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Planktonic Cyanobacteria forming blooms in reservoirs of northeastern Brazil

Nísia K. C. Aragão-Tavares[1], Ariadne do N. Moura[1] & Maria do Carmo Bittencourt-Oliveira[2]

[1] Universidade Federal Rural de Pernambuco, Departamento de Biologia, Área de Botânica, Rua Dom Manoel de Medeiros, s/n, Dois Irmãos, CEP 52171-900, Recife-PE, Brasil. E-mail: nisiakarine@yahoo.com.br; ariadne_moura@hotmail.com
[2] Universidade de São Paulo, Escola Superior de Agricultura Luiz de Queiroz, Departamento de Ciências Biológicas, Av. Pádua Dias, 11, Universitário, CEP 13418-900, Piracicaba-SP, Brasil. Caixa Postal 9. E-mail: mbitt@usp.br

ABSTRACT

This paper contributes to the inventory of cyanobacteria in freshwater environments in Northeastern Brazil. Forty-two samples were collected from 19 reservoirs between February 2009 and January 2010. Twenty-three species of cyanobacteria distributed among the orders Chroococcales (10), Oscillatoriales (8) and Nostocales (5) were identified, 12 of which constitute new records for the state of Pernambuco. The greatest degrees of species richness were recorded in three ecosystems (Alagoinha, Carpina and Ingazeira reservoirs). *Microcystis* was the most representative genus, with the greatest number of species (*Microcystis novacekii* (Komárek) Compère, *Microcystis panniformis* J. Komárek, J. Komárková-Legnerová, C.L. Sant'Anna, M.T.P. Azevedo & P.A.C, Senna, *Microcystis protocystis* W.B. Crow and *Microcystis* sp.). *Cylindrospermopsis raciborskii* (Woloszynska) Seenaya and Subba Raju (straight morphotype) had the greatest distribution (considered very frequent) and was present in 16 reservoirs (84.25%). Only four of the 42 samples did not have cyanobacteria.

Key words: cyanophyta, phytogeographic distribution, species richness, taxonomy

Cianobactérias planctônicas formadoras de florações em reservatórios do nordeste do Brasil

RESUMO

Este trabalho contribui para o inventário das cianobactérias de ambientes de água doce do Nordeste do Brasil. 42 amostras foram coletadas em 19 reservatórios, entre fevereiro de 2009 e janeiro de 2010. Foram identificadas 23 espécies de cianobactérias distribuídas nas ordens Chroococcales (10), Oscillatoriales (8) e Nostocales (5), dentre as quais 12 se constituem em novas citações para o estado de Pernambuco. A maior riqueza de espécies foi registrada em três ecossistemas (Reservatórios de Alagoinha, Carpina e Ingazeira). *Microcystis* foi o gênero mais representativo com maior número de espécies (*Microcystis novacekii* (Komárek) Compère, *Microcystis panniformis* J. Komárek, J. Komárková-Legnerová, C. L. Sant'Anna, M. T. P. Azevedo & P. A. C, Senna, *Microcystis protocystis* W. B. Crow and *Microcystis* sp.). *Cylindrospermopsis raciborskii* (Woloszynska) Seenaya e Subba Raju (morfotipo reto) apresentaram maior distribuição (considerada muito frequente), presentes em 16 reservatórios (84.25%). Apenas quatro das 42 amostras não apresentaram cianobactérias.

Palavras-chave: cyanophyta, distribuição fitogeográfica, riqueza de espécies, taxonomia

Introduction

Cyanobacteria are cosmopolitan organisms considered to be the first photosynthesizers with chlorophyll a and primary producers to release oxygen into the atmosphere (Chorus & Bartram, 1999). These organisms exhibit broad ecological tolerance, which contributes to their competitive success. One of the striking characteristics of this group is the ability to grow in the most varied environments – from hot springs to cold oceans as well as in terrestrial environments (Domitrovic & Forastier, 2005).

However, freshwater ecosystems are the most suitable environments for the development of cyanobacteria, especially in tropical regions, which have the most favorable conditions for cyanobacterial blooms – a phenomenon characterized by the intensive growth of these microorganisms in water (Chorus & Bartram, 1999). As well as increases in nutrients, changes in temperature and mixing regime are important factors related to these blooms (Paerl & Huisman, 2008).

