



First record of the invasive dinoflagellate *Ceratium furcoides* (Levander) Langhans, 1925 in a subtropical coastal freshwater lagoon in the state of Santa Catarina, Brazil

Primeiro registro do dinoflagelado invasor *Ceratium furcoides* (Levander) Langhans, 1925 em uma lagoa costeira subtropical de água doce no estado de Santa Catarina, Brasil

Renato Miziara Assef dos Santos^{*1} , Lorena Pinheiro Silva² , Odete Rocha³ ,
Mauricio Mello Petrúcio¹  and Luzia Cleide Rodrigues⁴ 

¹Laboratório de Ecologia de Águas Continentais, Departamento de Ecologia e Zoologia, Universidade Federal de Santa Catarina – UFSC, Campus Universitário Reitor João David Ferreira Lima, Trindade, 88040-900, Florianópolis, SC, Brasil

²Horn Point Laboratory, University of Maryland Center for Environmental Science, Cambridge, MD21613, Maryland, USA

³Departamento de Ecologia e Biologia Evolutiva, Universidade Federal de São Carlos – UFSCar, 13565-905, São Carlos, SP, Brasil

⁴Centro de Pesquisa em Limnologia, Ictiologia e Aquicultura, Universidade Estadual de Maringá – UEM, Maringá, Paraná, 87020-900, Brasil

*e-mail: renatoassef.bio@gmail.com

Cite as: Santos, R.M.A. et al. First record of the invasive dinoflagellate *Ceratium furcoides* (Levander) Langhans, 1925 in a subtropical coastal freshwater lagoon in the state of Santa Catarina, Brazil. Acta Limnologica Brasiliensia, 2025, vol. 37, e34. <https://doi.org/10.1590/S2179-975X2025>

Abstract: *Ceratium* is a planktonic dinoflagellate commonly found in temperate continental waters. In recent decades, *Ceratium* species have been reported in tropical water bodies, where they are considered invasive. These organisms exhibit high dispersal capacity, adaptability, and rapid colonization of new environments. This study reports the first occurrence of *Ceratium furcoides* in a natural environment in the state of Santa Catarina, Brazil, specifically in Peri Lake, a coastal freshwater lake in Florianópolis used for public water supply, recreation, and tourism. For species identification, several *Ceratium* specimens were analyzed focusing on the arrangement of apical plates, a key morphological trait distinguishing *C. furcoides* from *C. hirundinella*. The presence of *C. furcoides* was recorded during monthly zooplankton monitoring of Peri Lake. *Ceratium furcoides* is often associated with significant ecological impacts, causing alterations in aquatic communities and contributing to water quality degradation. Its uncontrolled proliferation can affect trophic structure, nutrient availability, and compromise local biodiversity. Continuous monitoring and studies correlating the dinoflagellate's occurrence with limnological variables are necessary to elucidate the main factors driving *C. furcoides* proliferation and to inform management strategies aimed at mitigating potential ecological, social, and economic issues.

Keywords: bioinvasion; exotic species; phytoplankton; coastal lake.



Resumo: *Ceratium* é um dinoflagelado planctônico comumente encontrado em águas continentais de regiões temperadas. Nas últimas décadas, espécies de *Ceratium* têm sido registradas em corpos d'água tropicais, sendo, nestes locais, consideradas espécies invasoras. Esses organismos apresentam alta dispersão, adaptação e rápida colonização aos ambientes. Este é o primeiro relato da ocorrência do *Ceratium furcoides* em um ambiente natural no estado de Santa Catarina, na Lagoa do Peri em Florianópolis, sendo uma lagoa costeira de água doce utilizada para o abastecimento público, atividades de recreação e turismo. Para a identificação da espécie, alguns exemplares de *Ceratium* foram analisados para verificar a disposição das placas apicais, característica primordial para distinguir o *C. furcoides* do *C. hirundinella*. O registro de ocorrência do *Ceratium furcoides* se deu durante as análises mensais do monitoramento na Lagoa do Peri. O *Ceratium furcoides* é frequentemente associado a impactos ecológicos significativos, promovendo alterações nas comunidades aquáticas e contribuindo para a degradação da qualidade da água. Seu crescimento descontrolado pode afetar a estrutura trófica dos ecossistemas, influenciar a disponibilidade de nutrientes e comprometer a biodiversidade local. O monitoramento e estudos de correlação entre o dinoflagelado e as variáveis limnológicas da lagoa são necessários para que seja possível entender os principais fatores que contribuem para a proliferação do *Ceratium furcoides* e para buscar medidas que possam sanar possíveis problemas ecológicos, sociais e econômicos.

