acus			0.07				0.18							
Phacus sp.	0.61	1.08	1.38				0.75	1.82		1.56	5.28	2.31	1.93	2.60

Trachelomonas sp.	0.05							0.17	0.05	0.06				
Dinophyceae														
Peridinium sp.	0.08			0.05				0.40	0.08	0.08	0.07	0.11	0.07	
Cryptophyceae														
Cryptomonas ovata	0.14	0.19	0.08	0.10	0.07	0.06	0.05	0.50	0.10	0.13	0.23	0.11	0.11	0.16
Diversity	**0.49**	**0.56**	**0.60**	**0.43**	**0.38**	**0.43**	**0.56**	**1.01**	**0.71**	**0.89**	**1.02**	**0.97**	**0.96**	**0.81**
Dominance	**0.91**	**0.90**	**0.89**	**0.91**	**0.93**	**0.91**	**0.89**	**0.74**	**0.83**	**0.78**	**0.73**	**0.75**	**0.77**	**0.81**

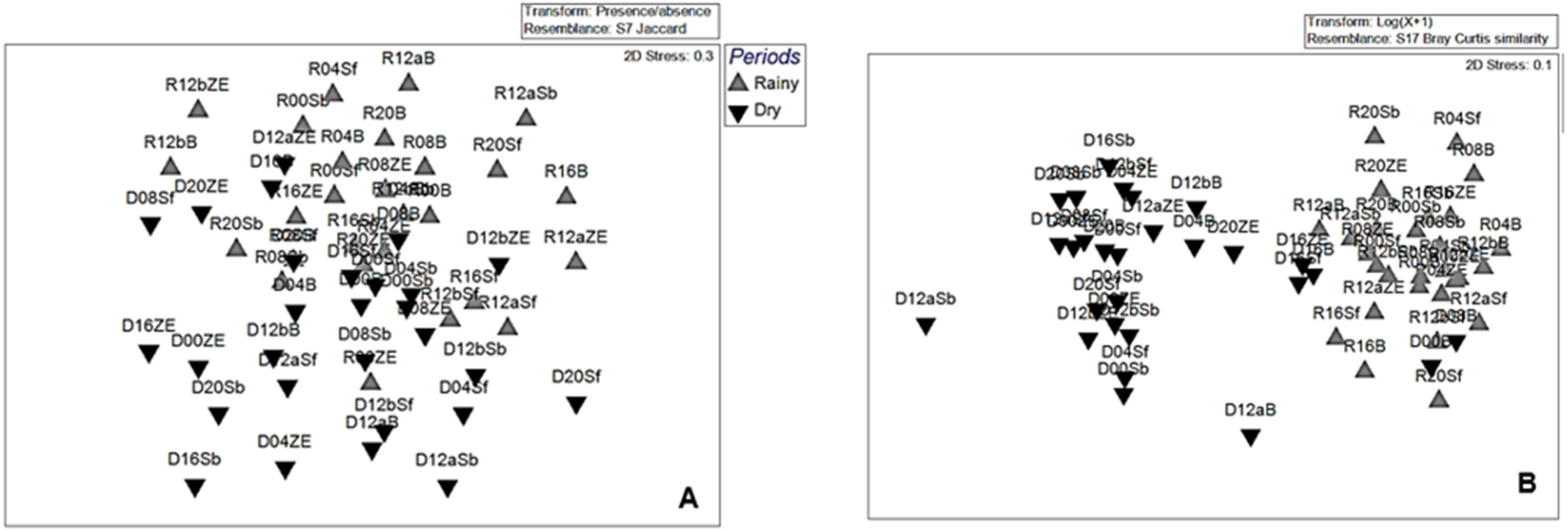

Figure 4. NMDS ordination of phytoplankton community during atelomictic and non-atelomictic periods, in temporal and spatial dynamics with data based on the Jaccard richness index (A) and Bray-Curtis biomass (B). D (dry period- non-atelomictic), R (rainy period- atelomictic); Day interval (24 hours): 12a (12PM = 1st sampling), 4PM, 8PM, 24AM, 4AM, 8AM, 12b (12PM = last sampling); Depth (Sf-Surface, Sb-Subsurface, ZE-photic zone and B-bottom).