Cyanobacteria possess a range of unique and highly-adaptable eco-physiological traits (Litchman et al., 2010). These traits, which can be specific at the genus level, such as: 1) the ability to grow in warmer temperatures; 2) buoyancy, due to gas vesicle production; 3) high affinity for, and ability to store, phosphorus; 4) nitrogen-fixation; 5) akinete production and associated life history characteristics; and 6) light capture at low intensities (Carey et al., 2012). Reservoirs in Northeastern Brazil offer these conditions and therefore favor the occurrence of cyanobacterial populations (Bittencourt-Oliveira & Molica, 2003; Chellapa et al., 2008; Dantas et al., 2008, 2012; Moura et al., 2007, 2010, 2011).

The extensive morphological plasticity and overlapping measures in species of cyanobacteria have caused problems in the correct identification of taxa, and therefore, according to Bittencourt-Oliveira et al. (2001), this can lead to a false understanding of the toxic potential of various species. Due to these problems, there are few works that aim as the primary focus aspects of taxonomic group, and thus, only about 5-10% of this diversity is known (Komárek, 2003).

In Pernambuco, studies on cyanobacteria began with Carvalho-De-La-Mora (1986) and were intensified after the "syndrome of Hemodialysis". Jochimsen et al. (1998) reported the occurrence of microcystin in the hemodialysis equipment of the Institute of kidney Diseases in Caruaru City (Pernambuco-Brazil) the place of contamination and death of humans by cyanotoxins. Then, Domingos et al. (1999) confirmed the production of microcystin by picoplankton cyanobacteria isolated from material collected in two reservoirs in the state of Pernambuco (Tabocas and Sr. José Maria), used to supply the city of Caruaru, suggesting that these organisms may have contributed to human poisoning in hemodialysis clinic of the municipality.

Then, several studies with distinct approaches (ecology, taxonomy, seasonal and spatial distribution) were carried out with cyanobacteria in many reservoirs used for public supply in the state of Pernambuco, (Bouvy et al., 2000, 2001, 2003; Huszar et al., 2000; Aragão et al., 2007; Dantas et al., 2008, 2011; Lira et al., 2010; Moura et al., 2010, 2011; Bittencourt-Oliveira et al., 2011). Considering the frequent blooms of cyanobacteria and the problems posed to aquatic ecosystems, the present study aimed to contribute to the knowledge of the diversity of these algae in reservoirs in Northeast of Brazil, since, in most cases, the blooms are formed by species potentially toxic, causing a risk to public health.

Material and Methods

Study Area and Sampling

Forty-two samples were taken from 19 reservoirs located in different phytogeographic regions in the state of Pernambuco (Figure 1) (Table 1), which are characterized by high temperatures and dry periods, especially between October and March (summer); the winter (April to September) is featured by greater precipitation and milder temperatures. These ecosystems are used mainly for the public water supply and fishing activities of about three million inhabitants (ANA, 2012).

Sampling was carried out at a single point at the subsurface near the bank between February 2009 and January 2010. The taxonomic study was performed based on semi-permanent slides with samples of living matter analyzed immediately after collection and complemented with samples preserved in formalin and Transeau solution. Analyses were performed with the aid of a ZEISS optical microscope (Jenaval model) with a measurement ocular (magnification: 400X and 1000X).

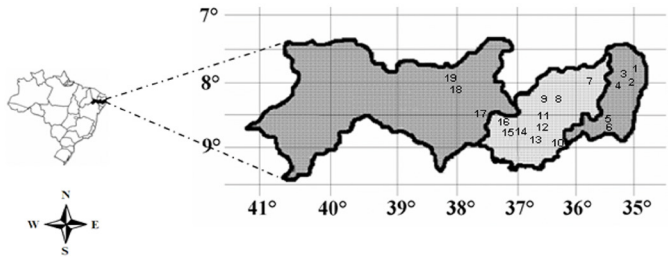

Figure 1. Map of location of the reservoirs in the state of Pernambuco. 1- Botafogo, 2- Duas Unas, 3- Tapacurá, 4- Carpina, 5- Pastora, 6- Santo Antônio dos Palmares, 7- Jucazinho, 8- Bitury, 9- Ipojuca, 10- Mundaú, 11- Alagoinha, 12- Venturosa, 13- Ingazeira, 14- Pedra, 15- Arcoverde, 16- Buíque, 17- Poço da Cruz, 18- Jazigo, 19- Saco I

Morphological taxonomic characteristics of the organisms were analyzed, such as shape and dimensions of the heterocyst, akinetes, trichomes and cells as well as the presence of aerotopes and coloration. Identification was carried out to the smallest possible taxonomic level using the specialized literature (Komárek & Anagnostidis, 1986; 2005; Anagnostidis & Komárek, 1988; Cronberg & Annadotter, 2006; Komárek & Zapomělová, 2007).

