

New records of *Cosmarium* Corda ex Ralfs (Desmidiaceae, Zygnematophyceae) in a tributary of the Itaipu Reservoir, Paraná, Brazil

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ABSTRACT

This work is part of a survey of the desmid flora in a tributary of the Itaipu Reservoir, in the state of Paraná, Brazil. The objective was to expand the knowledge base regarding the genus *Cosmarium* (Desmidiaceae, Zygnematophyceae). We conducted a qualitative analysis of 60 samples of phytoplankton, which were collected from along the banks of the São Francisco Falso River between July of 2003 and June of 2004. We identified, drew, and described 18 taxa of *Cosmarium*. Of those 18 taxa, 8 represent new records for the state of Paraná: *C. angulosum* Bréb. var. *angulosum*, *C. bireme* Nordst. var. *bireme*, *C. clepsydra* Nordst. var. *clepsydra*, *C. cf. galeritum* Nordst. var. *borgei*, *C. ginzbergeri*, *C. norimbergense* Reinsch var. *norimbergense*, *C. protractum* (Nägeli) De Bary var. *protractum*, and *C. rectangulare* var. *hexagonum* (Elfving) G.S. West & West.

Key words: algae, desmids, phytoplankton, taxonomy

Introduction

Cosmarium Corda ex Ralfs is one of the oldest and most species-rich genera of the family Desmidiaceae (Croasdale & Flint 1988). It is estimated that more than 1500 freshwater species have been described. These species can be cosmopolitan or have a very limited distribution, covering a wide range of taxonomic forms (Bicudo & Menezes 2006; Franceschini *et al.* 2010).

To date, eight taxonomic studies have shown the presence of *Cosmarium* Corda ex Ralfs in the state of Paraná, Brazil. Bittencourt-Oliveira (1993) inventoried the phytoplankton community in the Tibagi River and identified 14 taxa of *Cosmarium*. Cecy *et al.* (1997) and Picelli-Vicentim *et al.* (2001) inventoried the phytoplankton community in the Passaúna River Dam area and identified 15 and 4 *Cosmarium* taxa, respectively. When inventorying the desmids in the Salto Caxias Reservoir Hydroelectric Power Plant, Silva & Cecy (2004) identified 20 *Cosmarium* taxa, 13 of which were new records for the state. Felisberto & Rodrigues (2008) identified 17 *Cosmarium* taxa among the periphyton community in the Salto do Vau Reservoir. Those authors also identified 48 taxa of *Cosmarium* in three areas near the Rosana Reservoir Hydroelectric Power Plant. Bortolini *et*

al. (2010) surveyed the Cascavel Municipal Lake and identified 21 *Cosmarium* taxa, 10 of which were new records for the state. Finally, Menezes *et al.* (2011) found 23 taxa of *Cosmarium* in the São Francisco Falso River.

The objective of the present study was to gain a deeper understanding of the taxonomy and geographic distribution of *Cosmarium* in the São Francisco Falso River, thereby increasing our knowledge of and disseminating information on the diversity of algae in the state of Paraná. To that end, we conducted a geospecific taxonomic study of the genus.

Material and methods

The São Francisco Falso River is one of the main tributaries of the Itaipu Reservoir (24°05' -25°33'S; 54°00' -54°37'W) on the Brazilian side of the border with Paraguay, the creation of the reservoir having flooded an area of the city of Santa Helena, in the state of Paraná. Although it is affected by agricultural activities in the surrounding areas, as well as by tourism and leisure activities (artificial beaches), the São Francisco Falso River does not receive urban or industrial effluents (Silva *et al.* 2010).

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The study samples were collected monthly in the 2003-2004 period from five sampling stations along the São Francisco Falso River:

Station 1—24°52'41"S; 54°13'35"W

Station 2—24°52'28"S; 54°15'17"W

Station 3—24°51'52"S; 54°16'02"W

Station 4—24°51'30"S; 54°17'11"W

Station 5—24°51'14"S; 54°17'11"W

The samples were collected with a 25-mm mesh plankton net and were preserved in Transeau's solution (1:1), having been placed in the solution immediately after collection (Bicudo & Menezes 2006).

For qualitative analysis, we prepared temporary slides (20 slides per sample, on average, or as many slides as needed until no different taxa were observed). The slides were examined with a binocular microscope at magnifications of $\times 400$ and $\times 1000$, and *camera lucida* drawings were made at those same magnifications. The specimens were added to the *Herbário da Universidade Estadual de Maringá* (HUM, State University at Maringá Herbarium; Accession nos. 12,612-12,671), located in the city of Maringá, Brazil, and the *Herbário da Universidade Estadual do Oeste do Paraná* (UNOP, State University of Western Paraná Herbarium; Accession nos. 1824-2267), located in the city of Cascavel, Brazil. Measurements (length and width) are expressed in μm .

For each *Cosmarium* species, we calculated the constancy index, modified from the method proposed by Dajoz (1978) and expressed as a percentage, using the following equation: $C = (p \times 100)/P$, where p = number of samples containing a given species and P = total number of samples. On the basis of the results obtained, we determined the constancy of *Cosmarium* spp.: $C \geq 70$, constant species; $30 \leq C < 70$ = common species; $10 \leq C < 30$ = sporadic species; and $C < 10$ = rare species. The taxonomic distribution was based on taxonomic studies conducted in the state of Paraná up until 2011, including descriptions and illustrations.

Material and methods

Our taxonomic survey of the genus *Cosmarium* Corda ex Ralfs in the São Francisco Falso River allowed us to identify 41 taxa. Of those, 23 had been previously described by Menezes *et al.* (2011). Therefore, we registered and described 18 new taxa. Of those, 1 was identified down to the genus level, 2 were identified down to the species level, and 15 were described as variants. Of those 15 variants, 10 were typical and 5 were atypical (of their species). The distribution of the *Cosmarium* taxa inventoried is shown in Table 1.

