



## Periphytic *Cosmarium* (Zygnematophyceae, Desmidiaceae) in lentic environments of the Upper Paraná River floodplain: Taxonomy and ecological aspects

*Cosmarium* (Zygnematophyceae, Desmidiaceae) perifítico em ambientes lânticos da  
Planície de Inundação do Alto Rio Paraná: Taxonomia e aspectos ecológicos

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**Abstract: Aim:** A taxonomic study of the species of the genus *Cosmarium* Corda ex Ralfs (Desmidiaceae) was conducted in two lentic environments of the Upper Paraná River Floodplain (Garças and Patos lakes). **Methods:** The samples were collected in November 2016. Two petioles of *Eichhornia azurea* (Sw) Kunth were sampled and analyzed qualitatively. **Results:** Six species, nine varieties, and three forms were identified, with five taxa being common to both lakes, nine in Garças Lake, and four in Patos Lake. Of this, thirteen species represent the first records for the floodplain environment. **Conclusion:** This study contributes to the knowledge of the biodiversity of this region, providing support for future ecological studies and biomonitoring.

**Keywords:** desmids; periphyton; taxonomic study; lakes.

**Resumo: Objetivo:** Foi realizado um estudo taxonômico das espécies do gênero *Cosmarium* Corda ex Ralfs (Desmidiaceae) em dois ambientes lânticos da Planície de Inundação do Alto Rio Paraná (Lago das Garças e Lago dos Patos). **Métodos:** As coletas foram realizadas em novembro de 2016. Dois pecíolos de *Eichhornia azurea* (Sw) Kunth foram amostrados e analisados qualitativamente. **Resultados:** Seis espécies, nove variedades e três formas foram identificadas, sendo cinco taxa em comum a ambos os lagos, nove no lago das Garças e quatro no lago dos Patos. Deste total, 13 espécies representam o primeiro registro de ocorrência para os ambientes da planície. **Conclusão:** Este estudo contribui para o conhecimento da biodiversidade desta região, promovendo suportes a futuros estudos ecológicos e de biomonitoramento.

**Palavras-chave:** desmídias; perifíton; estudo taxonômico; lagos.



## 1. Introduction

The desmids (Desmidiaceae) are a group of microscopic green algae that are characterized by conjugation as a means of sexual reproduction, and by cells that are formed of two symmetrical semicells (Meesters & Coesel, 2007). They have a cosmopolitan distribution, occurring in periphyton, metaphyton, and plankton of almost all freshwater environments (Coesel, 1996). The richness of desmids species is high, and it is estimated that there are up to 12,000 species in this family. The imprecision in the number of species is due to the large number of synonymous taxa, particularly for species of the genus *Cosmarium* Corda ex Ralfs (Coesel & Krienitz, 2008).

According to Bicudo & Menezes (2017) and Araújo & Bicudo (2006), one of the oldest genera of Desmidiaceae, and of all green algae, is *Cosmarium* Corda ex Ralfs, with approximately 1,500 already described species. The algae of this genus have a very diverse morphology, and their taxonomy is based on the shape of the semicell, the shape of the basal angle, the type of apex, the face of the semicell, the isthmus, the margin of the semicell, the cell wall and median sinus, the presence or absence and morphology of the angular papillae, and the number of pyrenoids per chloroplast (Prescott et al., 1981; Bicudo & Menezes, 2017).

Dunck et al. (2018) prepared a checklist of periphytic and planktonic algae from the Upper Paraná River Floodplain, and observed 50 taxa of the genus *Cosmarium*, of which 40 were recorded in periphyton. This floodplain is characteristically shallow and supports large banks of macrophytes that allow the development of desmids in both periphyton and metaphyton. However, studies that provide taxonomical and ecological information regarding the occurrence of this genus remains scarce. Ecologically, some species of this genus prefer acidic habitats and clean waters, and studies report their occurrence in oligotrophic, alkaline, and organic-rich environments (Coesel, 1983; Bicudo & Menezes, 2006).

This study aimed to conduct a taxonomic and ecological survey of the species of the genus *Cosmarium* present in two lakes (Garças and Patos lakes) located in the Upper Paraná River floodplain during the highwater period. Given that it is essential to have information up to the specific level to increase our understanding of ecological characterization, our objective was also to contribute to future studies, to the list of current species in the

floodplain, and to increase the knowledge of the Brazilian *Cosmarium* biodiversity.