After analysis and taxonomic photomicrographs, samples preserved with formalin, were deposited in the Herbarium Professor Vasconcelos Sobrinho, Federal Rural University of Pernambuco (PEURF 50435 to 50476).

Frequency of occurrence was calculated based on the system proposed by Mateucci & Colma (1982), considering the following categories: > 70% = very frequent (VF); ≤ 70% and > 40% = frequent (F); ≤ 40% and > 10% = occasional (O); and ≤ 10% = sporadic or rare (S).

Table 1. Location of the reservoirs, sampling dates, phytogeographical region and coordinates

Reservoirs (City)	Sampling dates	Phytogeographical region	Coordinates
Alagoinha (Alagoinha)	04/2009, 10/2009	Agreste	8°27'31.9" S, 6°46'33.5" W
Arcoverde (Buíque)	05/2009, 11/2009	Agreste	8°33'32.5" S, 6°59'07.5" W
Bitury (Belo Jardim)	02/2009, 04/2009	Agreste	08°18'35" S, 36°25'36" W
Botafogo (Igarassu)	05/2009, 10/2009	Litorânea	7°50'11.8" S, 35°02'0.8" W
Buíque (Buíque)	06/2009, 11/2009	Agreste	8°37'52.7" S, 7°07'53.5" W
Carpina (Lagoa do carro)	04/2009, 10/2009	Zona da Mata	7°53'03.8" S, 5°20'37.8" W
Duas Unas (Jaboatão dos Guararapes)	05/2009, 10/2009	Zona da Mata	8°05'02" S, 35°30.6" W
Ingazeira (Venturosa)	04/2009, 10/2009	Agreste	8°36'41.2" S, 6°54'23.7" W
Ipojuca (Belo Jardim)	04/2009, 11/2009	Agreste	8°20'43.7" S, 36°22'31.5" W
Jazigo (Serra Talhada)	05/2009, 01/2010	Sertão	8°00'08.2" S, 38°12'38.5" W
Jucazinho (Surubim)	03/2009, 10/2009	Agreste	7°59'03" S, 35°48'36.7" W
Mundaú (Garanhuns)	03/2009, 11/2009	Agreste	8°56'42.8" S, 36°29'27.4" W
Pastora (Palmares)	06/2009	Zona da Mata	08°41'28.5" S, 5°36'53.8" W
Pedra (Pedra)	06/2009, 11/2009	Agreste	8° 29'37" S, 36°56'40" W
Poço da Cruz (Ibimirim)	05/2009, 01/2010	Sertão	8°30'31.5" S, 37°42'17.9" W
Saco I (Serra Talhada)	05/2009, 01/2010	Sertão	7°56'49.3" S, 38°17'13.1" W
Santo Antônio dos Palmares (Palmares)	06/2009	Zona da Mata	08°41'35.7" S, 5°39'24.6" W
Tapacurá (São Lourenço da Mata)	03/2009, 10/2009	Litorânea	8°02'31.9" S, 35°11'46.5" W
Venturosa (Venturosa)	04/2009, 10/2009	Agreste	8°34'43.6" S, 36°52'47.3" W

Results and Discussion

Cyanobacteria were recorded in 38 of the 42 samples analyzed. Twenty-three species were identified in the 19 ecosystems, distributed among the orders Oscillatoriales, (10 spp.), Chroococcales (8 spp.) and Nostocales (5 spp.) (Table 2). The greatest degrees of species richness were recorded in the Alagoinha, Carpina and Ingazeira reservoirs (10 spp.). *Cylindrospermopsis raciborskii* (Woloszynska) Seenayya et Subba Raju and *Sphaerospermopsis aphanizomenoides* (Forti) Zapomelová, Jezberová, Hrouzek, Hisem, Reháková & Komárková were present in all samples from these reservoirs.