Of the 18 taxa that we registered and described, 8 were new records for the state of Paraná: *Cosmarium angulosum* Bréb. var. *angulosum*, *C. bireme* Nordst. var. *bireme*, *C. clepsydra* Nordstedt var. *clepsydra*, *C. galeritum* Nordst. var. *borgei* W. Krieg. & Gerloff, *C. ginzbergeri* Grönblad, *C. norimbergense* Reinsch var. *norimbergense*, *C. protractum* (Nägeli) De Bary var. *protractum*, and *C. rectangulare* var. *hexagonum* (Elfving) G.S. West & W. West.

The *Cosmarium* algae found among the phytoplankton community in the São Francisco Falso River between 2003 and 2004 in the present study were predominantly rare or sporadic. Only *Cosmarium reniforme* var. *reniforme* was common during sampling, and none of the taxa were constant.

Cosmarium Corda ex Ralfs

Cosmarium Corda ex Ralfs are single, free-living cells that are usually deeply constricted medially. The median sinus ranges from shallow to fully dilated. In terms of shape, the semicells can range from nearly spherical to subpyramidal or conical. The lateral margins can be smooth, wavy, granular, dentate, or serrated, or they can have shallow incisions. The cell wall can be smooth, punctate, granular, scrobiculate, spiculate, or variously ornamented, having no angular or lateral spinules. The chloroplasts can be axial or, more rarely, parietal, each chloroplast containing one, two, four, or, more rarely, numerous pyrenoids (Bicudo & Menezes 2006; Francheschini *et al.* 2010).

Artificial key to identify the taxa of *Cosmarium* Corda ex Ralfs in the São Francisco Falso River:

1. Smooth or punctate cell wall
 2. Smooth cell wall
 3. Open median sinus..... 11. *C. moniliforme* var. *moniliforme*
 3. Closed median sinus
 5. Lateral margins with one concavity..... 12. *C. norimbergense* var. *norimbergense*
 5. Straight to convex lateral margins
 6. Convex lateral margins, oblong to trapeziform semicell with 2 pyrenoids and apical thickening..... 8. *Cosmarium* sp.
 6. Straight to slightly convex lateral margins, semicell of shapes other than those described above, with 1 pyrenoid and without apical thickening
 7. Obtusely conical or generally convex apical margin, subsemicircular to subtriangular semicell..... 5. *C. clepsydra* var. *clepsydra*
 7. Truncate apical margin, semicell of shapes other than those described above

- 8. Subtrapeziform semicell..... 1. *C. abbreviatum* var. *minus*
- 8. Angular-elliptical semicell
 - 9. Cell that is wider than it is long..... 4. *C. bireme* var. *huzelii*
 - 9. Cell that is as long as it is wide or that is longer than it is wide..... 3. *C. bireme* var. *bireme*
- 2. Punctate cell wall
 - 10. Open median sinus, subquadratic to subrectangular semicell..... 2. *C. angulosum* var. *angulosum*
 - 10. Closed median sinus, semicell of shapes other than those described above
 - 11. Narrow, slightly retuse to notched apical margin, semielliptical, slightly angular to subpyramidal semicell..... 10. *C. laeve* var. *laeve*
 - 11. Wide apical margin, semicell of shapes other than those described above
 - 12. Divergent lateral margins in the first part (converging to the apex), subhexagonal semicell..... 15. *C. rectangulare* var. *hexagonum*
 - 12. Lateral margins converging directly to the apex, pyramidal-trapezoidal semicell..... 8. *C. cf. galeritum* var. *borgei*
- 1. Granular cell wall
 - 13. Open median sinus
 - 14. Shallow median constriction
 - 15. Subcircular semicell..... 7. *C. excavatum* var. *excavatum*
 - 15. Subrectangular semicell..... 16. *C. regnesi* var. *regnesi*
 - 14. Deep median constriction, semicell of shapes other than those described above
 - 16. Three-lobed semicell, granules arranged in oblique, decussate series and becoming smaller as they reach the central bulge, where they are arranged in rings..... 14. *C. protractum* var. *protractum*
 - 16. Semicell of shapes other than those described above, granules arranged in ways other than those described above
 - 17. Reniform to rectangular semicell, granules arranged in longitudinal series..... 13. *C. portianum* var. *portianum*
 - 17. Semicircular to truncate pyramidal semicell, granules arranged densely and hexagonally 6. *C. decoratum*
 - 13. Closed median sinus
 - 18. Elliptical semicell, single series of intramarginal granules arranged apically and laterally, series of granules in the region of the isthmus..... 9. *C. ginzbergeri*
 - 18. Oblong-elliptical semicell, granules distributed throughout the cell 17. *C. reniforme* var. *reniforme*

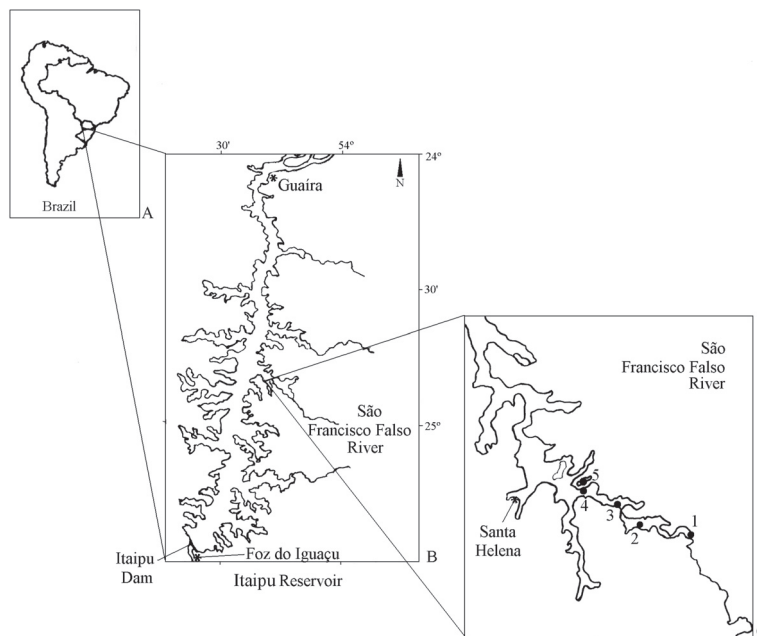


Figure 1. A. Map of the study area, Paraná, Brazil; B. São Francisco Falso River in the Itaipu Reservoir; C. Location of the sampling stations along the São Francisco Falso River (Source: Biolo *et al.* 2008, modified from Agostinho *et al.* 1999).