## 2. Materials and Methods

### 2.1. Study area

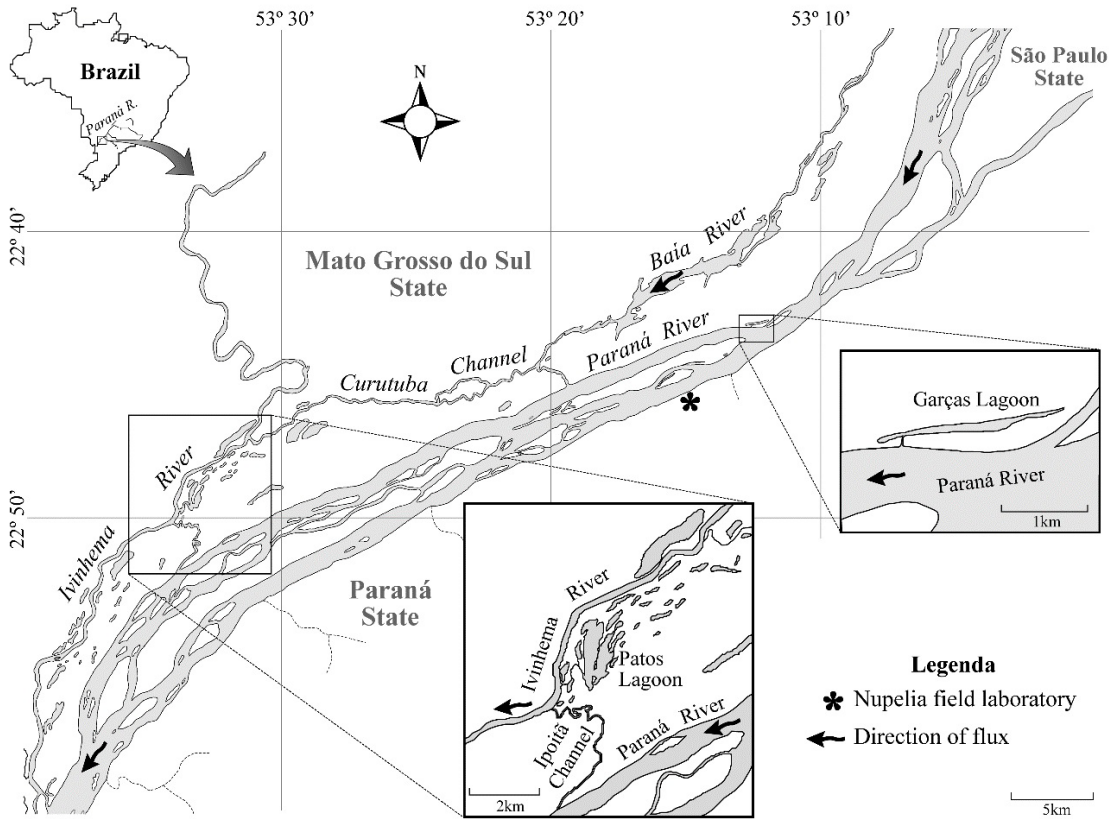
Samples were collected in November 2016 from two lakes in the Upper Paraná River floodplain (Figure 1): (i) Garças Lake (22°43'27.18"S, 53°13'4.56"W). This lake is on the right-hand side of the Paraná River, with which it is connected by a narrow channel that is approximately 100 m long. The littoral zone is dominated by multispecies stands of macrophytes, notably the emergent *Eichhornia azurea* (Sw.) Kunth. (ii) Patos Lake (22°49'33.66"S, 53°33'9.9"W). This lake is connected to the left-hand side of Ivinhema River through an approximately 10 m long channel. It is asymmetrical-shaped, with several multi-specific stands of macrophytes, including *E. azurea*.

Limnological variables were measured in the field for each lake: depth (m) (digital sonar–HawkEye); dissolved oxygen (% saturation and mg L<sup>-1</sup>) (digital oximeter–YSI55A); pH (digital portable pH meter–Digimed); conductivity (µS cm<sup>-1</sup>) (digital portable conductivity meter– Digimed); Secchi depth (m) (Secchi disk); turbidity (NTU) (digital turbidimeter–LaMotte2020e); total nitrogen and total phosphorus (µg L<sup>-1</sup>) (Bergamin et al., 1978; Mackereth et al., 1978); and alkalinity (µEq L<sup>-1</sup>) (Carmouze, 1994). To analyze suspended materials, samples were filtered under low pressure (<0.5 atm) using Whatman GF/F filters and kept cool for further laboratory analyses.

In addition, the trophic state index was calculated following an adapted Carlson's TSI to tropical lakes (Lamparelli, 2004). Based on this index we classify Patos Lake as eutrophic (TSI = 51) and Garças Lake as mesotrophic (TSI = 24). Notably, this calculation was performed from single point limnological conditions for each environment (Table 1). Because these are flood lakes, they can be affected by periodic flood pulses, and therefore the trophic value (TSI) can change according to the hydrological period analyzed. A summary of data for the selected water quality variables is shown in Table 1.

### 2.2. Species sampling of the genus *Cosmarium* Corda ex Ralfs

Periphytic microalgae of the genus *Cosmarium* were collected by scraping adult petioles of *E. azurea* using steel blades coated with aluminum foil, and with the aid of distilled water jets. The samples



**Figure 1.** Study area in the Upper Paraná River Floodplain: Garças and Patos lakes.

**Table 1.** Limnological parameters measured in November of 2016 in Garças and Patos lakes, in the Upper Paraná River Floodplain.

Abiotic characteristics	Garças Lake	Patos Lake
Depth (m)	1.70	3.70
Secchi depth (m)	1.10	0.45
Turbidity (NTU)	2.59	21.50
Alkalinity ( $\mu\text{Eq L}^{-1}$ )	531	358.9
Dissolved oxygen (%)	56.5	82.8
pH	7.03	7.31
Conductivity ( $\mu\text{S cm}^{-1}$ )	69.1	41.7
Total nitrogen ( $\mu\text{g L}^{-1}$ )	866.4	1094.9
Total phosphorus ( $\mu\text{g L}^{-1}$ )	24.5	51.3

were stored in appropriate bottles and fixed in 1:1 Transeau solution (Bicudo & Menezes, 2017).

The taxonomic study was performed from the population analysis (12 slides for each sample) under light microscopy. Morphological characteristics were observed and the total length (L), maximum width of the cell (W), and the isthmus (Isth) were measured using an eyepiece graticule, calibrated at 1000 $\times$  magnification using a stage micrometer. Digital images were made using a 14.0 MP LOPT14003 camera and Image-Pro Premier

9.1.4 software. Species were identified based on specialized literature such as Prescott et al. (1981) and Lenzenweger (1999), as well as local references (Aquino et al., 2016; Biolo et al., 2013; Felisberto & Rodrigues, 2008).

The identified species were described using taxonomic characteristics, ecological aspects, and their occurrence records in the Upper Paraná River floodplain. The samples used in the study were deposited in the Herbário do Nupélia (HNUP) - Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura, with the registration numbers HNUP-16499, HNUP-16500, HNUP-16501, and HNUP-16502. A key was devised to facilitate identification of these species in the studied environments.

### 3. Results and Discussion

We catalogued six species, nine varieties, and three forms of *Cosmarium* Corda ex Ralfs. A total of nine taxa were registered at Garças Lake, and a total of four taxa were recorded at Patos Lake. These lakes shared five species in common. Of this, thirteen species represent the first record of occurrence in the floodplain environments.

