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Occurrence of *Ceratium furcoides* (Levander) Langhans 1925 (Dinophyceae: Ceratiaceae) in Two Reservoirs of the Capibaribe Watershed Located in Semiarid Region

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ABSTRACT

(Occurrence of *Ceratium furcoides* (Levander) Langhans 1925 (Dinophyceae: Ceratiaceae) in Two Reservoirs of the Capibaribe Watershed Located in Semiarid Region). This study reported the first occurrence of *Ceratium furcoides* (Levander) Langhans 1925 species in two eutrophic in the Capibaribe river basin (Pernambuco-Brazil), located in semiarid region. Fortnightly, samples were collected in the sub-surface reservoirs. The following abiotic variables were analyzed: pH, apparent color, turbidity, conductivity, total hardness, chlorides, ammonia, nitrate, nitrite, inorganic phosphate, iron, copper, manganese and zinc. Phytoplankton biomass was quantified through its density. *C. furcoides* occurred in 17% of the samples in both reservoirs, and also presented high biomass (2.14 $mm^3.L^{-1}$ in Jucazinho and 4.04 $mm^3.L^{-1}$ in Toritama). The studied reservoirs are eutrophic and showed high concentrations of nutrients, particularly nitrite, as well as high conductivity and total hardness values.
Keywords: dinoflagellate, eutrophication, invasive species, Northeastern Brazil, reservoir ecology

INTRODUCTION

Ceratium furcoides (Levander) Langhans 1925 belongs to the Ceratiaceae family, order Peridinales. It is a relatively big dinoflagellate with a body length between 162 and 322 µm, and a variable width between 28 and 42(56) µm. It has a big horn in the epi-valve and two, rarely three, in the hypo-valve. Its life cycle comprises a

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vegetative cell and benthic cysts which are the result of sexual fusion; asexual reproduction occurs by means of oblique binary fusion (Popovský & Pfiester 1990). According to Bicudo and Menezes (2006), the representatives of this species are solitary, free-swimming with asymmetric and strongly flattened on the dorsoventral direction cell.

This is a cosmopolitan species commonly found in marine environments (Davies & Ugwumba 2013, Jardim & Cardoso 2013, Souza *et al.* 2013, Koffi *et al.* 2014, Soler-Figueroa & Otero 2015, Yurimoto *et al.* 2015), considered invasive in continental waters (Cassol *et al.* 2014, Moreira *et al.* 2015).

Over the past years, *C. furcoides* has been recorded worldwide in freshwater ecosystems, including blooms developing (Gil *et al.* 2012, Solis *et al.* 2013). In Brazil, its occurrence has been registered in these environments, especially in eutrophic water bodies both lentic (Santos-Wisniewski *et al.* 2007, Matsumura-Tundisi *et al.* 2010, Silva *et al.* 2012, Cavalcante *et al.* 2013, Moreira *et al.* 2015) and lotic (Severiano *et al.* 2012).

In semiarid regions, however, studies are lacking, highlighting the work carried by Asencio (2014) in reservoirs located in Spain and by Oliveira *et al.* (2011) reporting the first occurrence of the species in semiarid ecosystems of Brazil. Even though blooms in freshwater ecosystems are not toxic, they still bring harmful effects to aquatic communities as anoxic conditions causing the death of a local population of lobsters (Santos-Wisniewski *et al.* 2007, Cassol *et al.* 2014).

C. furcoides is normally found in waters rich in nutrients, especially phosphate and nitrate (Silva *et al.* 2012) and usually in association with Cyanophyceae (Matsumura-Tundisi *et al.* 2010). Occurrence in ecosystems with low nutrient concentrations is also reported (Soler-Figueroa & Otero 2015).

This species tolerates wide range of conditions, and other abiotic factors are also listed as responsible for the development of this species, such as high hardness, high calcium concentrations (Cardoso & Torgan 2007), long residence time (Ginkel *et al.* 2001) and elevated temperatures (Cavalcanti *et al.* 2013, Soler-Figueroa & Otero 2015).

If the development of *C. furcoides* is favored in eutrophic ecosystems and considering its cosmopolitan and invasive habit, beyond the physicochemical and hydrological characteristics of the ecosystems analyzed, it can be predicted that this species will be observed in the sampling stations located in Jucazinho and reservoirs Toritama. These urban reservoirs, especially constructed for supplying water, receive substantial quantities of domestics and industrial sewage, leading these systems to high trophic levels.

The present work aims to show the first occurrence of *C. furcoides* in reservoirs of the Capibaribe river basin (Pernambuco, Brazil), located in semiarid region.

MATERIAL AND METHODS

Area of study - The Jucazinho and Toritama reservoirs are located in the semiarid region of Pernambuco State (Brazil), at the coordinates 7°41'20"S, 08°19'30"W and 08°00'39"S; 36°03'38"W, respectively, and belong to Capibaribe river basin, being built to public water supply and leisure.

