



GEOGRAPHICAL DISTRIBUTION OF EXOTIC DINOFLAGELLATE OF FRESHWATER *CERATIUM FURCOIDES* (LEVANDER) LANGHANS 1925 IN BRAZIL

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Abstract: Biological invasions are becoming serious environmental problems. In several records, they cause irreparable damage to biodiversity. This job is about a short review on the current state of expansion of the species *Ceratium furcoides* (Levander) Langhans 1925 in Brazil, based on what has already been published. The species has now been recorded in several rivers and reservoirs from at least six of the 26 states. The occurrence of high densities in Brazil is always linked to high temperatures, which is an aggravating factor for our country. Effective limnological monitoring is needed to identify and seek measures to address such problems as soon as possible, as well as correlations studies of cellular densities of *C. furcoides* with abiotic parameters such as temperature, pH, salinity, levels of nitrogen compounds and phosphates.

Keywords: spatial distribution, ecology, exotic species, limnology.

DISTRIBUIÇÃO GEOGRÁFICA DO DINOFLAGELADO EXÓTICO DE ÁGUA DOCE *CERATIUM FURCOIDES* (LEVANDER) LANGHANS 1925 NO BRASIL

Resumo: Invasões biológicas estão se tornando graves problemas ambientais. Em diversos registros, causam danos irreparáveis a biodiversidade. Esse trabalho se trata de uma revisão curta sobre o atual estado da expansão do táxon *Ceratium furcoides* (Levander) Langhans 1925 no Brasil, com base no que já foi publicado. Atualmente a espécie já foi registrada em vários rios e reservatórios, em pelo menos seis dos 26 estados do país. A ocorrência de altas densidades no Brasil está sempre vinculada as altas temperaturas, o que é um agravante para nosso país. Necessita-se de monitoramento limnológico eficiente, para identificar e buscar medidas que sanem tais problemáticas o quanto antes, bem como estudos de correlação de densidades celulares de *C. furcoides* com parâmetros abióticos, como temperatura, pH, salinidade, níveis de compostos nitrogenados e fosfatados.

Palavras-chave: distribuição espacial, ecologia, espécies exóticas, limnologia

The growing record of biological invasions, linked to climate change, are becoming a prevailing situation worldwide, causing serious threats to biodiversity (Vitousek et al., 1997; Moro et al., 2012; Traveset & Richardson, 2014). Anthropogenic activities have averaged 30% of the native flora of most of the global regions in recent decades (Heywood, 1989). The success of introduced organisms depends on some factors, including their ability to survive under unfavorable conditions as well as their adaptability to the new environment (Baker & Stebbins, 1965).

The dynamics of continental aquatic ecosystems lead to unperceived dispersal of invaders, resulting in short and medium-time problems (Nentwig, 2007; Zaburlín et al., 2016). Phytoplankton makes up the base of the food chain by converting inorganic matter into protein and lipid components, for the most part, and consequently a source of energy for subsequent groups (Singh & Gu, 2010). For this reason, this is one of the first communities to be affected by changes in the physical and chemical parameters.

Dinoflagellates are algae that have two flagella, although some do not, and relatively low in continental environments, it is estimated that no more than 220 species (Bellinger & Sigee, 2010). *Ceratium* Schrank 1793 are asymmetric and solitary microalgae, having only six species in continental waters worldwide (Popovský & Pfister, 1990) and an exotic species registered in Brazil, which is expanding (Santos-Wisniewski et al., 2007). *Ceratium furcoides* (Levander) Langhans 1925 may produce harmful effects on water, such as unpleasant taste and bad smell. Eventually, this situation has an impact on local communities, especially in areas with water supply problems. These negative effects may make it impossible to consume, depending on the intensity (Matsumura-Tundisi et al., 2010; Cavalcante et al., 2013).

The present job intends to explain a critical analysis of the status as well as perspectives, both for the academy and for governmental entities, based on what has already been published about the specie *C. furcoides* in Brazil. This paper does not intend to be an exhaustive review of the literature, but rather an additional update to the published works that record the occurrence of *C. furcoides* in Brazilian aquatic bodies. In addition, this article describes the importance of conservation practices in environments that aim to maintain freshwater ecosystems.