Discussion

The Pedra reservoir may be considered a tropical ecosystem, eutrophic and shallow, has been characterized by changes in community structure, which are directly related to the different thermal patterns (Bouvy et al., 2000; Pannard et al., 2008; Dantas et al., 2011).

These distinct patterns were found throughout the cycles nycthemeral, which could be classified into atelomictic and non-atelomictic period. The atelomictic characterized by alternating temperatures where the diel heating causes superficial stratification, followed by overnight cooling with mixing, promoted by temperature decrease, can change the biotic and abiotic conditions along the water column (Lewis, 1973; Barbosa & Padisák, 2002) the non-atelomictic period, was marked only by the presence of thermal stratification throughout the nycthemeral cycle.

According Esteves (1998), atelomictic event were characterized by typical polymictic hot water ecosystems, which have repeated periods of movement and short heating intervals with light layering, followed by rapid cooling of the water column. This scenery has been observed by several researchers (Barbosa & Padisák, 2002; Lopes et al., 2005; Tavera & Martínez-Almeida, 2005; Souza et al., 2008; Becker et al., 2009; Lopes et al., 2009; Barbosa et al., 2011; Borics et al., 2011), which highlight the influence of this phenomenon in the distribution of phytoplankton along the water column, as a driver factor species-specific.

The atelomictic phenomenon, according to Bouvy et al. (2003), occurs due the changes in the density of water in the surface layers, promoted by the increase of the air temperature and the incidence of light during the day, forming layers that are dissolved with cooling at night. Studies has indicated that in aquatic ecosystems, mainly tropical, there is permanent thermocline in a seasonal period, i.e., stratification, and in another period, there is the presence of atelomixis (Barbosa & Padisák, 2002; Bouvy et al., 2003; Lopes et al., 2005; Becker et al., 2008; Souza et al., 2008; Lopes et al., 2009; López et al., 2012). Some of these argue that this phenomenon presents a controlling factor for maintaining species listings in the epilimnion during periods of thermal stratification, thus bringing the success of Chlorophyceae species in these environments (Barbosa & Padisák, 2002; Souza et al., 2008; López et al., 2012). In Pedra reservoir, although wealth has been represented mostly by Chlorophyceae, but this group did not contribute with representatives' biomasses.

The different periods analyzed were not marked by destratification during the rainy period and stratification during the dry period, related to seasonal thermal pattern, as observed for others works to the tropics (Barbosa et al., 2011; Dantas et al., 2011; Bittencourt-Oliveira et al., 2012). In this study, the atelomictic event in rainy season, may have occurred because of hydrological changes (severe droughts throughout the year, making it atypical), and probably this thermal condition has not contributed strongly to changes in most physical and chemical conditions between the two periods, and therefore has not promoted changes on the composition and species dominance.

Regarding abiotic variables, it was found that the pattern of chemical stratification, in dissolved oxygen concentration, followed the pattern of thermal stratification, revealing a clinograde profile with oxygen deficit, especially in the hypolimnion. While the stage with destratification (atelomictic period, at night) was demonstrated a trend variable homogeneity throughout the water column.

According to Esteves (1998), the oxygen deficit is mainly determined by high temperatures, by morphometric characteristics, which hinder or facilitate the action of wind, and high concentration of organic matter in the aquatic ecosystem. Concerning pH, this appeared neutral to alkaline, characteristic buffered environments in both nycthemeral cycles.

The electrical conductivity and turbidity were presents higher concentrations during non-atelomictic period (stratified), this is because they are associated with low rain fall, evaporation rate, and possible exogenous contributions by human action, especially the entry of domestic sewage and runoff water. The increase of nutrient concentrations is also favored by these actions, promoting artificial eutrophication, and hence siltation and death of the water body (Margalef, 1983). In this study we showed higher ammoniacal nitrogen and total phosphorus concentrations in the hypolimnion, during the atelomictic period, and at metalimnion, during non-atelomictic. Besides these, was also found higher concentrations of orthophosphate during the event with atelomixis.