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Sampling and laboratory testing - Water samples were collected fortnightly between July and September 2014 at a same point located in the limnetic zone of the reservoirs. All samples were obtained in duplicate in sub-surface reservoirs (approximately 30 cm deep), fixed with formalin solution 4% (v/v). *In situ* measurements were made for the determination of pH, apparent color (UH), turbidity (NTU) and conductivity (µS.cm^{-1}), using a potentiometer (Digimed, DMHP-2), a colorimeter (Poli Control, Acqua Color), a turbidimeter (Hach, 2100N) and a conductivity meter (Hach), respectively. Total hardness (mg.L^{-1}), chlorides (mg.L^{-1}), ammonia (□mol), nitrate (□mol), nitrite (□mol), phosphate (mg.L^{-1}), iron (mg.L^{-1}), copper (mg.L^{-1}), manganese (mg.L^{-1}) and zinc (mg.L^{-1}) were performed in the laboratory accordance with APHA (2012). Quantitative analyses followed Utermöhl (1958), using inverted microscope (Leica DMLB German) and the taxonomic identification was performed according to Popovský & Pfiester (1990) and Bicudo & Menezes (2006). Biomass (mm^3.L^{-1}) was calculated from values of cell biovolume, based on Hillebrand *et al.* (1999).

RESULTS AND DISCUSSION

The main physical and chemical variables measured at Jucazinho and Toritama reservoirs are presented (see Table 1).

As shown in Table 1, both reservoirs have high concentrations of phosphate. With respect to nitrogen compounds, Jucazinho showed higher concentrations of nitrate and in Toritama reservoir predominated less oxidized forms. In both reservoirs, the pH values at the surface were alkaline, probably due to photosynthesis. High hardness values were observed in both reservoirs. Metal concentrations were higher in Toritama while in Jucazinho chloride concentrations were higher.

Table 1. Limnological parameters at Jucazinho Reservoir and Reservoir Toritama Pernambuco, Brazil), belonging to the basin of Capibaribe river during the study period. Min = minimum value; Max = maximum value; + = below the detection limit of the methodology (Oliveira, 2016).

Reservoirs	Jucazinho		Toritama	
Variables	**Max**	**Min**	**Max**	**Min**
pH	8.0	7.9	7.5	7.4
Apparent color (UH)	71	57	64	53
Turbidity (NTU)	6.7	6.4	3.8	3.0
Conductivity (µS.cm^{-1})	1,454	1,146	2,610	1,817
Total hardness (mg.L^{-1})	387	380	1,000	900
Chlorides (mg.L^{-1})	544	540	90	85
Ammonia (µmol)	0.07	0.02	0.35	0.25
Nitrate (µmol)	0.40	0.40	0.01	+
Nitrite (µmol)	0.05	0.07	0.67	0.59
Phosphate (µmol)	0.69	0.13	0.53	0.19
Iron (mg.L^{-1})	0.10	+	0.30	0.23
Copper (mg.L^{-1})	+	+	0.30	0.27
Manganese (mg.L^{-1})	0.15	+	0.10	0.04
Zinc (mg.L^{-1})	+	+	+	+

Concerning to the phytoplankton community, in Jucazinho, occurs Cyanophyta blooms, mainly *Planktothrix agardhii* (Gomont) Anagnostidis and Komárek 1988 at all times, reaching average biomass values of 3.58 mm^3.L^{-1}. Moreover, in the Toritama reservoir, there was extensive occurrence of different diatoms species, whose average total biomass reached 21.67 mm^3.L^{-1}.

The species *C. furcoides* presented an occurrence frequency of 17% of the samples (n = 6) in both reservoirs, being considered as rare occurrence species. However, higher average biomass of this species (2.89 e 6.01 mm^3.L^{-1} in Jucazinho and Toritama, respectively) were observed, mainly due to high biovolume values.

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The Capibaribe river has a large area and crosses several cities of the state of Pernambuco (Brazil), among them Surubim and Toritama, where the studied reservoirs are located (Jucazinho and Toritama, respectively), consisting of different ecosystems despite being in the same river. Jucazinho is a deep and large reservoir, while the Toritama is shallow and small.

For a long time, the dominant phytoplankton community on the Jucazinho reservoirs was Cyanophyceae, such as *P. agardhii* and *Cylindrospermopsis raciborskii* (Woloszynska) Seenaya and Suba Raju 1972 (Albuquerque & Oliveira 2010). However, in Toritama reservoir, this is the first study about phytoplankton communities performed, and it is not possible a comparison with other works.