History and Geographical Expansion -

Freshwater species of the genus *Ceratium* occur in many temperate and subtropical areas of the world, from cold waters from Asia to South America (Pandeirada et al., 2013, Napiórkowska-Krzebietke 2014). *C. furcoides* (Fig. 1) were recorded in the last two decades showing an

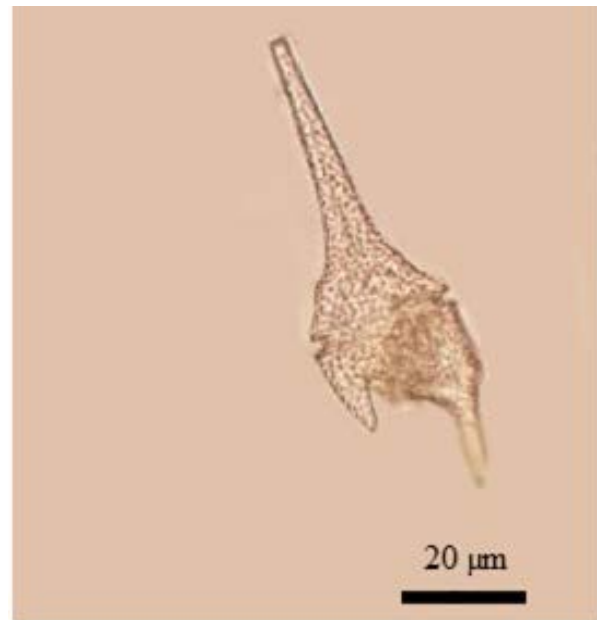


Fig. 1. *Ceratium furcoides* (Levander) Langhans. Image in optic microscopy.

invasive behavior and a rapid colonization in the southern part of America; it is emphasized that both species are not native to the inland waters of this continent (Cavalcante et al., 2013; Zaburlín et al., 2016).

In most cases, the occupation of *C. furcoides* occurred in environments not inhabited by the genera and later, replaced the population of *C. hircundinella* species, thus pointing to an ecological succession (Boltovskoy et al., 2013). *C. furcoides* was recorded for the first time in South America in Colombia (Ramírez-R et al., 2005), later registered for the first time in Brazil, in the state of Minas Gerais (Santos-Wisniewski et al., 2007).

The species has now been recorded in rivers and reservoirs of several aquatic bodies in at least six of the twenty-six states of Brazil (Tab. 1).

Species that make up this genus rarely constitute zooplankton food (Santer, 1996). This low pressure herbivory is due to its relative mobility (Santos-Wisniewski et al., 2007), low nutritional value (Williamson, 1984) and its size (Pollinger, 1987).

Occurrence of high densities in Brazil are always linked to high temperatures (Santos-Wisniewski et al., 2007; Jati et al., 2014). However, the species is able to withstand low temperatures, up to 1°C, allowing its continuous dispersion in several lakes here. Transposition work and inadequate management works in water quality monitoring, in existing cases, contribute to its continuous expansion.

The presence of *C. furcoides* may be linked to the resistance of their cysts. These are on the sediment surface of the reservoirs, and can be

Tab. 1. Locations of occurrence, state and study area, of *Ceratium furcoides* (Levander) Langhans in the Brazil.

State	Study area	Reference
Pernambuco	Capibaribe bay	Macedo, 2016
	Cachoeira II reservoir	Oliveira, 2018
Bahia	Sobradinho reservoir	
	Itaparica reservoir	Oliveira et al., 2016
	Paulo Afonso reservoir	
Minas Gerais	Furnas reservoir	Santos-Wisniewski et al., 2007
	Sub-basin of the Sapucaí and Grande river	Silva et al., 2012
	Lagoa seca lake	Moreira et al., 2016
São Paulo	Billings reservoir	Matsumura-Tundisi et al., 2010
Paraná	Sampling by Companhia Paranaense of Energy (COPEL)	Cavalcante et al., 2013
	Paraná river	Jati et al., 2014
Rio Grande do Sul	Sampling by Companhia Riograndense de Saneamento (CORSAN)	Cavalcante et al., 2013
	Itaúba reservoir	Cassol et al., 2014
	Maestra and Faxial reservoir	Cavalcante et al., 2016

suspended by the mixing effect in periods of rainy (Sestro et al., 2013, Moreira et al., 2015), thus showing that the presence of *C. furcoides* coincides with rainy seasons (Gil et al., 2012).

Future Perspectives - Several factors are associated with species dispersal and may contribute positively to invasion success. Some studies show that the blooms of *C. furcoides* have a strong relation with high temperatures, a worrying factor, since in the scenario of global temperature rise, the occurrence of these blooms would become more and more frequent.

Efficient limnological monitoring are needed to identify and seek measures to address such problems as soon as possible. A possible solution to avoid the expansion and domination of the species in aquatic bodies, would be the introduction of species of copepados, in advanced stage of life (Brandl & Fernando, 1979). The introduction of zooplankton would also serve as a source of natural food for the ichthyological community present in the environment - since the fishery activities are still frequent in Brazilian lakes and reservoirs.