### 3.1. *Cosmarium* Corda ex Ralfs

The majority of *Cosmarium* Corda ex Ralfs species have semicells that are oval or elliptic in apical view. In lateral view, the semicells are mainly oval or elliptic shape, but often with swellings or protrusions into the transverse plane. The median incision of the cell may be a mere notch and open, or it may be deep, linear, and closed. The sinus may be inflated at the apex, closed for a short distance outwardly, and then open in varying degrees. The cell wall may be smooth, punctate, granulate, scrobiculate, with conical teeth, or with combinations of these features. The margins of the semicells as seen in front view may be smooth or variously undulate, granulate, toothed, serrate, or with shallow incisions (depressions or invaginations). The chloroplasts are large, axial, or parietal, and vary in number from one or two, rarely as many as eight in each semicell. The pyrenoids also are large and conspicuous, with one or two (rarely more) in each chloroplast. The nucleus is suspended in the isthmial region (Prescott et al., 1981).

Identification key for *Cosmarium* Corda ex Ralfs species in the Upper Paraná River floodplain:

1. Cell wall granulate, punctate, or finely punctuated ..... 2
1. Cell wall smooth ..... 15
  2. Median constriction shallow ..... 3
  2. Median constriction deep ..... 4
3. Chloroplast with 2 pyrenoids per semicell ..... *Cosmarium excavatum* var. *duplo-maius*
3. Chloroplast with 4 pyrenoids per semicell..... *Cosmarium pseudoconnatum* var. *pseudoconnatum*
  4. Semicell semicircular ..... *Cosmarium candianum* var. *candianum* f. *candianum*
  4. Semicell shaped otherwise ..... 5
5. Sinus widely open in throughout its extension ..... *Cosmarium porteanum*
5. Sinus without such characteristic ..... 6
  6. Semicell pyramidal or pyramidal-truncate ..... 7
  6. Semicell shaped otherwise ..... 9
7. Margins smooth ..... *Cosmarium granatum* var. *concauum*
7. Margins undulated..... 8

8. Cell wall punctate... *Cosmarium naegelianum*
8. Cell wall granulate ..... *Cosmarium crenatum* var. *crenatum* f. *crenatum*
  9. Presence of 2 pyrenoids per semicell..... 10
  9. Presence of 1 pyrenoids per semicell..... 12
10. Semicell trapezoidal, more broad than long. .... *Cosmarium lacunatum*
10. Semicell without such characteristic ..... 11
  11. Cells more long than broad, or as broad as long ..... *Cosmarium ornatum*
  11. Cells 1.2–1.4 times longer than broad ... *Cosmarium protractum* var. *protractum*
12. Cell wall granulate ..... *Cosmarium punctulatum* var. *punctulatum*
12. Cell wall punctate ..... 13
  13. Cell twice as long as broad ..... *Cosmarium exiguum* var. *exiguum* f. *exiguum*
  13. Cell 1.2 times longer than broad ..... 14
14. Cell wall with punctuation regular; semicell trilobed..... *Cosmarium trilobulatum*
14. Cell wall with punctuation irregular; semicell not-trilobed..... *Cosmarium pseudoretusum* var. *pseudoretusum*
  15. Cell more than 1.4 times longer than broad ..... 16
  15. Cell less than 1.4 times longer than broad ..... 17
16. Margins lateral with 8 undulations ..... *Cosmarium impressulum* var. *impressulum*
16. Margins lateral without undulations ..... *Cosmarium contractum* var. *contractum*
  17. Semicells rectangular ..... *Cosmarium norinbergense* var. *depressum*
  17. Semicells elliptic ..... *Cosmarium montrealense*

*Cosmarium candianum* Delponte var. *candianum* f. *candianum*, Mém. R. Accad. Sc. Torino 28: 113, pl. 8, fig. 1-6. 1877.

Cells 1.2 times broader than long, semicells semicircular, lateral margins and apex rounded, smooth; deep median constriction, linear median sinus, closed; punctuated cell wall; chloroplasts



with 2 pyrenoids per semicell. L: 40.42–44.48 µm, W: 38.87–41 µm, Isth: 13–16 µm. Figures 2a-b

Material examined: HNUP-16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: Morphologically *Cosmarium candianum* can be compared to *C. bailey* Wolle var. *bailey*, however, *C. bailey* differs in that it has sub-cylindrical cells, rounded isthmus, and roughly punctuated cell walls.

Ecology comments: This species was only found in Garças Lake, a mesotrophic environment with a neutral pH.

***Cosmarium contractum*** Kirchner var. *contractum*, in Cohn's Kryptogamen-Flora Schlesiens 2(1):147, 1878.

Cells 1.4–1.8 times longer than broad; semicells in face and vertical view broadly elliptic, in lateral view circular; smooth cell wall; median constriction deep, sinus opening, broad, isthmus slightly elongated; chloroplast axial with single central pyrenoid per semicell. L: 24–32 µm, W: 15.5–17.5 µm, Isth: 6–7 µm. Figure 3

Material examined: HNUP-16499, 16500.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: *Cosmarium moniliforme* Ralfs resembles *C. contractum* Kirchner. The former can be distinguished from the latter by the clearly circular semicells and by the lobed axial chloroplast. (Prescott et al., 1981).

Ecology comments: This species was only found in Patos Lake, a eutrophic environment.

***Cosmarium crenatum*** Ralfs ex Ralfs var. *crenatum* f. *crenatum*, Brit. Desm, p. 96. pl. 15, fig. 7.1848.

Cells medium-sized, longer than broad; semicells pyramidal, with lateral margins rounded, slightly retrics with 4 undulations, truncated apex margins with 4 undulations; vertical view is elliptic with median region inflated on both sides; deep median constriction and linear sinus not completely closed; chloroplasts without observed pyrenoids. L: 26–26.5 µm, W: 17–18 µm, Isth: 6–7 µm. Figure 4

Material examined: HNUP-16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: This species presents great morphological variation, and the individuals found in this study are similar to those found by Aquino et al. (2016).