Table 1. Distribution of the *Cosmarium* taxa found at sampling stations along the São Francisco Falso River between July of 2003 and June of 2004.

Taxon	Collection date												Sampling station				
	2003						2004						1	2	3	4	5
	Jul 1	Jul 28	Sep 1	Oct 6	Nov 4	Dec 8	Jan 19	Feb 3	Mar 10	Apr 5	May 4	Jun 17	1	2	3	4	5
<i>C. abbreviatum</i> Racib. var. <i>minus</i> (West & G.S. West) W. Krieg. & Gerloff B.	●	●	●	●	●	●			●	●	●	●	○	○	○	○	○
<i>C. angulosum</i> Bréb. var. <i>angulosum</i>		●	●	●	●	●				●					○	○	○
<i>C. bireme</i> Nordst. var. <i>bireme</i>	●					●	●			●		●	○	○	○	○	○
<i>C. bireme</i> Nordst. var. <i>huzelii</i> Förster				●							●	●	○	○	○	○	○
<i>C. clepsydra</i> Nordst. var. <i>clepsydra</i>						●			●								○
<i>C. decoratum</i> West & G.S. West		●								●	●			○			○
<i>C. excavatum</i> Nordst. var. <i>excavatum</i>										●							○
<i>C. galeritum</i> Nordst. var. <i>borgei</i> W. Krieg. & Gerloff		●	●			●				●				○	○	○	○
<i>C. ginzbergii</i> Grönblad		●												○			
<i>C. laeve</i> Rabenh. var. <i>laeve</i>		●	●	●	●	●		●		●		●	○	○	○	○	○
<i>C. moniliforme</i> (Turpin) Ralfs var. <i>moniliforme</i>		●	●	●	●	●	●			●			○	○	○	○	○
<i>C. norimbergense</i> Reinsch var. <i>norimbergense</i>		●											○	○	○	○	○
<i>C. portianum</i> Archer var. <i>portianum</i>		●	●	●	●	●	●			●	●			○	○	○	○
<i>C. protractum</i> (Nägeli) De Bary var. <i>protractum</i>									●					○			○
<i>C. rectangularare</i> var. <i>hexagonum</i> (Elfving) G.S. West & W. West		●	●	●	●					●		●		○	○	○	○
<i>C. regnesi</i> Reinsch var. <i>montanum</i> Schmidle																	○
<i>C. reniforme</i> (Ralfs) Archer var. <i>reniforme</i>		●	●	●	●	●		●	●	●	●	●	○	○	○	○	○
<i>Cosmarium</i> sp.	●							●	●		●			○			○

1. *Cosmarium abbreviatum* var. *minus* (West & G.S. West)

Willi Krieger & Gerloff, Die Gattung *Cosmarium* 3-4: 242. 1965; 2: pl. 42, fig. 18. 1965. 1969.

Cosmarium abbreviatum f. *minor* West & G.S. West, Trans. Yorkshire Nat. Union 5(23): 92. 1900.

A cell that is as wide as it is long, deep median constriction, closed median sinus; subtrapeziform semicell, rounded basal angles, slightly retuse lateral margins medially, truncate apical margin; smooth cell wall, chloroplast = 1, pyrenoid = 1. Dimensions: 10.0-14.3 µm in length; 10.0-14.3 µm in width; isthmus, 3.0-4.2 µm.

Constancy: sporadic.

Distribution in the state of Paraná: Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010).

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 01/VII/2003, Bueno 855 (HUM, UNOP), 28/VII/2003, Bueno 861 (HUM, UNOP), 01/IX/2003, Bueno 871, 874 (HUM, UNOP), 06/X/2003, Bueno 883 (HUM, UNOP), 04/XI/2003, Bueno 888 (HUM, UNOP), 08/XII/2003, Bueno 904, 906 (HUM, UNOP), 10/III/2004, Bueno 921 (HUM, UNOP), 05/IV/2004, Bueno 926 (HUM, UNOP), 17/VI/2004, Bueno 938 (HUM, UNOP).

Because *C. abbreviatum* var. *minus* shows considerable polymorphism, Bicudo (1988) and Bicudo (1996) proposed a list of synonyms, which was employed by Felisberto & Rodrigues (2004; 2008). The variety *minus* can be distinguished from the typical variety of the species by its smaller size and its lateral angles, which are not as rounded or pronounced. Our cell measurements yielded values that were lower than were those initially reported by Felisberto & Rodrigues (2004) but consistent with those later reported by the same authors (Felisberto & Rodrigues 2008).

2. *Cosmarium angulosum* Bréb. var. *angulosum*, Mém. Soc. Impér. Nat. Cherbourg 4: 127. pl. 1, fig. 17. 1856.

A cell that is 1.5 times as long as it is wide, deep median constriction, open median sinus; subquadratic to subrectangular semicell, smooth, straight, or slightly convex lateral margins, rounded, truncate apical margin; punctate cell wall, chloroplast = 1, pyrenoid = 1; angular-elliptical apical view, subcircular lateral view. Dimensions: 18.4-24.5 µm in length; 12.2-16.3 µm in width; isthmus, 2.0-4.4 µm.

Constancy: sporadic.

Distribution in the state of Paraná: First record of the taxon.

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 28/VII/2003, Bueno 861 (HUM, UNOP), 01/IX/2003, Bueno 872 (HUM, UNOP), 06/X/2003, Bueno 883 (HUM, UNOP), 04/XI/2003, Bueno 888 (HUM, UNOP), 08/XII/2003, Bueno 904 (HUM, UNOP), 05/IV/2004, Bueno 926, 928 (HUM, UNOP).