Both studied reservoirs are considered eutrophic, getting great contribution of effluents from local communities. In addition, the Toritama reservoir receives effluent of textile industries and laundry located surrounding (Almeida 2008). Eutrophication can be confirmed by the high phosphate and nitrogen compounds concentrations, mainly ammonia. According to Esteves & Amado (2013) e Lira (2015), ammonia and nitrate nitrogen are the forms most commonly used by phytoplankton and the high concentrations of reduced forms of nitrogen in Toritama reservoir suggests recent pollution in the water body.

Elevated values of conductivity (above $100\mu s.cm^{-1}$, Margalef 1983) also corroborate eutrophication of the ecosystem (Silva 2011; Daruich *et al.* 2013, Smith *et al.* 2014), due to the high degree of decomposition of organic matter, which releases greater amount of ions in the water column (Matsuzaki *et al.* 2004), commonly observed in reservoirs of northeast Brazil (Chellapa *et al.* 2008, Costa *et al.* 2009). The Jucazinho and Toritama reservoirs are used for leisure and recreation by the surrounding population, contributing to the process of eutrophication. Furthermore, high conductivity, iron, copper and total hardness values at Toritama reservoir may occur due to the laundry and textile industry effluent released constantly.

In this scenario of eutrophic ecosystems, high *C. furcoides* biomasses were observed. Reynolds (1997), when presenting theories and hypothesis related to the succession and development of phytoplankton populations in pelagic environments, emphasises the importance of the matrix of possibilities related to the distribution of downwelling irradiance and limiting nutrient concentration in relation to mixed depth represented by temperature distribution and algal growth supporting capacity. Five years later, Reynolds *et al.* (2002) proposed a classification into functional groups, in which the genus *Ceratium* is included in the Lm group, typical of epiliminion environments from mesotrophic or eutrophic ecosystems, presenting thermal stratification and suffering mixing of the water column.

The presence of *C. furcoides* can be attributed to the maintenance of resistance cysts in the surface of the sediments of the reservoirs, which may be suspended by the mixing effect (Tundisi-Matsumura *et al.* 2010, Sestro *et al.* 2013, Moreira *et al.* 2015). This helps explain the occurrence of these organisms in samples taken during the rainy season, in which there is greater turbulence of the water column, especially in Toritama, due it shallowness. Study by Gil *et al.*

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(2012) also points out the presence of this species coinciding with the beginning of the rainy season.

Study carried out by Matsumura-Tundisi *et al.* (2010) e Silva *et al.* (2012) in eutrophic reservoir from São Paulo and Minas Gerais states (Brazil), respectively, highlighted the presence of *Ceratium* in waters with high concentration of phosphate and nitrogen compounds. Gil *et al.* (2012) reported occurrence of high *C. furcoides* biomass in reservoirs with high ammonia and low nitrate concentrations. These results corroborate the data from this study, however differ from studies carried out by Ginkel *et al.* (2001) and Koenig & Lira (2005) that indicated the presence of *C. furcoides* in ecosystems with low nutrients concentrations and even the work of Donald *et al.* (2013), who detected no significant influence of the ammonia and nitrate concentrations over the growth of *C. furcoides*. Studies indicate that *Ceratium* species prefer hard water with high calcium concentrations, high conductivity and salinity levels between 15 and 30 ‰ (Silva *et al.* 2009, 2012). In this study, high hardness values were observed in both ecosystems. Salinity analysis was not performed, but high chloride concentrations in Jucazinho reservoir were found, helping to explain the presence of this organism.

C. furcoides was observed under low turbidity values in both reservoirs, corroborating studies carried by Matsumura-Tundisi *et al.* (2010), however it disagrees of works by Okolodkov (2010), Gil *et al.* (2012) and Solis *et al.* (2013) who point out umbriphilic growth of the species Rare occurrence of *C. furcoides* as well as other species of the genus *Ceratium* can be explained because these organisms are s-strategists, with low growth rate and metabolic activity, even under ideal environmental conditions (Lee 2008).

As observed by Oliveira *et al.* (2011), reporting the occurrence of *C. furcoides* in the São Francisco river (Pernambuco, Brazil), these findings for the ecosystems that make up part of the Capibaribe river system indicate that the invasion of this genus followed the course of the river. The appearance of this genus in different ecosystems of the semiarid region of Brazil is likely related to climatic and hydrological conditions of the region.

It can be stated that waste released into the Capibaribe river basin, carried to the reservoirs, including Jucazinho and Toritama, can cause changes in physical-chemical aspects, leading to the emergence of *C. furcoides*. Further information regarding the colonizationof and full *C. furcoides* establishment in pristine tropical water bodies are not available and would be valuable for a better understanding of the dynamics of the invasion process as a whole.

Thus the initial hypothesis of this study that *C. furcoides* invasion and establishment in Jucazinho and Toritama reservoirs is related to the eutrophication was accepted.

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