Palavras-chave: bioinvasão; espécies exóticas; fitoplâncton; lagoa costeira.

Dinoflagellates of the genus *Ceratium* have been recorded across multiple continents and countries (Moreira et al., 2015). Globally, there are 10 accepted species in this genus, according to taxonomic data from AlgaeBase (*Ceratium*, Guiry & Guiry, 2025). However, in South America, *Ceratium furcoides*, a species native to the Northern Hemisphere (Carty & Parrow, 2015), is considered invasive in freshwater ecosystems (Crossetti et al., 2019).

The first record of a *Ceratium* species in Brazilian continental waters was made by Branco et al. (1963), who identified *Ceratium hirundinella* in Brazil. Many years later, Santos-Wisniewski et al. (2007) reported the first occurrence of *Ceratium furcoides* in the Furnas Reservoir, Minas Gerais, in the Southeast region of the country. Since then, several studies have reported the occurrence of this dinoflagellate in different Brazilian regions, including Billings Reservoir in São Paulo (Matsumura-Tundisi et al., 2010); Furnas Reservoir and the Rio Grande basin, Minas Gerais (Silva et al., 2012); reservoirs in Northeastern states such as Alagoas, Bahia, Pernambuco, and Sergipe (Oliveira et al., 2016); temporary high-altitude lakes in the Iron Quadrangle, Minas Gerais (Moreira et al., 2015); Rio Grande do Sul and the Paraná basin (Cavalcante et al., 2013); Garças Reservoir, São Paulo (Crossetti et al., 2019) as well as recent studies confirming the species' expansion throughout almost the entire state of Rio Grande do Sul (Silva et al., 2018; Silva et al., 2024).

The occurrence of *Ceratium furcoides* in freshwater ecosystems with distinct characteristics demonstrates its high ecophysiological plasticity

(Almanza et al., 2016). The species exhibits key adaptive strategies essential for development and stabilization in different environments, including sedimentation resistance, high dispersal capacity, and swimming ability that allows vertical movement in the water column to seek favorable microhabitats (Hickel, 1988; Cavalcante et al., 2016). Additionally, its size and shape make it unpalatable, resulting in low zooplankton grazing pressure (Cavalcante et al., 2016).

This study recorded the first occurrence of the dinoflagellate *Ceratium furcoides* in Peri Lake (Florianópolis, Santa Catarina), a coastal freshwater ecosystem that plays a crucial role in providing ecosystem services to the island of Florianópolis, including the water supply for the local population. Therefore, the appearance of this dinoflagellate in the lake may have not only ecological consequences, but also economic and social consequences. *Ceratium furcoides* is often associated with changes in water taste and odor, as well as challenges for the water supply system, affecting distribution, treatment, and storage processes (Morales, 2016).

Samples were collected from the water surface at four monitoring stations during the monthly analyses of the plankton community in Peri Lake in 2017 (Figure 1). Collection was performed using a 53 µm plankton net, filtering 50 liters of water with the aid of a 5 L bucket. Organisms were fixed in 4% formaldehyde and stored in polyethylene bottles. *Ceratium* specimens were counted in 1 mL subsamples using a Sedgewick-Rafter counting chamber under a Zeiss Scope A1 compound microscope, with images captured at magnifications of up to 1000×.