When describing taxa of *C. angulosum* var. *angulosum*, Prescott *et al.* (1981) reported an open median sinus; how-

ever, the illustrations clearly show a linear median sinus. In the present study, we found individuals whose characteristics were consistent with those described by Prescott *et al.* (1981), some specimens having shown a slightly linear sinus. We chose to identify *C. angulosum* var. *angulosum* in accordance with the description provided by Prescott *et al.* (1981). Therefore, our description and our pictorial representation show an open median sinus.

3. *Cosmarium bireme* Nordst. var. *bireme*, Vidensk. Medd. Naturh. Foren. Kjöbenhavn 1869(14/15): 212, pl. 3, fig. 33. 1870.

A cell that is 1.1 times as long as it is wide or that is as long as it is wide, deep median constriction, closed median sinus dilated at the apex; angular-elliptical semicell, rounded lateral margins, truncate apical margin; smooth cell wall, chloroplast = 1, pyrenoid = 1; an apical view with a central papilla on the semicell surface. Dimensions: 10.0-22.0 µm in length; 9.0-20.0 µm in width; isthmus, 4.0-8.0 µm.

Constancy: sporadic.

Distribution in the state of Paraná: First record of the taxon.

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 01/VII/2003, Bueno 885 (HUM, UNOP), 08/VII/2003, Bueno 904 (HUM, UNOP), 19/I/2004, Bueno 911 (HUM, UNOP), 05/IV/2004, Bueno 928 (HUM, UNOP), 04/V/2004, Bueno 931, 932 (HUM, UNOP), 17/VI/2004, Bueno 940 (HUM, UNOP).

The apical view was suggestive of *C. bireme* Nordst. var. *bireme*; however, it was impossible to draw the apical view. Our cell measurements yielded values that were higher than were those reported in the literature (6.0-19.0 µm in length; 6.0-12.0 µm in width; isthmus, 3.0-5.0 µm; Prescott *et al.* 1981).

4. *Cosmarium bireme* Nordst. var. *huzelii* Kurt Först., Amazoniana, 2(1/2): 45, pl.14, fig. 11-12. 1969.

A cell that is 1.1 times as wide as it is long, deep median constriction, closed median sinus dilated at the apex; angular-elliptical semicell, rounded lateral margins, rounded, truncate apical margin; smooth cell wall, chloroplast = 1, pyrenoid = 1. Dimensions: 10.0-20.0 µm in length; 9.0-22.0 µm in width; isthmus, 3.0-8.2 µm.

Constancy: rare.

Distribution in the state of Paraná: Salto Caxias Reservoir Hydroelectric Power Plant (Silva & Cecy 2004); Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010).

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 04/XI/2003, Bueno 888 (HUM, UNOP), 04/V/2004, Bueno 931, 936 (HUM, UNOP), 17/VI/2004, Bueno 940 (HUM, UNOP).

The apical view was suggestive of *C. bireme* var. *huzelii*; however, it was impossible to draw the apical view. The

variety in question (*huzelii*) differs from the typical variety in that it has cells that are wider than they are long, resembling *C. polygonum* (Näg.) Archer var. *polygonum* f. *rectum* C. Bicudo, which has straight lateral margins. Our cell measurements yielded values that were higher than were those previously reported for *C. bireme* var. *huzelii* in the São Francisco Falso River (Silva & Cecy 2004; Felisberto & Rodrigues 2010).

5. *Cosmarium clepsydra* Nordst. var. *clepsydra*, Vidensk. Medd. Naturh. Foren. Kjøbenhavn (14/15) 212. 1869.

Cells that are 1.1 times as long as they are wide or that are as long as they are wide, deep median constriction, narrow, closed median sinus dilated at the apex; subsemicircular to subtriangular semicell, slightly convex or nearly straight lateral margins; obtusely conical or generally convex apical margin; smooth cell wall, no chloroplasts, no pyrenoids; rhomboid apical view, concave lateral margins, obtuse angles. Dimensions: 20.0 µm in length; 18.3-20.0 µm in width; isthmus, 4.0-5.0 µm.

Constancy: rare.

Distribution in the state of Paraná: First record of the taxon.

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 08/XII/2003, Bueno 906 (HUM, UNOP), 05/IV/2004, Bueno 928 (HUM, UNOP).

6. *Cosmarium decoratum* West & G.S. West, Trans. Linn. Soc. London, Bot., II, 5(2): 61, pl.7, fig.21. 1895.

A cell that is 1.4-1.6 times as long as it is wide, deep median constriction, slightly open sinus, tapering toward the apex and dilated at the apex; semicircular to truncate pyramidal semicell, rounded basal and apical angles, convex lateral margins, rounded apical margin; granular cell wall, hexagonally arranged series of dense granules, no chloroplasts, no pyrenoids. Dimensions: 74.0-84.0 µm in length; 48.0-58.8 µm in width; isthmus, 16.8-20.0 µm.

Constancy: rare.

Distribution in the state of Paraná: Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010).

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 28/VII/03, Bueno 860 (HUM, UNOP), 04/V/2004, Bueno 935 (HUM, UNOP).

According to Felisberto & Rodrigues (2010), *C. decoratum* is very similar to *C. logiense* Bisset. However, the former is larger in length and width, features that are consistent with our findings. In addition, *C. logiense* can be distinguished from *C. decoratum* by its elliptical cells, subquadrangular shape, retuse lateral margins, and apical margin with one concavity (Prescott *et al.* 1981).

7. *Cosmarium excavatum* Nordst. var. *excavatum*, Vidensk. Medd. Naturh. Foren. 1869(14/15): 214. 1869(1870); 1887: pl. 3, fig. 25. 1887.

A cell that is 1.7-1.9 times as long as it is wide, shallow median constriction, excavated median sinus, rounded apex; subcircular semicell, convex, wavy apical and lateral margins; granular cell wall, granules arranged in 4-5 vertical series in the front view, chloroplast = 1, pyrenoid = 1; circular apical view. Dimensions: 26.4-30.4 µm in length, 14.0-18.4 µm in width; isthmus, 7.2-9.6 µm.

Constancy: rare.

Distribution in the state of Paraná: Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010).