The total number of species identified was relatively smaller than that recorded in previous studies with emphasis at cyanobacteria community at Northeastern of Brazil (Aragão et al., 2007; Costa et al., 2009; Dantas et al., 2011; Lira et al., 2011) who recorded greater cyanobacterial richness. The lower number of taxa in the present study is likely due to the occurrence of *blooms* dominated by one or more species of cyanobacteria in the majority of reservoirs studied. The genus *Microcystis* was the most representative, with four species (*M. novacekii* (Komárek) Compère, *M. panniformis* J. Komárek, J. Komárková-Legnerová, C.L. Sant'Anna, M.T.P. Azevedo & P.A.C, Senna, *M. protocystis* W.B. Crow and *Microcystis* sp.). These same species were

Table 2. Taxa of Cyanobacteria and frequence of occurrence (F.O. %) in 19 reservoirs of semiarid region of state of Pernambuco. Reservoir: 1-Alagoinha, 2-Arcoverde, 3-Bitury, 4-Botafogo, 5-Buíque, 6-Carpina, 7-Duas Unas, 8-Ingazeira, 9-Ipojuca, 10-Jazigo, 11-Jucazinho, 12-Mundaú, 13-Pastora, 14-Pedra, 15-Poço da Cruz, 16-Saco I, 17-Santo Antônio dos Palmares, 18-Tapacurá and 19-Venturosa

Taxa/Reservoirs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	F.O. (%)
Chroococcaceae																				
Chroococcus obliteratus	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	10.52(O)
Chroococcus sp.	+	-	-	-	-	+	-	-	-	-	-	-	-	+	+	-	-	-	+	26.31(O)
Merismopedia glauca	-	+	-	-	+	-	-	+	-	-	-	-	+	-	-	+	-	-	-	26.31(O)
M. tenuissima	+	+	-	+	-	-	-	+	-	-	-	+	-	+	-	-	-	+	+	42.10(F)
Microcystaceae																				
Microcystis novacekii	+	-	-	-	-	-	+	-	-	-	-	+	-	+	-	-	-	-	-	21.05(O)
M. panniformis	+	+	-	-	-	+	+	-	-	-	-	+	-	+	-	-	-	+	-	36.84(O)
M. protocystis	+	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	+	-	21.05(O)
Microcystis sp.	+	-	-	+	+	-	+	-	+	-	+	+	-	-	-	-	-	+	-	42.10(F)
Oscillatoriaceae																				
Lyngbya cf. *ceylanica*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	5.26(S)
Oscillatoria princeps	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	10.52(O)
Oscillatoria sp.	-	-	-	-	-	+	-	-	-	+	+	-	-	+	-	-	-	+	-	26.31(O)
Phormidiaceae																				
Planktothrix agardhii	+	+	-	-	-	+	+	+	+	-	+	-	-	-	-	-	+	+	-	47.36(F)
P. isothrix	-	-	-	-	-	+	-	-	+	-	+	-	-	+	-	-	-	-	-	21.05(O)
Planktothrix sp.	-	-	-	+	-	-	-	-	-	+	-	-	-	-	+	+	+	-	-	26.31(O)
Pseudanabaenaceae																				
Geitlerinema amphibium	+	+	+	-	+	+	+	+	+	-	+	+	-	+	+	+	-	+	-	73.68(VF)
Pseudanabaena catenata	+	+	+	+	+	+	-	+	+	-	+	+	-	+	-	-	-	+	-	63.15(F)
P. papillaterminata	-	+	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	+	-	21.05(O)
Spirulina major	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	5.26(S)
Nostocaceae																				
Cylindrospermopsis raciborskii (Straight)	+	+	+	-	+	+	+	+	+	-	+	+	-	+	+	+	+	+	+	84.25(VF)
C. raciborskii (Coiled)	+	-	+	-	+	+	+	+	+	-	+	+	-	+	+	+	-	+	-	68.42(F)
Dolichospermum maximum	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	5.26(S)
D. torques-reginae	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	10.52(O)
Dolichospermum sp.	+	-	+	-	-	+	-	+	+	-	+	-	-	-	-	-	-	+	-	36.84(O)
Sphaerospermopsis aphanizomenoides	+	+	+	+	+	+	+	+	+	-	+	-	-	-	-	+	-	+	-	63.15(F)

recorded by Costa et al. (2006) forming blooms in the Armando Ribeiro Gonçalves reservoir in the state of Rio Grande do Norte (Northeastern Brazil).