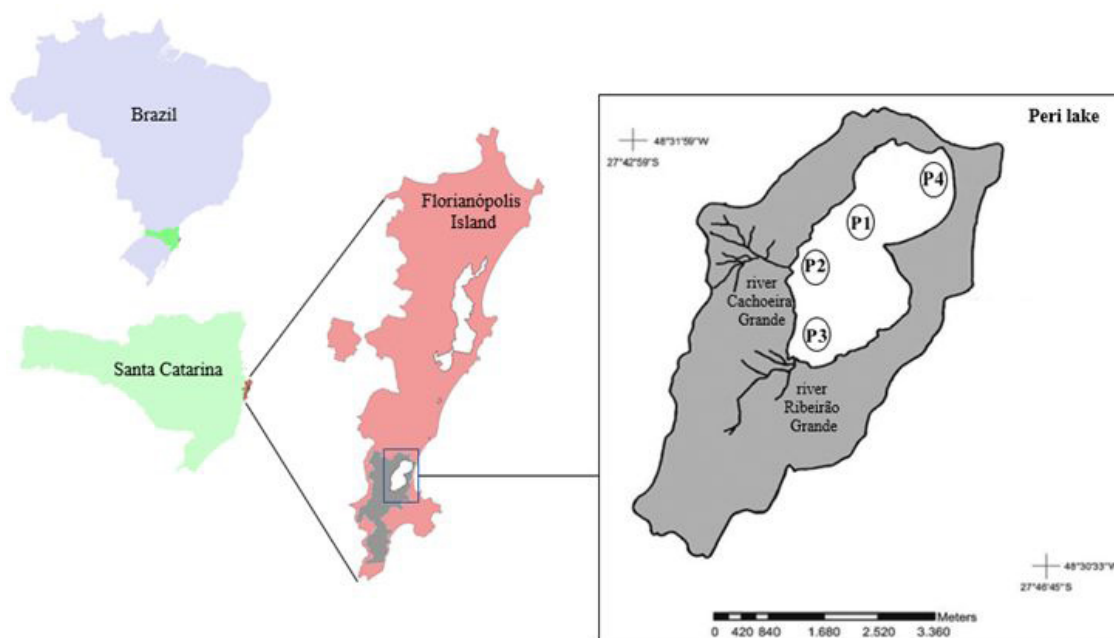


Figure 1. Location of Lagoa do Peri in Florianópolis, Santa Catarina, Brazil and the four sampling points (P1, P2, P3 and P4).

The occurrence of *Ceratium furcoides* was recorded for the first time during the monthly analysis of March 2017, a particularly surprising finding considering that the lake had been monitored continuously on a monthly basis since 2007. In 2017, the recorded average density was 32 ind. ml⁻¹. In the following years, the species exhibited monthly variations, with a gradual increase over time, culminating in a peak density of 400 ind. ml⁻¹ in 2024. This history highlights the rapid population growth and the establishment of alternation dynamics typical of invasive species. The absence of previous records, combined with the documented population increase, underscores the novelty and significance of this finding.

To identify the species, some specimens of *Ceratium* were analyzed to verify the arrangement of the apical plates, a key characteristic to distinguish *Ceratium furcoides* from *Ceratium hirundinella* (Cavalcante et al., 2013). These species are very similar in morphology, with the main difference being the arrangement of these plates: while *Ceratium hirundinella* has four apical plates reaching the apex, *Ceratium furcoides* has only three apical plates reaching the apex, since the fourth plate is reduced (Santos-Wisniewski et al., 2007; Cavalcante et al., 2013). In our analyses, the specimens examined presented a reduced fourth plate, allowing confirmation of the identification of *Ceratium furcoides* (Figure 2).

Ceratium furcoides has specific characteristics, such as high swimming capacity, morphology that reduces herbivory, cyst formation, potential for mixotrophic nutrition and ability to generate blooms, making it a strong competitor of Brazilian phytoplankton (Cavalcante et al., 2016). Thus, its stabilization in Peri Lake can cause significant changes in species composition and ecosystem dynamics.

Although it is not a toxic species, its morphology makes it unpalatable, preventing predation (Santer, 1996). At high densities, *Ceratium furcoides* can lead to resource depletion and oxygen reduction in the water column (Matsumura-Tundisi et al., 2010). Several studies have linked this species to bloom events, resulting in changes in zooplankton community structure (Hart & Wragg, 2009), high fish mortality (Taylor et al., 1995; Morales, 2016), and invertebrate die-offs (Landsberg, 2002), as well as the deterioration of water quality (Matsumura-Tundisi et al., 2010).

Peri Lake, although classified as oligo-mesotrophic, has historically been dominated by the cyanobacterium *Raphidiopsis raciborskii* in its phytoplankton community (Tonetta et al., 2015). The introduction of *Ceratium furcoides* into this ecosystem may profoundly alter this dynamic due to its potential impact on competition for nutrients, light, and microhabitats (Silva et al., 2019). The species swimming ability and mixotrophy confer feeding flexibility, allowing it to occupy spatial niches distinct from those of cyanobacteria (Tucci & Sant'Anna, 2003; Reynolds, 2006).