Ecology comments: According to Meesters & Coesel (2007), this species is predominantly found in mesotrophic environments, in substrates that are moist, and slightly acid or neutral. This information is consistent with our results, in which this species was also found in a mesotrophic and neutral environment.

***Cosmarium excavatum*** Nordst. var. *duplo-maius*, Vidensk. MeddrNaturh. Foren. Kjöbenhavn 21: 214, pl. 3, fig. 25.1870.

Cells two times longer than broad; semicells subcircular, convex apex and lateral margins with 12 undulates, 12 intramarginal granules; hyaline and granulate cell wall, granules arranged in 4–5 vertical series in frontal view; shallow median constriction, semicircular median sinus, rounded end; axial chloroplasts with two pyrenoids per semicell. L: 30 µm, W: 18 µm, Isth: 12 µm. Figures 5a-b

Material examined: HNUP-16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: *Cosmarium excavatum* Nordst. var. *duplo-maius* has cells approximately twice the size of those of the typical variety.

Ecology comments: According to Taniguchi et al. (2003), the typical form is usually found in periphytic habitats, while in the present study, *C. excavatum* var. *duplo-maius* was found in a neutral pH and mesotrophic lake.

***Cosmarium exiguum*** W.Archer var. *exiguum* f. *exiguum* in Prescott et al., Syn. N.A. Desmids, 2(3): 195. 1981.

Cells median, approximately twice as long as broad; semicells subquadrate with angles rounded, sometimes slightly subpyramidal; apex almost straight; median constriction fairly deep; axial chloroplast with one pyrenoid per semicell. L: 24–25 µm, W: 19–20 µm, Isth: 6 µm. Figure 6

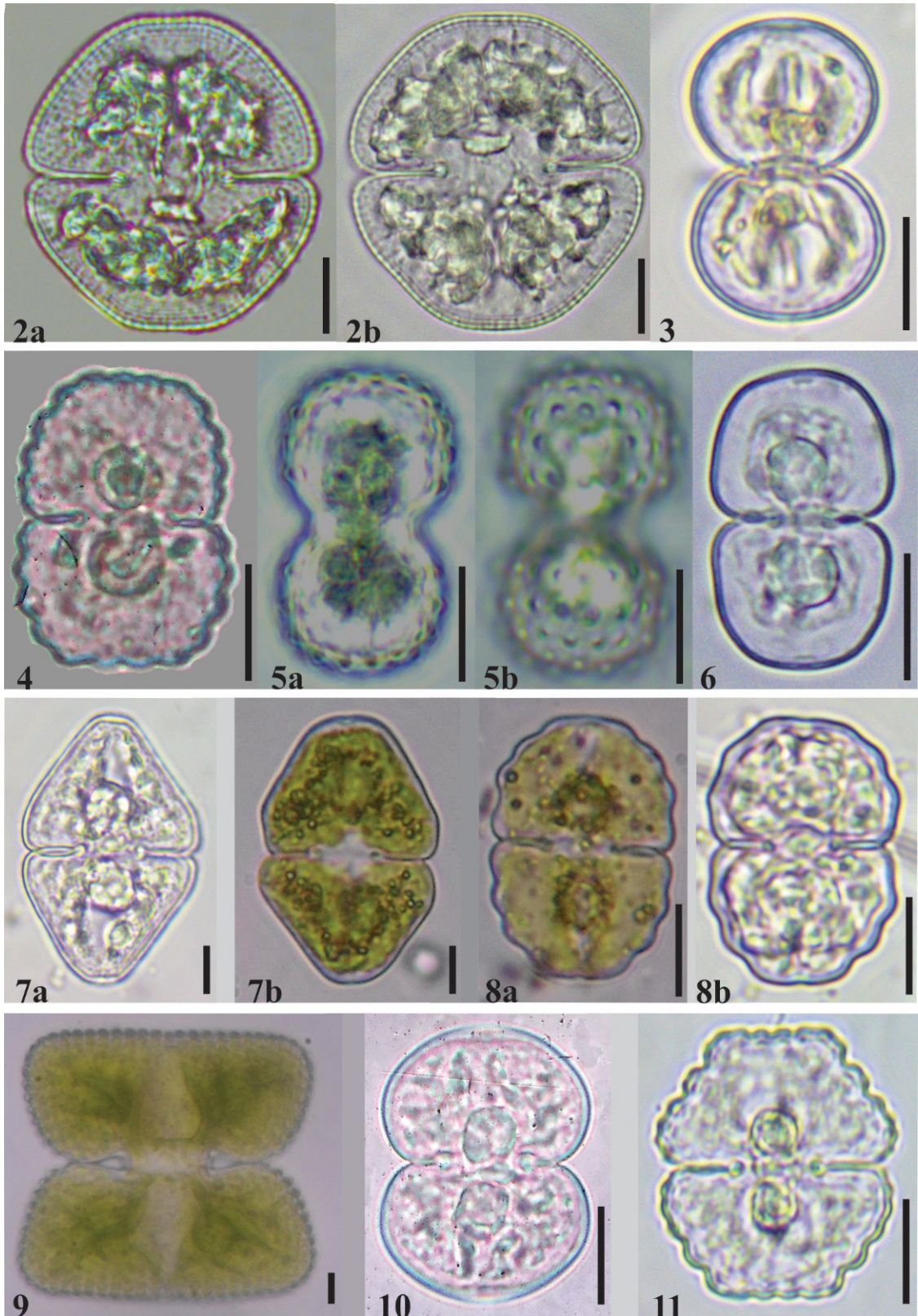
Material examined: HNUP- 16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: The individuals analyzed showed variability in the width of the semicells, which broader than those observed for the individuals analyzed by Prescott et al. (1981).

Ecology comments: This species was only found in Garças Lake, a neutral pH mesotrophic environment. In Estrela et al. (2011), this form was found in a slightly acidic (pH 6.0) environment.