It was expected that, during the atelomictic period, a greater input of nutrients along the water column, due the resuspension of the pellet process (Chellappa & Costa, 2003). This condition favors important misture of the water column, changes in light availability in the epilimnion, vertical gradient of other abiotic factors, and changes in the structure of algal, as replacement of cyanobacteria by other phytoplankton groups or even by other species of cyanobacteria (Heo & Kim, 2004; Becker et al., 2008; Dantas et al., 2011).

During the atelomictic and non-atelomictic periods, changes in the structure of phytoplankton was observed in biomass, diversity and dominance, since a reduction in the diversity and biomass was observes at the atelomictic period, with a consequent increase in species dominance. Although there was a decrease in the biomass in this period, throughout the study, blooms with monospecific dominance of cyanobacteria *C. raciborskii*, which persisted throughout the period. In Northeast Brazil ecosystems, the only event of dominance, throughout the year, it has been registered, with variations in biomass may be related to changes in temperature or thermal patterns (Bouvy et al., 1999; Huszar et al., 2000; Dantas et al., 2011).

The dense development of *C. raciborskii* was also recorded by Shafik et al. (2001) during the atelomictic event, but the authors did not associate the occurrence of this cyanobacteria with thermal event, but the fact of this species is adapted to different environmental conditions, like low luminosity.

Bittencourt-Oliveira et al. (2012) other semiarid reservoir, observed changes in composition and biomass of cyanobacteria during stratification and destratification periods, with marked by seasonal differences, without occurrence of atelomictic phenomenon. In this work it was observed that during the stratification period, occurred the dominance of *C. raciborskii*, and during destratification occurred, a reduction of algal biomass, although the dominance of cyanobacteria has persisted throughout the study period.

According to Melack (1979), tropical lakes are generally ecosystems exposed to low climate variability, which has directed a low diversity of species, due the persistence of one or few phytoplankton species. The dominance and persistence observed in this work, specifically to *C. raciborskii* occurred regardless of the particular pattern of atelomixis and can thus interpret different thermal patterns, and in some cases do not interfere with the establishment of algae.

In eutrophic-hypertrophic reservoirs in the Northeast, it is common the presence of perennial blooms formed by one or several species of cyanobacteria that can regulate their position in the column, because this species normally have vacuoles that aids in buoyancy (Moura et al., 2011). Among these, *C. raciborskii* is a species often found in these environments (Bouvy et al., 2000; Chellappa & Costa, 2003; Von Sperling et al., 2008; Moura et al., 2011), and its persistent dominance can be attributed to great and frequent temperature conditions, as well as tolerance to low light intensity.

The low diversity values observed throughout the study were therefore influenced by the low richness and dominance of only one specie (*C. raciborskii*), corroborated with Calijuri & Dos Santos (1996) and Dos Santos & Calijuri (1998), which showed low fluctuations in the structure of phytoplankton. According to Holzmann (1993), the low diversity occurs when the conditions select few species which dominate the environment and the effect of predation becomes resistant. Thus, the decrease in phytoplankton diversity is attributed to the formation of algal blooms, thereby contributing to a negative ecological impact on the aquatic ecosystems.

Conclusion

Differences in thermal patterns that occurring in nycthemeral cycles showed changes in the structure of the phytoplankton community. In the present study, the atelomictic event contributed in changing of the algal structure, especially in biomass, dominance and diversity that shows significant differences between periods.

In a less stable thermal condition, such as the atelomictic event, the reduction of diversity has led to the increased dominance of *C. raciborskii* and can thus be concluded that during this period, a greater adaptation of this dominant species occurs, even though the biomass was lower in the stratified period.

Although the biomass values were elevated throughout the work, during the atelomixis event, it was observed formation of multiple thermoclines with diurnal stratification followed by destratification at night, there was a reduction in algal biomass at all sampling depths, and it can be thus observed that this change occurred as a result of the mobility of organisms in the water column in a nycthemeral cycle.

Dominance of cyanobacteria has persisted, performing at steady state, throughout the year, regardless of the variations in thermal regime, thereby reducing the phytoplankton diversity.

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