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 05/IV/2004, Bueno 928 (HUM, UNOP).

C. excavatum Nordst. var. *excavatum* is similar to *C. isthmium* West in terms of how the granules are arranged on the cell wall. However, the latter taxon shows larger cell size, higher density granules on the cell wall, and a deeper, more tightly closed median sinus. Our cell measurements yielded values higher than those reported by Ramos *et al.* (2011).

8. *Cosmarium cf. galeritum* Nordst. var. *borgei* W. Krieg. & Gerloff, Die Gattung *Cosmarium* 1: 108, pl. 23, fig. 2. 1962.

A cell that is 1.2 times as wide as it is long or that is as long as it is wide, deep median constriction, closed median sinus; pyramidal to trapezoidal semicell, convex lateral margins, truncate apical margin; punctate cell wall with apical thickening, chloroplast = 1, pyrenoid = 1. Dimensions: 30.0-46.7 µm in length; 26.0-45.9 µm in width; isthmus, 6.0-14.3 µm.

Constancy: rare.

Distribution in the state of Paraná: First record of the taxon.

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 28/VII/2003, Bueno 860 (HUM, UNOP), 01/IX/2003, Bueno 871 (HUM, UNOP), 08/XII/2003, Bueno 906 (HUM, UNOP), 05/IV/2004, Bueno 926, 928 (HUM, UNOP).

Prescott *et al.* (1981) described *C. galeritum* as having chloroplasts with approximately 10 radial plates containing 2 pyrenoids or, more rarely, 1 pyrenoid, whereas Bortolini *et al.* (2010) described *C. galeritum* as having axial chloroplasts containing 2 pyrenoids. Felisberto & Rodrigues (2004) described *C. galeritum* var. *borgei* as having 2 pyrenoids but provided no information on chloroplast shape. Bicudo & Ungaretti (1986) provided no written or pictorial information on the pyrenoids in *C. galeritum* var. *borgei*. Because the remaining characteristics of the semicells in the individuals found in the present study were consistent with those described in the literature, those individuals were provisionally identified as *C. galeritum* var. *borgei*, despite having only 1 pyrenoid.

Other varieties of *C. galeritum* were recorded in the state: *C. galeritum* var. *triangulare*, in the Tibagi River

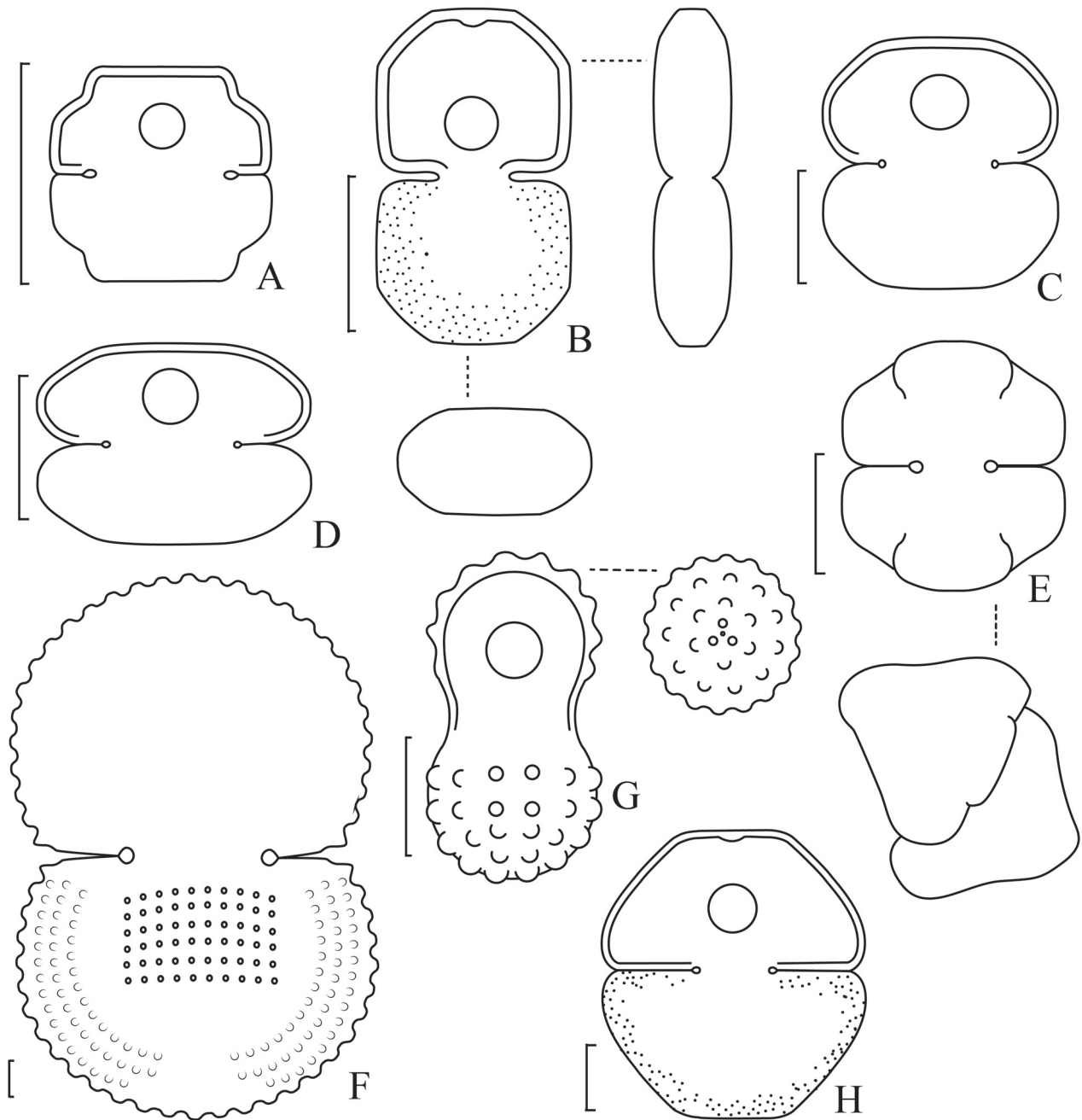


Figure 2. A. *Cosmarium abbreviatum* Racib. var. *minus* (West & G.S. West) W. Krieg. & Gerloff; B. *C. angulosum* Bréb. var. *angulosum*; C. *C. bireme* Nordst. var. *bireme*; D. *C. bireme* Nordst. var. *huzelii* Förster; E. *C. clepsydra* Nordst. var. *clepsydra*; F. *C. decoratum* West & G.S. West; G. *C. excavatum* Nordst. var. *excavatum*; H. *C. cf. galeritum* Nordst. var. *borgei* W. Krieg. & Gerloff. Scale bar = 10 µm (in A-F and H) and 15 µm (in G).