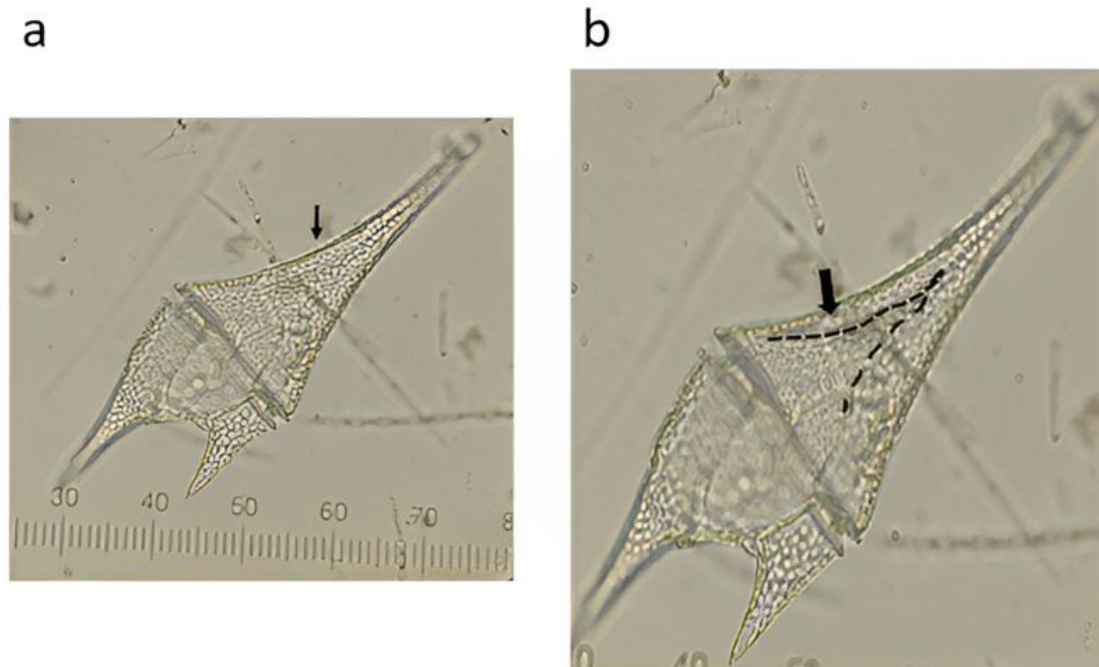


Figure 2. *Ceratium furcoides* (a) and the highlight of the fourth reduced plate (b).

Studies have shown that freshwater systems invaded by *Ceratium* often had historical cyanobacterial blooms, and the arrival of the dinoflagellate appears to reverse cyanobacterial dominance (Nishimura et al., 2015; Cavalcante et al., 2016; Crossetti et al., 2019). During the colonization process by *C. furcoides*, the phytoplankton community may experience reductions in species diversity and richness (Almanza et al., 2016; Rojas-Castillo et al., 2023). Conversely, in some cases, *C. furcoides* blooms have been observed alongside peaks or blooms of cyanobacteria (Silva et al., 2012; Almeida et al., 2016; Silva et al., 2025). These mechanisms may be analogous in the case of *R. raciborskii*, leading to shifts in the balance between dinoflagellates and cyanobacteria and potentially promoting seasonal fluctuations or even substitutions in the phytoplankton community composition.

Another study is currently underway to investigate in greater detail the potential impacts of this dinoflagellate on Peri Lake and its biotic communities. The results from the present study, particularly the post-2017 increase in *Ceratium furcoides* density, with monthly fluctuations leading to a peak of 400 individuals per milliliter in 2024, provide a crucial reference for these future analyses. These findings highlight the species' rapid establishment and potential to alter ecological interactions, including its likely influence on the historical dominance of the

cyanobacterium *Raphidiopsis raciborskii* in Peri Lake. The proliferation of *C. furcoides* may shift competition for light, nutrients, and microhabitats, potentially promoting seasonal fluctuations or even a partial replacement of cyanobacterial dominance. Additionally, analyzing its distribution across South America and Brazil will help elucidate ecological preferences and environmental drivers, ultimately contributing to more effective water management and treatment strategies.

Acknowledgements

To the Laboratório de Ecologia de Águas Continentais (LIMNOS) of the Universidade Federal de Santa Catarina for providing the samples and granting the laboratory for the analyses. To the Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura (NUPELIA) of the Universidade Estadual de Maringá for helping to identify the species. To the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the doctoral scholarship granted to the first author.

Data availability

The dataset analyzed in this study is available from the corresponding author on reasonable request, as the data are still being used in complementary analyses.