***Cosmarium granatum*** Bréb. ex Ralfs var. *concauum* Lagerh., Anales Univ. Quito 4(27):



**Figures 2-11.** *Cosmarium* Corda ex Ralfs in the Upper Paraná River Floodplain. 2a-b. *Cosmarium candianum* var. *candianum* f. *candianum*; 3. *Cosmarium contractum* var. *contractum*; 4. *Cosmarium crenatum* var. *crenatum* f. *crenatum*; 5a-b. *Cosmarium excavatum* var. *duplo-maius*, 5b. detail of the wall ornamentation; 6. *Cosmarium exiguum* var. *exiguum* f. *exiguum*; 7a-b. *Cosmarium granatum* var. *concauum*; 8a-b. *Cosmarium impressulum* var. *impressulum*; 9. *Cosmarium lacunatum*; 10. *Cosmarium montralense*; 11. *Cosmarium naegelianum*; Scale: 10  $\mu$ m.



282, 1890; Borge, Ark. F. Bot. 1:95. pl. 3, fig. 11, 1903.

Cells 1.2–1.4 times longer than broad; semicells pyramidal-truncate, lateral margins concave, apex rounded-truncate, both smooth; rounded basal and apex angles, with thickening in apex; deep median constriction, closed sinus, punctuated cell wall; chloroplasts with one pyrenoid per semicell. L: 32–41.7  $\mu\text{m}$ , W: 21–29  $\mu\text{m}$ , Isth: 7–10  $\mu\text{m}$ . Figures 7a-b

Material examined: HNUP-16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: This variety differs from the typical because it presents concave sides, basal angles rounded and is tumid in apical view (Prescott et al., 1981).

Ecology comments: This species was only found in Garças Lake, a neutral pH mesotrophic environment.

***Cosmarium impressulum*** Elfving. var. *impressulum*, Acta Soc. Fauna Flora Fenn. 2(2): 13, pl. 1, fig. 9. 1881.

Cells 1.4–1.6 times longer than broad; semicells semicircular, rounded basal and higher angles, convex lateral margins, 8-undulate, bi-undulate higher margins; deep median constriction, closed sinus; smooth cell wall; chloroplasts with one pyrenoid per semicell. L: 26–30  $\mu\text{m}$ , W: 17–20  $\mu\text{m}$ , Isth: 5–6  $\mu\text{m}$ . Figures 8a-b

Material examined: HNUP-16499, 16500, 16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: *Cosmarium impressulum* var. *impressulum* may be confused with *Cosmarium undulatum* Corda ex Ralfs, based on similarities in morphology. *C. undulatum* has a higher number of undulations, and larger cells.

Ecology comments: *C. impressulum* var. *impressulum* is cosmopolitan, occurs in mesotrophic environments, and has benthic and planktonic habitats. Occurs in lentic and acid to alkaline (pH: 5-9) environments (John et al., 2002; Šťastný, 2010). In the present study, this species occurs in both the lakes studied, which are characterized as mesotrophic and eutrophic environments.

***Cosmarium lacunatum*** G.S. West, Journal of the Linnean Society, Botany, v. 38, p. 122, pl. 7, fig. 9, 1907.

Cells 1.2 times broader than long; semicells trapeziform, rounded basal and apical angles, convex and divergent lateral margins, apical margin

widely straight-retuse; deep median constriction, median sinus is narrow externally; granular cell wall, punctuated, granules arranged in oblique series; chloroplasts with two pyrenoids per semicell. L: 78–85  $\mu\text{m}$ , W: 75–84  $\mu\text{m}$ , Isth: 22–31  $\mu\text{m}$ . Figure 9

Material examined: HNUP-16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: *Cosmarium lacunatum* G.S. West can be easily confused in frontal view with *Cosmarium biretum* Bréb. ex Ralfs. However, the apical view of the *C. lacunatum* cell is elliptical, with straight margins, and without the intumescence in the median region of both margins that characterizes *C. biretum*.

Ecology comments: This species was only found in Garças Lake, a neutral pH mesotrophic environment.

***Cosmarium montrealense*** Croasdale in Prescott et al., Syn. N.A. Desmids, 2(3): 195. 1981.

Cell 1.2–1.4 times longer than broad; semicells transversely elliptic but with a reniform base and strongly rounded apex, widely rounded angles, smooth lateral and apical margins; cell wall smooth; median constriction deep, with linear sinus closed; chloroplasts with one pyrenoid per semicell. L: 27.5–30  $\mu\text{m}$ ; W: 20–26  $\mu\text{m}$ ; Isth: 6–7  $\mu\text{m}$ . Figure 10

Material examined: HNUP-16499, 16500, 16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: Prescott et al. (1981) differentiate *Cosmarium montrealense* from *Cosmarium bioculatum* Bréb. ex Ralfs by the first sinus being closed, and the second sinus open. In addition, *C. montrealense* cells are larger than *C. bioculatum* cells, which do not exceed 20  $\mu\text{m}$ .

Ecology comments: It is considered a cosmopolitan species, occurring mainly in acid environments (pH: 5), with metaphytic habit (Sophia et al., 2005). We recorded *C. montrealense* in both the lakes studied, with mesotrophic and eutrophic characteristics.

***Cosmarium naegelianum*** Bréb., Mém. Soc. Impér. Sci. Nat. Cherbourg 4: 127. 1856.

Cell 1.15–1.23 times longer than broad; semicells truncate-pyramidal, undulate margins; in lateral view, semicells subhexagonal, in vertical view, cell elliptic; cell wall sparsely punctate; median constriction very deep, linear sinus closed;

chloroplasts with one pyrenoid per semicell. L: 25–27 µm, W: 19–21 µm, Isth: 7 µm. Figure 11  
Material examined: HNUP-16499, 16500.

Occurrence: Algarte et al. (2006); Rodrigues & Bicudo (2001)

Taxonomy comments: This species had already been found in the Itaipu-Paraná Reservoir (Menezes et al., 2011), but the individuals examined in the present study were longer, with larger isthmuses (1–2 µm) than of those found in the floodplain.