(Bittencourt-Oliveira 1993); *C. galeritum* var. *galeritum*, in the Cascavel Municipal Lake (Bortolini *et al.* 2010); and *C. galeritum* var. *subtumidum* Borge, in the Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010). *C. galeritum* var. *borgei* is characterized by an apex that is wider than is that seen in the typical variety of the species (Bicudo & Ungaretti 1986).

9. *Cosmarium ginzbergeri* Grönblad, Acta Societatis Scientiarum Fennicae, new series B II(6): 18, pl. VI, fig. 112. 1945.

A cell that is 1.5 times as long as it is wide, deep median constriction, linear, closed median sinus dilated at the apex; uniformly rounded, semielliptical semicell, rounded basal

angles; granular cell wall, isthmus ornamented with a single series of granules, intramarginal granules arranged in a single series laterally and apically, chloroplast = 1, pyrenoid = 1. Dimensions: 122.4 µm in length; 83.6 µm in width; isthmus, 30.6 µm.

Constancy: rare.

Distribution in the state of Paraná: First record of the taxon.

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 28/VII/2003, Bueno 860 (HUM, UNOP)

When describing *C. ginzbergeri* for the first time, Grönblad (1945) highlighted the great beauty of the species, which was found among material collected in the Brazilian Amazon. The author also described the lateral view as showing four series of intramarginal granules and parietal chloroplast with numerous pyrenoids. In our specimen, we found only 1 pyrenoid in one of the semicells.

10. *Cosmarium laeve* Rabenh. Flor. Europ. Alg. III, p. 161. 1868.; Nordst., in Nordstedt & Wittrock, Öfv. Kongl. Vet-Akad. Förhandl. 6: 29, pl. 12, fig. 4. 1876. var. *laeve*. *Cosmarium laeve* Rabenh. var. *septentrionale* Wille, in Miller, Univ. Wyoming Publ. Sci. Bot. 2(6): 90, pl. 4, figs. 10-12. 1936.

A cell that is 1.5 times as long as it is wide, deep median constriction, linear, closed median sinus dilated at the apex; slightly angular, semielliptical to subpyramidal semicell, flat, narrow apex that can range in shape from slightly retuse to notched; finely punctate cell wall, chloroplast = 1, pyrenoid = 1. Dimensions: 17.8-24.5 µm in length; 12.0-16.3 µm in width; isthmus, 4.1-8.0 µm.

Constancy: sporadic.

Distribution in the state of Paraná: Salto Caxias Reservoir Hydroelectric Power Plant (Silva & Cecy 2004); Salto do Vau Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2008); Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010).

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 28/VII/2003, Bueno 861 (HUM, UNOP), 01/IX/2003, Bueno 870, 872 (HUM, UNOP), 06/X/2003, Bueno 883, 885 (HUM, UNOP) 4/XI/2003, Bueno 888 (HUM, UNOP), 08/XII/2003, Bueno 904, 905 (HUM, UNOP), 03-II-2004, Bueno 912, 913 (HUM, UNOP), 10/III/2004, Bueno 920 (HUM, UNOP), 05/IV/2004, Bueno 924 (HUM, UNOP), 17/VI/2004, Bueno 938 (HUM, UNOP)

C. laeve Rabenhorst resembles *C. montrealense* Croasdale, which was first described by Croasdale and which can be distinguished from *C. laeve* Rabenhorst by its widely rounded apex and smooth cell wall (Silva & Cecy 2004). Although the length-to-width ratio found in the present study was higher than was that found by Silva & Cecy (2004), it is consistent with that found by Prescott *et al.* (1981). Felisberto & Rodrigues (2004) found wider individuals.

11. *Cosmarium moniliforme* (Turpin) Ralfs, Brit. Desm., 107, pl. 17, fig. 6. 1848. var. *moniliforme*. *Tessarhronia moniliformis* Turpin, Dic. Sci. Nat., pl. 7, fig. 1. 1820.

A cell that is 1.4-1.8 times as long as it is wide, deep median constriction, acute, open median sinus; circular semicell, convex and smooth lateral and apical margins; smooth cell wall with apical thickening, chloroplast = 1 (with 6-7 lobes), pyrenoid = 1; circular apical view. Dimensions: 23.1-32.0 µm in length; 16.8-18 µm in width; isthmus, 6.3-8.0 µm.

Constancy: rare.

Distribution in the state of Paraná: Tibagi River (Bittencourt-Oliveira 1993); Salto Caxias Reservoir Hydroelectric Power Plant (Silva & Cecy 2004)

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 28/VII/2003, Bueno 859 (HUM, UNOP), 01/IX/2003, Bueno 871 (HUM, UNOP), 06/X/2003, Bueno 882 (HUM, UNOP), 04/XI/2003, Bueno 890 (HUM, UNOP), 19/I/2004, Bueno 908 (HUM, UNOP).

C. moniliforme Ralfs closely resembles *C. contractum* Kirchner. The latter can be distinguished from the former by its widely elliptical cell and elliptical apical view (Prescott *et al.* 1981).

12. *Cosmarium norimbergense* Reinsch var. *norimbergense*, Acta Societatis Senckenbergensis, 6: 117, pl. 22-A-IV, fig. 1-11. 1867.