Studies of correlation between densities of *C. furcoides* and abiotic parameters, as temperature, salinity, pH, ammonia, nitrite, phosphate and others, need to be performed more frequently, especially in the Brazilian semiarid region, where the water issue is strongly impacted, so that new aquatic bodies do not become unviable for antropic exploration. In addition, this silent expansion of *C. furcoides* presents serious risks to the commitment of native phytoplankton.

REFERENCES

- Baker, H. G. & G. L. Stebbins.** 1965. Genetics of colonizing species: proceedings of the first International Union of Biological Sciences Symposia on General Biology. Academic Press, New York. 588 p.

- Bellinger, E. G. & D. C. Sigeo.** 2010. Introduction to freshwater algae. In: Bellinger, E. G. & D. C. Sigeo. *Freshwater algae: Identification and use as bioindicators*. John Wiley & Sons, pp.1-40.
- Boltovskoy, A., R. O. Echenique & J. M. Guerrero.** 2013. Sucesivas invasiones de especies de *Ceratium* (Dinophyceae) em Sudamérica: un proceso que lleva dos décadas. *Bol. de la Soc. Arg. de Bot.* 48: 1–27.
- Brandl, Z. & C. H. Fernando.** 1979. The impact of predation by the copepod *Mesocyclops edax* (Forbes) on zooplankton in three lakes in Ontario, Canada. *Can. J. of Zoo.* 57(4): 940–942.
- Cassol, A. P. V., Pereira Filho, W., Oliveira, M. A., Domingues, A. L., Correa, F. S., & Buriol, G. A.** 2014. First record of a bloom of the invasive species *Ceratium furcoides* (Levander) Langhans 1925 in Rio Grande do Sul state, Brazil. *Braz. J. of Bio.* 74(2): 515–517.
- Cavalcante, K. P., J. C. Zanotelli, C. C. Müller, K. D. Scherer, J. K. Frizzo, T. A. V. Ludwig & L. Souza Cardoso.** 2013. First record of expansive *Ceratium* Schrank, 1793 species (Dinophyceae) in Southern Brazil, with notes on their dispersive patterns in Brazilian environments. *Check List.* 9(4): 862–866.
- Cavalcante, K. P., L. Souza Cardoso, R. Susella & V. Becker.** 2016. Towards a comprehension of (Dinophyceae) invasion in Brazilian freshwaters: autecology of *C. furcoides* in subtropical reservoirs. *Hydrob.* 77(1): 265–280.
- Gil, C. B., J. J. R. Restrepo, A. Boltovskoy & A. Vallejo.** 2012. Spatial and temporal change characterization of *Ceratium furcoides* (Dinophyta) in the equatorial reservoir Riogrande II, Colombia. *Acta Limnol. Bras.* 24(2): 207–219.
- Heywood, V. H.** 1989. Patterns, extents and modes of invasions by terrestrial plants. In: Drake, J. H., H. A. Mooney, F. di Castri, R. H. Groves, F. J. Kruger, M. Rejmánek & M. Williamson. (Eds.). *Biological invasions: a global perspective*, pp.31–60.
- Jati, S., L. C. Rodrigues, J. C. Bortolini, A. C. M. Paula, G. A. Moresco, L. M. Reis, B. F. Zanco & S. Train.** 2014. First record of the occurrence of *Ceratium furcoides* (Levander) Langhans (Dinophyceae) in the Upper Paraná River Floodplain (PR/MS). Brazil. *Braz. J. of Biol.* 74(3): S235–S236.
- Macedo, I. M. E.** 2016. Ocorrência de *Ceratium furcoides* (Levander) Langhans 1925 (Dinophyceae: Ceratiaceae) em Dois Reservatórios da Baía de Capibaribe Localizada na Região Semiárida. *Rev. Geama.* 2(3): 300–308.
- Matsumura-Tundisi, T., J. G. Tundisi, A. P. Luzia & R. M. Degani.** 2010. Occurrence of *Ceratium furcoides* (Levander) Langhans 1925 bloom at the Billings Reservoir, São Paulo State, Brazil. *Braz. J. of Biol.* 70(3): 825–829.
- Moreira, R. A., O. Rocha, R. M. Santos, R. Laudares-Silva, E. S. Dias & E. M. Eski-nazi-Sant’anna.** 2015. First record of *Ceratium furcoides* (Dinophyta), an invasive species, in a temporary high-altitude lake in the Iron Quadrangle (MG, Southeast Brazil). *Braz. J. of Biol.* 75(1): 98–103.
- Moreira, R. A., Rocha, O., Santos, R. M. D., Dias, E. S., Moreira, F. W. A., & Sant’Anna, E. M. E.** 2016. Composition, body-size structure and biomass of zooplankton in a high-elevation temporary pond (Minas Gerais, Brazil). *Oecol. Austr.* 20 (2): 219–231.
- Moro, M. F., V. C. Souza, A. T. D. Oliveira-Filho, L. P. D. Queiroz, C. N. D. Fraga, M. J. Nogueira Rodal, F. S. Araújo & F. R. Martins.** 2012. Alienígenas na sala: o que fazer com espécies exóticas em trabalhos de taxonomia, florística e fitossociologia? *Acta Bot. Bras.* 26(4): 991–999.
- Napiórkowska-Krzebietke, A.** 2014. Phytoplankton of artificial ecosystems – an attempt to assess water quality. *Arch. Pol. Fish.* 22 (1): 81–97.
- Nentwig, W.** (Ed.) 2007. *Biological invasions: 193*. Springer-Verlag, Berlin/Heidelberg. 468 p.