References

- Almanza, V., Bicudo, C.E.M., Parra, O., & Urrutia, R., 2016. Características morfológicas y limnológicas de las floraciones de *Ceratium furcoides* (Dinophyta) en un lago somero de Chile Central. *Limnetica* 35(1), 253-268. <http://doi.org/10.23818/limn.35.21>.
- Almeida, C.R., Spiandorello, F.B., Giroldo, D., & Yunes, J.S., 2016. The effectiveness of conventional water treatment in removing *Ceratium furcoides* (Levander) Langhans, *Microcystis* sp. and microcystins. *Water S.A.* 42(4), 606-610. <http://doi.org/10.4314/wsa.v42i4.11>.
- Branco, S.M., Branco, W.C., Lima, H.A.S., & Martins, M.T., 1963. Identificação e importância dos principais gêneros de algas de interesse para o tratamento de águas e esgoto. *Rev. Dep. Águas e Esgotos*, (48-50), 1-59.
- Carty, S., & Parrow, M.W., 2015. Dinoflagellates. In: Wehr, J.D., Sheath, R.G., & Kociolek, J.P., eds. *Freshwater algae of North America: ecology and applications*. Cambridge: Academic Press, 343-368. 2nd ed. <http://doi.org/10.1016/B978-0-12-385876-4.00017-7>.
- Cavalcante, K.P., Zanotelli, J.C., Müller, C.C., Scherer, K.D., Frizzo, J.K., Ludwig, T.A.V., & Cardoso, L.D.S., 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. <http://doi.org/10.15560/9.4.862>.
- Cavalcante, K.P., Cardoso, L.S., Sussella, R., & Becker, V., 2016. Towards a comprehension of *Ceratium* (Dinophyceae) invasion in Brazilian freshwaters: autecology of *C. furcoides* in subtropical reservoirs. *Hydrobiologia* 771(1), 265-280. <http://doi.org/10.1007/s10750-015-2638-x>.
- Crossetti, L.O., Bicudo, D.D.C., Bini, L.M., Dala-Corte, R.B., Ferragut, C., & Bicudo, C.E.M., 2019. Phytoplankton species interactions and invasion by *Ceratium furcoides* are influenced by extreme drought and water-hyacinth removal in a shallow tropical reservoir. *Hydrobiologia* 831(1), 71-85. <http://doi.org/10.1007/s10750-018-3607-y>.
- Guiry, M.D., & Guiry, G.M., 2025. *AlgaeBase*: Entry for *Ceratium* [online]. Galway: National University of Ireland. Retrieved in 2025, August 8, from: <https://www.algaebase.org/browse/taxonomy/#6795>
- Hart, R.C., & Wragg, P.D., 2009. Recent blooms of the dinoflagellate *Ceratium* in Albert Falls Dam (KZN): history, causes, spatial features and impacts on a reservoir ecosystem and its zooplankton. *Water S.A.* 35(4), 455-468. <http://doi.org/10.4314/wsa.v35i4.76807>.
- Hickel, B., 1988. Sexual reproduction and life cycle of *Ceratium furcoides* (Dinophyceae) in situ in the lake Plußsee (F.R.). *Hydrobiologia* 161(1), 41-48. <http://doi.org/10.1007/BF00044098>.
- Landsberg, J.H., 2002. The effects of harmful algae blooms on aquatic organisms. *Rev. Fish. Sci.* 10(2), 113-390. <http://doi.org/10.1080/20026491051695>.
- Matsumura-Tundisi, T., Tundisi, J.G., Luzia, A.P., & Degani, R.M., 2010. Occurrence of *Ceratium furcoides* (Levander) Langhans 1925 bloom at the Billings Reservoir, São Paulo State, Brazil. *Braz. J. Biol.* 70(3 suppl), 825-829. <http://doi.org/10.1590/S1519-69842010000400013>.
- Morales, E.A., 2016. Floracion de *Ceratium furcoides* (Levander) Langhans (Dinoflagellata, Dinophyceae) en la represa de La Angostura, Cochabamba, Bolivia, Cochabamba, Bolivia. *Acta Nova* 7, 389-398.
- Moreira, R.A., Rocha, O., Santos, R.M., Laudaes-Silva, R., Dias, E.S., & Eskinazi-Sant'Anna, E.M., 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. Biol.* 75(1), 98-103. <http://doi.org/10.1590/1519-6984.08013>.
- Nishimura, P.Y., Pompêo, M., & Moschini-Carlos, V., 2015. Invasive dinoflagellate *Ceratium furcoides* (Levander) Langhans in two linked tropical reservoirs. In: Pompeo, M., Moschini-Carlos, V., Nishimura, P.Y., Silva, S.C., & Doval, J.C.L., eds. *Ecologia de reservatórios e interfaces*. São Paulo: Instituto de Biociências da Universidade de São Paulo, 132-142.
- Oliveira, F.H.P.C., Macêdo, I.M.E., Moreira, C.H.P., Shinohara, N.K.S., Lira, O.O., & Ramalho, W.P., 2016. Occurrence of *Ceratium furcoides* (Levander) Langhans 1925 (Dinophyceae: Ceratiaceae) in two reservoirs of the Capibaribe watershed located in Semiarid region. *Rev. Geama* 6(1), 25-33.
- Reynolds, C.S. 2006. *The ecology of phytoplankton*. Cambridge: Cambridge University Press.. <http://doi.org/10.1017/CBO9780511542145>.
- Rojas-Castillo, A.O., Pereira, L., Buffon, P., & Cardoso, L.S., 2023. Drivers and ecology of *Ceratium furcoides* invasion of a Brazilian subtropical reservoir and its interaction with the phytoplankton community. *Limnologica* 101, 126080. <http://doi.org/10.1016/j.limno.2023.126080>.
- Santos-Wisniewski, M.J., Silva, L.C., Leone, I.C., Silva, L.R., & Rocha, O., 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. Biol.* 67(4), 791-793. <http://doi.org/10.1590/S1519-69842007000400033>.
- Santer, B., 1996. Nutritional suitability of the dinoflagellate *Ceratium furcoides* for four copepod species. *J. Plankton Res.* 18(3), 323-333. <http://doi.org/10.1093/plankt/18.3.323>.
- Silva, L.C., Leone, I.C., Santos-Wisniewski, M.J., Peret, A.C., & Rocha, O., 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. <http://doi.org/10.1590/S1676-06032012000200010>.