A cell that is 1.1 times as long as it is wide, deep median constriction, narrow, closed median sinus dilated at the apex; vertically rectangular semicell, rounded, rectangular basal angles, lateral margin with one concavity, retuse to slightly convex apical margin; smooth cell wall, chloroplast = 1, pyrenoid = 1. Dimensions: 14.0 µm in length; 12.7 µm in width; isthmus, 6.3 µm.

Constancy: rare.

Distribution in the state of Paraná: First record of the taxon.

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 28/VII/2003, Bueno 859 (HUM, UNOP).

In the state of Paraná, *C. norimbergense* var. *depressum* has been found in the Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010).

13. *Cosmarium portianum* Archer, Proc. Dubl. Nat. Hist. Soc. 3: 49, pl. 1, figs. 8, 9; Quart. Jour. Microsc. Sci. 8: 235. pl. 11. 1860. var. *portianum*

A cell that is 1.2-1.3 times as long as it is wide, deep median constriction, open median sinus; reniform to rectangular semicell; granular cell wall (20-23 granules being visible at the edge of the semicell), granules arranged in

longitudinal series, chloroplast = 1, pyrenoids = 2; oblong lateral view. Dimensions: 39.0-49.0 µm in length; 33.0-38.8 µm in width; isthmus, 11.2-16.8 µm.

Constancy: sporadic.

Distribution in the state of Paraná: Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010).

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 01-VII-2003, Bueno 858 (HUM, UNOP), 28/VII/2003, Bueno 861, 863 (HUM, UNOP), 01/IX/2003, Bueno 871, 873, 874 (HUM, UNOP), 04/XI/2003, Bueno 888, 890 (HUM, UNOP), 08/XII/2003, Bueno 903, 904 (HUM, UNOP), 05/IV/2004, Bueno 925 (HUM, UNOP).

Our cell measurements yielded values that were higher than were those reported in the literature (Prescott *et al.* 1981; Rodrigues & Bicudo 2004).

14. *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. *Euastrum protractum* Nägeli, Gatt. Einzell. Alg.: 119, pl. VII, A, fig. 4. 1849.

A cell that is 1.1 times as wide as it is long, deep median constriction, open median sinus that is slightly closed in the first portion and dilated at the apex; 3-lobed semicell, subrectangular incision between the apical lobe and each lateral lobe, rounded and narrow lateral lobes, prominent apical lobe, rounded apical angles, retuse apical margin; granular cell wall, granules arranged in oblique, decussate series and becoming smaller as they reach the central bulge, where they are arranged in rings; chloroplast = 1, pyrenoids = 2. Dimensions: 56.0 µm in length; 50.0 µm in width; isthmus, 12.0 µm.

Constancy: rare.

Distribution in the state of Paraná: First record of the taxon.

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 10/III/2004, Bueno 919 (HUM, UNOP).

Prescott *et al.* (1981) and Felisberto & Rodrigues (2004) discussed the differences between *C. protractum* and *C. ornatum*, the former showing a markedly prominent apex in which an apical lobe is formed and the latter being reniform to subreniform and similar to *C. protractum* in terms of cell wall ornamentation, with a slightly elevated but little prominent apex. Cell measurements performed by Cecy *et al.* (1997) and Felisberto & Rodrigues (2004) yielded values that were lower than were those found in the present study.

15. *Cosmarium rectangulare* var. *hexagonum* (Erfvings) West & G.S. West, Monogr. III, 56, pl. 70, fig. 4. 1908. *Cosmarium hexagonum* Erfvings, Acta Soc. Fauna Flora Fennica 2(2): 12, pl. 1, fig. 8. 1881.

A cell that is 1.1-1.2 times as long as it is wide, deep median constriction, closed median sinus dilated at the apex; subhexagonal semicell, straight, truncate apex; finely punctate cell wall, chloroplast = 1, pyrenoid = 1. Dimensions: 15.2-26.5 µm in length; 14.3-22.4 µm in width; isthmus, 4.0-8.0 µm.

Constancy: sporadic.

Distribution in the state of Paraná: First record of the taxon.

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 01/VII/2003, Bueno 855 (HUM, UNOP), 28/VII/2003, Bueno 863 (HUM, UNOP), 01/IX/2003, Bueno 870, 871, 874 (HUM, UNOP), 04/XI/2003, Bueno 888, 932 (HUM, UNOP), 17/VI/2004, Bueno 938, 940 (HUM, UNOP).

C. rectangulare var. *hexagonum* differs from the typical variety in that the cells are smaller in size and nearly as long as they are wide, as well as being slightly flattened. Our cell measurements yielded values that were lower than were those found by Prescott *et al.* (1981) and slightly higher than were those found by Sophia *et al.* (2005) but consistent with most of those reported by Lopes & Bicudo (2003; 16-21.2 µm in length; 14.0-20 µm in width; isthmus, 5.6 µm).

16. *Cosmarium regnesi* Reinsch var. *regnesi*, Act. Soc. Senckenberg 6: 116. 1867.

A cell that is 1.1 times as wide as it is long, deep median constriction, excavated, open median sinus, rounded apex; subrectangular semicell, jagged lateral and apical margins; smooth cell wall, no chloroplasts, no pyrenoids. Dimensions: 12.8 µm in length; 14.4 µm in width; isthmus, 4.0 µm.

Constancy: rare.

Distribution in the state of Paraná: Salto do Vau Reservoir (Felisberto & Rodrigues 2008); Cascavel Municipal Lake (Bortolini *et al.* 2010); Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010).

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 05/IV/2004, Bueno 928 (HUM, UNOP).

Prescott *et al.* (1981) identified as *C. regnesi* var. *montanum* those individuals that were larger in size than were those of the typical variety (6.0-10.0 µm in length; 6.2-9.5 µm in width; isthmus, 3.0-5.5 µm). We found only one such specimen in the present study. Because the remaining characteristics of that specimen were consistent with those of the typical variety, we chose to identify it as *C. regnesi* var. *regnesi*.

17. *Cosmarium reniforme* (Ralfs) W. Archer, J. Bot. 12: 92. 1874. *Cosmarium margaritifera* Menegh. var. *reniformis* Ralfs, Brit. Desm., 100, pl. 16, fig. 2a. 1848.