Ecology comments: It is a cosmopolitan species of freshwater environments (Prescott et al., 1981; Guiry & Guiry, 2017). However, we found this species only in a eutrophic lake.

***Cosmarium norinbergense* var. *depressum*** (West et West) Krieger & Gerloff, Die Gattung *Cosmarium* 3/4: 292. pl. 48, fig. 1. 1969.

Basionym: *Cosmarium bioculatum* f. *depressa* (Schaarschm.) Schmidle

Cells as long as wide; semicells transversely rectangular, the lateral margin retuse but subparallel to a truncate apex which is as wide as the semicell base, semicells semicircular in lateral view; cell wall smooth and semicell face without a protrusion; median constriction deep, with linear sinus closed; chloroplasts with one pyrenoid per semicell. L: 11–12.5 µm, W: 11.8–12.5 µm, Isth: 4.6 µm. Figure 12

Material examined: HNUP-16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: According to Prescott et al. (1981), this variety differs from the typical one in that it has vertically narrower semicells, as if the lobes were flatter, that are wider than they are long.

Ecology comments: This species was only found in Garças Lake, a neutral pH mesotrophic environment.

***Cosmarium ornatum*** Ralfs ex. Ralfs, Brit. Desmidiaceae: 104, pl. 17, fig. 7. 1848.

Cells medium-sized, approximately as long as broad; reniform semicells showing granular protuberances in the median region, lateral margin with 7 to 9 prominent and rounded granules, semicells elliptical in apical view, with inflation in the central region on both sides; granulated cell wall; median constriction deep, with linear sinus closed; chloroplasts with two pyrenoids per semicell. L: 25 µm, W: 28 µm, Isth: 7 µm. Figure 13

Material examined: HNUP-16499, 16500.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: The individuals found in the present study were smaller than the ones described by Prescott et al. (1981), with the following dimensions: L: 32–41 µm, W: 30–41 µm and I: 9–13 µm. However, the sizes documented in the present are in agreement with those described by Aquino et al. (2016).

Ecology comments: Cosmopolitan species, occurring in both mesotrophic and oligotrophic lentic environments, in benthic habitats. It occurs mainly in acidic waters (Tell et al., 1994; John et al., 2002; Štátný, 2010). However, in the present study, this species was found in a eutrophic environment. It also occurs in environments with medium-high calcium concentrations (Brook, 1981).

***Cosmarium porteanum*** W.Archer, Proc. Dubl. Nat. Hist. Soc. 3: 49, pl. 1, figs. 8-9. 1860.

Cell 1.2–1.4 times longer than broad; semicells slightly reniform to rectangular, semicells circular in lateral view; granulated cell wall; median constriction deep, the sinus gradually opening from a rounded extremity, isthmus slightly elongated; chloroplasts with two pyrenoids per semicell. L: 42–48 µm, W: 31–45 µm, Isth: 8–14 µm. Figures 14a-c

Material examined: HNUP-16499, 16500, 16501, 16502.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: The cellular measurements presented in the present study showed higher values than those reported by Prescott et al. (1981). However, these measurements were very close to those of the species found in the Itaipú Reservoir recorded by Biolo et al. (2013).

Ecology comments: The species is considered cosmopolitan, present in mesotrophic, oligotrophic, meso-oligotrophic, and eutrophic habitats, and our results concur with this. It occurs mainly in lentic environments with pH ranges from 5.1 to 8.2. It is a species with a benthic habitat, generalist, and indicative of environments with high concentrations of iron (Prescott et al., 1981; Tell et al., 1994; John et al., 2002; Štátný, 2010; Montoya-Moreno & Aguirre, 2013).

***Cosmarium protractum*** (Nägeli) De Bary var. ***protractum***, Untersuch.Conjugaten: 72. 1858. G.West & W. West, Monogr. III, p. 181, pl. 82, fig. 8, pl. 94, figs. 4-5.

Basionym: *Euastrum protractum* Nägeli



Cells as long as wide; semicells 3-lobed, subretangular to subcircular, truncate and prominent apex, rounded margins, with granular protrusions in the median region; semicells oval in lateral view, with protuberances on each side near the base; granulated cell wall; median constriction deep, the sinus narrowly linear with a slightly dilated extremity; chloroplasts with two pyrenoids per semicell. L: 32–35 µm, W: 33–35.6 µm, Isth: 9–11 µm. Figures 15a-c

Material examined: HNUP-16499, 16500, 16501, 16502.

Occurrence: Moresco et al. (2015)

Taxonomy comments: This taxon was identified according to Prescott et al. (1981), which differentiated *C. protractum* from *C. ornatum* by the following characteristics: individuals with a prominent apex forming the apical lobe are identified as *C. protractum*, whereas those with reniform or subreniform forms and slightly elevated apices are considered as *C. ornatum*.

Ecology comments: This species was found in both lakes of the present study, in mesotrophic and eutrophic environments.

***Cosmarium pseudoconnatum*** Nordst. var. ***pseudoconnatum***, Vidensk. Medd. Naturh. Foren. Kjöbenhavn 21: 214, pl. 3, fig. 17.1870.

Cells 1–1.5 times longer than broad; semicells semielliptic, rounded basal angles, with lateral view of semicell similar to frontal, circular apical view; finely punctured wall; slight median constriction, the sinus very broad and shallow; chloroplasts with four pyrenoids per semicell. L: 37–45 µm, W: 32–37 µm, Isth: 32 µm. Figures 16a-c

Material examined: HNUP-16499, 16500, 16501, 16502.

Occurrence: Algarte et al. (2006); Bichoff et al. (2016); Dunck et al. (2016); Train et al. (2004).

Taxonomy comments: Morphologically, the present species is similar to *C. connatum* Bréb. in that they both have relatively small cells, slighter medial constriction, and proportionally rounded semicells (Bicudo, 1969).