Ten new taxa are recorded for the state of Pernambuco: *Chroococcus obliteratus* Richter, *Microcystis novacekii*, *M. protocystis*, *Lyngbya* cf. *ceylanica* Wille¸ *Planktothrix isothrix* (Skuja) Komárek & Komárková, *Pseudanabaena papillaterminata* (Kiselev) Kukk¸ *Spirulina major* Kützing ex Gomont, *Dolichospermum maximum* (Cronberg et Komárek) Wacklin, *D. torques-reginae* (Komárek) Wacklin and *Sphaerospermopsis aphanizomenoides*. Moreover, the genera *Dolichospermum* and *Sphaerospermopsis* were renamed, as previous studies have described these genera as *Anabaena* and *Aphanizomenon*, respectively (Wacklin et al., 2009; Zapomělová et al., 2010).

C. raciborskii is one of cyanobacteria bloom-forming species in Brazilian ecosystems and populations with straight and coiled trichomes have been observed in Northeastern Brazil (Bittencourt-Oliveira et al., 2011). The straight morphotype of *C. raciborskii and Geitlerinema amphibium* (Agardh ex Gomont) Anagnostidis were very frequent species with 84.25% and 73.68% of occurrence, followed by the coiled morphotype of *C. raciborskii*, *Merismopedia tenuissima* Lemmermann, *Microcystis* sp., *Planktothrix agardhii* (Gomont) Anagnostidis & Komárek, *Pseudanabaena catenata* Lauterborn and *S. aphanizomenoides*, which were considered

Figure 2. Planktonic Cyanobacteria recorded in reservoirs in the state of Pernambuco. a. *Cylindrospermopsis raciborskii* coiled morphotype, b. *C. raciborskii* straight morphotype, c. *Geitlerinema amphibium*, d. *Planktothrix agardhii*, e. *Pseudanabaena catenata*, f. *Sphaerospermopsis aphanizomenoides*, g. *Merismopedia tenuissima*, h. *Microcystis* sp., i. *Microcystis panniformis*, j. *Microcystis protocystis*. Scale bar= 10µm

frequent. *D. maximum*, *Lyngbya* cf. *ceylanica* and *S. major,* each with a single record (5.26%) were considered sporadic species (Table 2).

Among the organisms identified, *C. raciborskii*, *G. amphibium*, *P. agardhii*, *P. catenata*, *S. aphanizomenoides*, *M. tenuissima* and *Microcystis* sp. had the broadest distribution, occurring in approximately 42% to 84% of the reservoirs (Figure 2a-h). Some studies have reported the frequent occurrence of *C. raciborskii* in other Brazilian ecosystems (Bouvy et al., 2000, 2001; Bittencourt-Oliveira & Molica, 2003; Costa et al., 2006; Aragão et al., 2007; Moura et al., 2007; Panosso et al., 2007; Chellappa et al., 2008; Bittencourt-Oliveira et al., 2011; Dantas et al., 2011; Lira et al., 2011; Moura et al., 2011). The frequency of this species in semiarid ecosystems occurred, in general, when the ecosystem is stratified with a high degree of intermittence in availability of nutrients (Bormans et al., 2005; Dantas et al., 2011).

The frequency, persistence and high density or biomass of one or multispecies of cyanobacteria in drinking reservoir are a greatest problem from the fact of some species, like: *C. raciborskii*, *G. amphibium*, *Microcystis* spp., *P. agardhii* and *S. aphanizomenoides* are potentially toxic (Figure 2a-b, d, f, h-j).

Conclusions

Cyanobacteria were present in all the reservoirs studied, and among the 23 identified species, *C. raciborskii* was the only one considered very common, predominating in most environments. The genus *Microcystis* was the most representative, with four species (*M. novacekii*, *M. panniformis*, *M. protocystis* and *Microcystis* sp.). Ten new taxa were recorded for the first time for the state of Pernambuco.

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