- Silva, W.J., Nogueira, I.D.S., Melo-Magalhães, E.M., Benício, S.H.M., Pessoa, S.M., & Menezes, M., 2018. Expansion of invasive *Ceratium furcoides* (Dinophyta) toward north-central Brazil: new records in tropical environments. *Acta Limnol. Bras.* 30(0), e210. <http://doi.org/10.1590/s2179-975x5917>.
- Silva, L.N., Medeiros, C.M., Cavalcante, K.P., & Cardoso, L.S., 2019. Invasion and establishment of *Ceratium furcoides* (Dinophyceae) in an urban lake in Porto Alegre, RS, Brazil. *Acta Bot. Bras.* 33(4), 654-663. <http://doi.org/10.1590/0102-33062018abb0429>.
- Silva, R.D., Rosa, L.M., & Cardoso, L.S., 2024. Spread and persistence of the invasive dinoflagellate *Ceratium furcoides* (Levander) Langhans through South America: watersheds in Rio Grande do Sul, Brazil. *Aquat. Sci.* 86(2), 28. <http://doi.org/10.1007/s00027-024-01042-5>.
- Silva, R.D., Crossetti, L.O., Rosa, L.M., & Cardoso, L.S., 2025. *Ceratium furcoides* (Dinophyceae) and *Microcystis* spp. (Cyanophyceae) segregation patterns are ruled by nutrient availability and meteorological shifts in a subtropical region. *Hydrobiologia* 852(7), 1717-1742. <http://doi.org/10.1007/s10750-024-05771-4>.
- Taylor, F., Fukuyo, Y., & Larson, J., 1995. Taxonomy of harmful dinoflagellates. In *Manual of harmful marine microalgae* (G.M. Hallengraeff, D.M. Andersen & A.D. Cembella, eds.). Intergovernmental Oceanographic Commission, UNESCO, Paris, 551p.
- Tonetta, D.H.M.C., Hennemann, M.C., Brentano, D.M., & Petrucio, M.M., 2015. Considerations regarding the dominance of *Cylindrospermopsis raciborskii* under low light availability in a low phosphorus lake. *Acta Bot. Bras.* 29(3), 448-451. <http://doi.org/10.1590/0102-33062015abb0039>.
- Tucci, A., & Sant'Anna, C.L., 2003. *Cylindrospermopsis raciborskii* (Woloszynska) Seenayya & Subba Raju (Cyanobacteria): weekly variation and relation with environmental factors in an eutrophic lake, São Paulo, SP, Brazil. *Braz. J. Bot.* 26(1), 97-112. <http://doi.org/10.1590/S0100-84042003000100011>.

Received: 14 March 2025

Accepted: 17 October 2025

Associate Editor: Danielle Katharine Petsch.