- Oliveira, H. S. B., A. N. Moura & M. K. Cordeiro-Araújo.** 2016. First record of *Ceratium* Schrank, 1973 (Dinophyceae: Ceratiaceae) in freshwater ecosystems in the semiarid region of Brazil. *Check List.* 7 (5): 626-628.
- Oliveira, C. Y. B.** 2018. Microalgas do semiárido: florações nocivas, variabilidade sazonal e suas possíveis aplicações biotecnológicas. Curso de graduação em Engenharia de Pesca, Universidade Federal Rural de Pernambuco, Monografia, 80 p.
- Pandeirada, M. S., S. C. Craveiro & A. J. Calado.** 2013. Freshwater dinoflagellates in Portugal (W Iberia): a critical checklist and new observations. *Nova Hedwigia.* 97 (3-4): 321-348.
- Pollinger, U.** 1988. Freshwater armored dinoflagellates: growth, reproduction strategies, and population dynamics. In: Sandgren, C. D. [Ed.] *Growth and Reproductive Strategies of Freshwater Phytoplankton.* Cambridge University Press, New York, pp. 134-74.
- Popovský, J. & L. A. Pfiester.** 1990. Dinophyceae (Dinoflagellida). Fischer, Stuttgart. 272 p.
- Ramírez-R, J. J., F. L. Gutiérrez & A. Vargas.** 2005. Respuesta De La Comunidad Fito-planctónica A Experimentos De Eutrofización Artificial Realizados En La Represa La Fe, El Retiro, Antioquia, Colombia. *Caldasia.* 27(1): 103-115.
- Santer, B.** 1996. Nutritional suitability of the dinoflagellate *Ceratium furcoides* for four copepod species. *J. of Plankt. Res.* 18 (3): 323-333.
- Santos-Wisniewski, M. J., L. C. Silva, I. C. Leone, R. Laudares-Silva & O. Rocha.** 2007. First record of the occurrence of *Ceratium furcoides* (Levander) Langhans 1925, an invasive species in the hydroelectricity power plant Furnas Reservoir, MG, Brazil. *Braz. J. of Biol.* 67 (4): 791-793.
- Sestro, M., E. Sánchez, M. Flores, S. Astacio, J. Rodríguez, M. Santiago, K. Olivieri, V. Fracis & J. Nuñez, J.** 2013. Population fluctuations of *Pyrodinium bahamense* and *Ceratium furca* (Dinophyceae) in Laguna Grande, Puerto Rico, and environmental variables associated during a three-year period. *Rev. de Biol. Trop.* 61 (4): 1799-1813.
- Silva, L. C. D., I. C. Leone, M. J. D. Santos-Wisniewski, A. C. Peret & O. Rocha.** 2012. Invasion of the dinoflagellate *Ceratium furcoides* (Levander) Langhans 1925 at tropical reservoir and its relation to environmental variables. *Biota Neotrop.* 12 (2): 93-100.
- Singh, J. & S. Gu.** 2010. Commercialization potential of microalgae for biofuels production. *Renew. and Sust. Ener. Rev.* 14(9): 2596-2610.
- Traveset, A. D. M. & Richardson.** 2014. Mutualistic interactions and biological invasions. *Ann. Rev. of Ecol., Evol. and System.* 45: 89-113.
- Vitousek, P. M., H. A. Mooney, J. Lubchenco & J. M. Melillo.** 1997. Human domination of Earth's ecosystems. *Science.* 277 (5325): 494-499.
- Williamson, C. E.** 1981. Foraging behavior of a freshwater copepod: frequency changes in looping behavior at high and low prey densities. *Oecol.* 50, 332-336.
- Zaburlín, N. M., R. E. Vogler, M. J. Molina & V. M. Llano.** 2016. Potential distribution of the invasive freshwater dinoflagellate *Ceratium furcoides* (Levander) Langhans (Dinophyta) in South America. *J. of Phyc.* 52 (2): 200-208.

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