Ecology comments: It is a cosmopolitan species with a periphytic habitat, and occurs in lentic environments with pH ranges from 6 to 8, mainly in alkaline waters (Tell et al., 1994; John et al., 2002; Taniguchi et al., 2003). In the present study, we found this species in both lakes, in mesotrophic and eutrophic environments.

***Cosmarium pseudoretusum*** F.Ducell. var. ***pseudoretusum***, Bull. Soc. Bot. Genève, II, 10: 99. 1918.

Cells 1.2 times longer than broad; semicells in face view with sides slightly diverging and slightly retuse from the sinus, apical and lateral angles rounded, basal angles rather sharp and typically bearing a small papilla, lateral view of semicells elliptic, vertical view elliptic with slight median swelling; cell wall irregularly punctate, the puncta stronger near the basal angles; median constriction deep, sinus closed; chloroplasts with one pyrenoid per semicell. L: 23–24 µm, W: 19–20 µm, Isth: 5–6 µm. Figure 17

Material examined: HNUP-16499, 16500.

Occurrence: First record for the Upper Paraná River Floodplain.

Taxonomy comments: *Cosmarium pseudoretusum* F. Ducell. is very similar to *C. trilobulatum* Reinsch, differing only in that *C. pseudoretusum* has a less flattened apex, and the ventral view is tumider than for *C. trilobulatum* (Prescott et al., 1981).

Ecology comments: *C. pseudoretusum* var. *pseudoretusum* occurs in oligo-mesotrophic environments (Meesters & Coesel, 2007; Krasznai et al., 2008). In the present study, however, it was found in a eutrophic environment.

***Cosmarium punctulatum*** Bréb. var. ***punctulatum***, Mém. Soc. Imp. Sci. nat. Cherbourg, 4: 129, pl. 1, fig. 16. 1856.

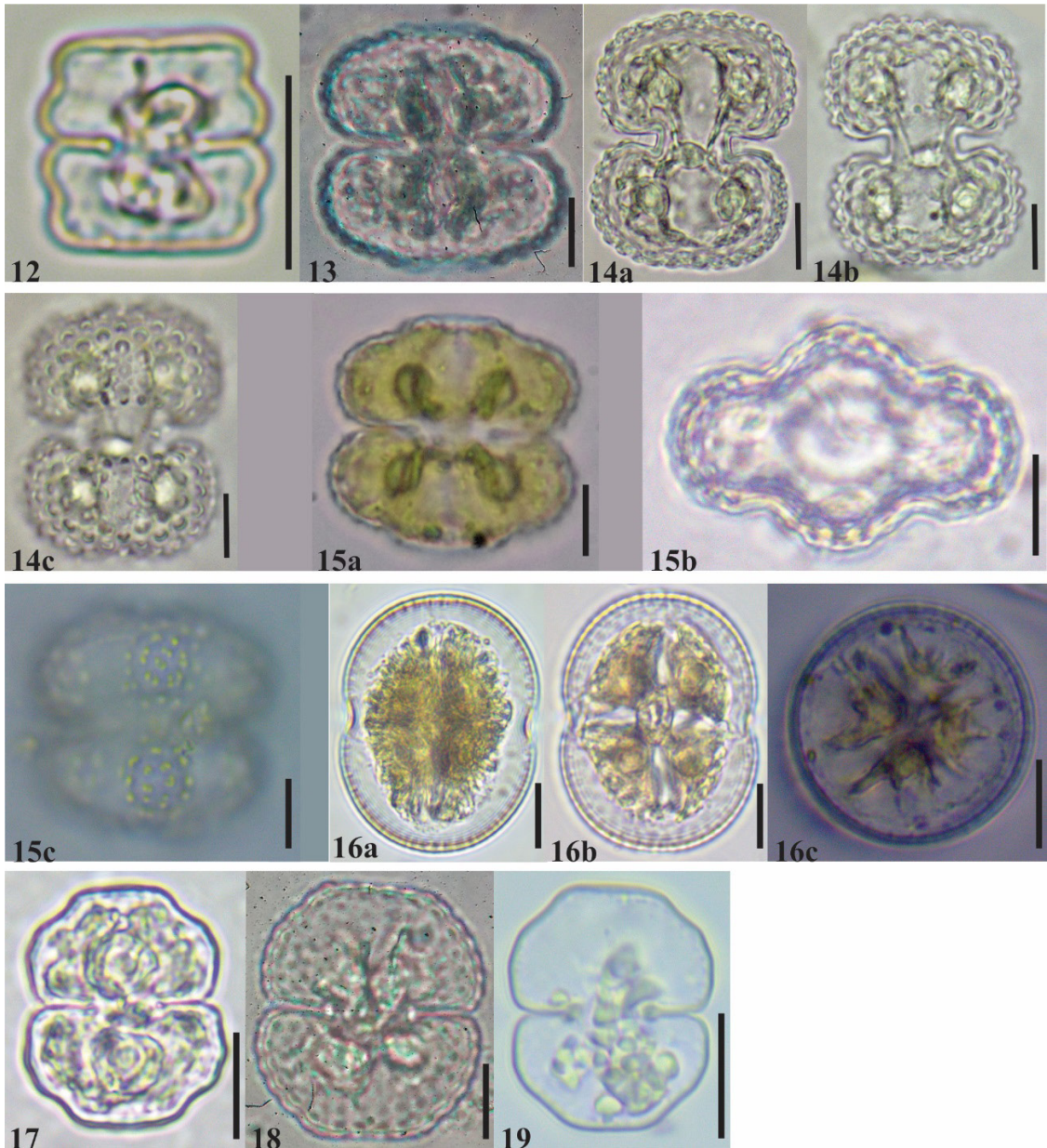
Cells 1.1 times longer than broad; semicells oblong-trapeziform, lower angles rounded, apex broadly truncate, in lateral view semicells circular, in vertical view cell elliptic; cell wall granulate, granules solid; median constriction very deep, sinus closed; chloroplasts with one pyrenoid per semicell. L: 32–32.5 µm, W: 27–29 µm, Isth: 9 µm. Figure 18

Material examined: HNUP-16501, 16502.

Occurrence: Algarte et al. (2006); Biolo & Rodrigues (2011).

Taxonomy comments: In the analyzed specimens, granules were observed in the central region. Prescott et al. (1981) reported that these granules in the central region of the semicell may be small (and therefore difficult to see using light microscopy), and may sometimes not occur in the central region.

Ecology comments: This taxon is uncommon in slightly acidic to alkaline waters (Meesters & Coesel, 2007), and we recorded its presence in a mesotrophic environment.



**Figures 12-19.** *Cosmarium* Corda ex Ralfs in the Upper Paraná River Floodplain. 12. *Cosmarium norinbergense* var. *depressum*; 13. *Cosmarium ornatum*; 14a-c. *Cosmarium porteanum*, 14b-c. detail of the wall ornamentation; 15a-c. *Cosmarium protractum* var. *protractum*, 15b. apical view, 15c. wall ornamentation detail; 16a-c. *Cosmarium pseudoconnatum* var. *pseudoconnatum*, 16b. chloroplast detail, 16c. apical view; 17. *Cosmarium pseudoretusum* var. *pseudoretusum*; 18. *Cosmarium punctulatum* var. *punctulatum*; 19. *Cosmarium trilobulatum*. Scale: 10  $\mu$ m.

***Cosmarium trilobulatum*** Reinsch, Acta Soc. Senckenberg 6: 118(10), pl. 22(3) A II, figs. 1-6. 1867.

Cells 1.2–1.3 times longer than broader; semicells trilobulate, convergent lateral margins, apical margin broadly truncated, retrics in the middle part; deep median constriction, sinus closed; final punctuated cell wall; chloroplasts with one pyrenoid per semicell. L: 17–22.8  $\mu$ m, W: 10–19  $\mu$ m, Isth: 4–7  $\mu$ m. Figure 19

Material examined: HNUP-16501, 16502.

Occurrence: Algarte & Rodrigues (2013); Algarte et al. (2006); Biolo & Rodrigues (2011).

Taxonomy comments: We did not observe a population of this species sufficient enough to identify a variety. The variety most similar to the population in the present study is *C. trilobulatum* var. *abscissum*, but the measurements previously observed for this variety are somewhat higher than those recorded in the present study.

**Table 2.** Species and infraspecific taxa found in November 2016 in Garças and Patos lakes, in the Upper Paraná River Floodplain, where: presence (x), and absence (-).

Species and infraspecific taxa	Garças Lake	Patos Lake
<i>Cosmarium candianum</i> var. <i>candianum</i> f. <i>candianum</i> Delponte	x	-
<i>Cosmarium contractum</i> var. <i>contractum</i> Kirchner	-	x
<i>Cosmarium crenatum</i> var. <i>crenatum</i> f. <i>crenatum</i> Ralfs	x	-
<i>Cosmarium excavatum</i> var. <i>duplo-maius</i> Nordst.	x	-
<i>Cosmarium exiguum</i> var. <i>exiguum</i> f. <i>exiguum</i> Archer	x	-
<i>Cosmarium granatum</i> var. <i>concaum</i> Lagerheim	x	-
<i>Cosmarium impressulum</i> var. <i>impressulum</i> Elfving*	x	x
<i>Cosmarium lacunatum</i> G.S.West	x	-
<i>Cosmarium montrealense</i> Croasdale*	x	x
<i>Cosmarium naegelianum</i> Brébisson	-	x
<i>Cosmarium norinbergense</i> var. <i>depressum</i> (West et West) Krieger & Gerloff	x	-
<i>Cosmarium ornatum</i> Ralfs	-	x
<i>Cosmarium porteanum</i> Archer*	x	x
<i>Cosmarium protractum</i> var. <i>protractum</i> (Nägeli) De Bary*	x	x
<i>Cosmarium pseudoconnatum</i> var. <i>pseudoconnatum</i> Nordst*	x	x
<i>Cosmarium pseudoretusum</i> var. <i>pseudoretusum</i> Duceillier	-	x
<i>Cosmarium punctulatum</i> var. <i>punctulatum</i> Brébisson	x	-
<i>Cosmarium trilobulatum</i> Reinsch	x	-

\*Cosmopolitan species.

Ecology comments: According Taniguchi et al. (2003), individuals of this species are periphytic and metaphytic. It is known to occur in humid places, such as sand (Meesters & Coesel, 2007). In the present study, we recorded its presence in a mesotrophic environment.

From the eighteen taxa included in this study (Table 2), five species are considered cosmopolitan in other studies (as indicated in the Table 2). Only five species were recorded in both lakes, which are all commonly occurring taxa in Brazilian flora. The common occurrence of these taxa may be related to their adaptive capacity to occupy differing aquatic environments and occur at higher frequencies in the analyzed samples, since our lakes have different limnological characteristics.

In previous studies, the desmids rarely occurred in both lakes studied, contributing only to species richness in Garças Lake (Murakami et al., 2009), and with little representation in Patos Lake (Carapunarla et al., 2014). However, Krasznai et al. (2008) suggests that the rarity of *Cosmarium* species in a given environment limits the knowledge about the tolerance of these species, or even of their presence in these environments, because conclusions based only on the occurrence of these taxa do not provide information on their tolerance levels to environmental changes.

Ecologically, some *Cosmarium* species prefer acidic habitats, with clean water and oligotrophic environments (Coesel, 1983; Bicudo & Menezes,

2017). In the present study, we observed that species of this genus can also be found in mesotrophic (most) and eutrophic environments, with turbid waters and a neutral pH. This does not correlate with data published in the literature.

In conclusion, this study contributes towards an increase in knowledge of biodiversity in this region, since of the 19 species documented, fourteen are recorded for the first time for this flood plain. Thus, studies similar to the present study are indispensable in promoting future ecological and biomonitoring studies.

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