A cell that is 1.1-1.3 times as long as it is wide, deep median constriction, closed median sinus dilated at the

apex; reniform semicell, convex lateral margins, straight or slightly convex apical margins; granular cell wall, 33 visible granules at the edge of the semicell, chloroplast = 1, pyrenoids = 2; oblong-elliptical apical view. Dimensions: 32-51 µm in length; 30.0-40.8 µm in width; isthmus 8.0-12.0 µm.

Constancy: common.

Distribution in the state of Paraná: Rosana Reservoir Hydroelectric Power Plant (Felisberto & Rodrigues 2010).

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 01/VII/2003, Bueno 858 (HUM, UNOP), 28/VII/2003, Bueno 859, 861, 863 (HUM, UNOP), 01/IX/2003, Bueno 872, 873, 874 (HUM, UNOP), 06/X/2003, Bueno 882, 883 (HUM, UNOP), 08/XII/2003, Bueno 904, 906 (HUM, UNOP), 19/I/2004, Bueno 911 (HUM, UNOP), 03/II/2004, Bueno 912 (HUM, UNOP), 10/III/2004, Bueno 921 (HUM, UNOP), 05/IV/2004, Bueno 924, 925, 926 (HUM, UNOP), 04/V/2004, Bueno 932 (HUM, UNOP), 17/VI/2004, Bueno 936, 940 (HUM, UNOP).

Our cell measurements yielded values that were lower than were those reported by Bicudo *et al.* (1992) but comparable to those reported by Sophia *et al.* (2005).

18. *Cosmarium* sp.

A cell that is 1.1 times as long as it is wide, deep median constriction, narrow, closed median sinus dilated at the apex; oblong and trapeziform semicell, smooth, convex lateral margins, retuse apical margin; smooth cell wall with apical thickening, chloroplast = 1, pyrenoids = 2. Dimensions: 12.8-23.2 µm in length; 11.2-21.6 µm in width; isthmus 3.2-4.4 µm.

Constancy: rare.

Distribution in the state of Paraná: First record of the taxon.

Material examined: **BRAZIL. Paraná:** Santa Helena, São Francisco Falso River, 01/VII/2003, Bueno 855 (HUM, UNOP), 03/II/2004, Bueno 916 (HUM, UNOP), 10/III/2004, Bueno 921 (HUM, UNOP), 04/V/2004, Bueno 932 (HUM, UNOP).

Those individuals that showed well-defined angular margins, 2 pyrenoids, and apical cell wall thickening (and that were therefore similar to *C. bireme*) were separated and were provisionally identified at the genus level as *Cosmarium* sp.

July of 2003 was the month that was richest in *Cosmarium* spp. (91.7%). The period between January and March of 2004 was the least rich in *Cosmarium* spp. (25-41.7%). However, April of 2004 was a month that was again rich in *Cosmarium* spp. (83.3%). Regarding the sampling stations along the São Francisco Falso River, Stations 5 and 2 were the richest in *Cosmarium* spp. (*Cosmarium* spp. having accounted for 83.3% and 66.7%, respectively, of all taxa found), whereas Station 4 was the least rich in *Cosmarium*

spp. (16.6%). *C. laeve* var. *laeve* e *C. reniforme* var. *reniforme* were the only taxa that were found at all sampling stations.

Those spatiotemporal variations in the proportion of *Cosmarium* spp. among the phytoplankton community in the São Francisco Falso River were probably related to certain environmental characteristics, which contributed to the presence of those algae (and desmids in general) in certain places (Biolo *et al.* 2008; Menezes *et al.* 2011). Such characteristics possibly consist of variations in the following limnological parameters: the trophic status of the environment, which can range from oligotrophic to mesotrophic (Silva *et al.* 2010); water transparency and luminosity, which were found to be particularly high at Stations 2, 3, and 5 in the present study; and the presence of aquatic macrophytes (Brook 1981; Coesel 1982; Bicudo & Ungaretti 1986; Felisberto & Rodrigues 2005; Melo *et al.* 2005), metaphytic and periphytic forms breaking off the substrate contributing to an increase in the amount of desmids in the phytoplankton community (Taniguchi *et al.* 2000; Rodrigues *et al.* 2003). Despite the characteristics of the lotic environment, including greater water flow, unidirectional flow, and allochthonous influence (especially from the Itaipu Reservoir and the region around the river, due to agricultural activities and tourism), the characteristics of the river shore provided a variable environment that allowed the development of desmids, principally *Cosmarium* spp., which are tolerant to variations in limnological conditions (Gough & Woelkerling 1976).

Cosmarium are algae that have a cosmopolitan distribution, specifically in tropical regions (Bicudo & Menezes 2006). Biolo *et al.* (2008) inventoried the desmids in the same tributary of the Itaipu Reservoir and found *Cosmarium* to be the most species-rich genus, the authors having identified a total of 41 species and 12 genera. The finding of Biolo *et al.* (2008) is consistent with those of Bicudo & Ungaretti (1986), Bicudo *et al.* (1992), Cecy *et al.* (1997), Lopes & Bicudo (2003), Silva & Cecy (2004), Felisberto & Rodrigues (2004), Felisberto & Rodrigues (2008), Ramos *et al.* (2011), and Menezes *et al.* (2011).

A total of 23 taxa found in the São Francisco Falso River between 2003 and 2004 were provisionally identified as *Cosmarium* spp. (Menezes *et al.* 2011). A new analysis resulted in a substantial number of species being identified, the present study having contributed to the addition of 18 *Cosmarium* taxa to the Paraná state desmid flora database.

Of the 18 *Cosmarium* taxa identified in the present study—1 taxon not having been identified at the species level—8 were new records for the state of Paraná. This underscores the importance of surveying the biodiversity of algae in the state. Despite the studies conducted so far, taxonomic and ecological data on the desmid flora in the state of Paraná remain scarce. Further studies investigating algal communities (particularly desmids) in various aquatic environments and habitats are needed in order to increase our understanding of the biodiversity in the state and therefore contribute to biodiversity conservation.

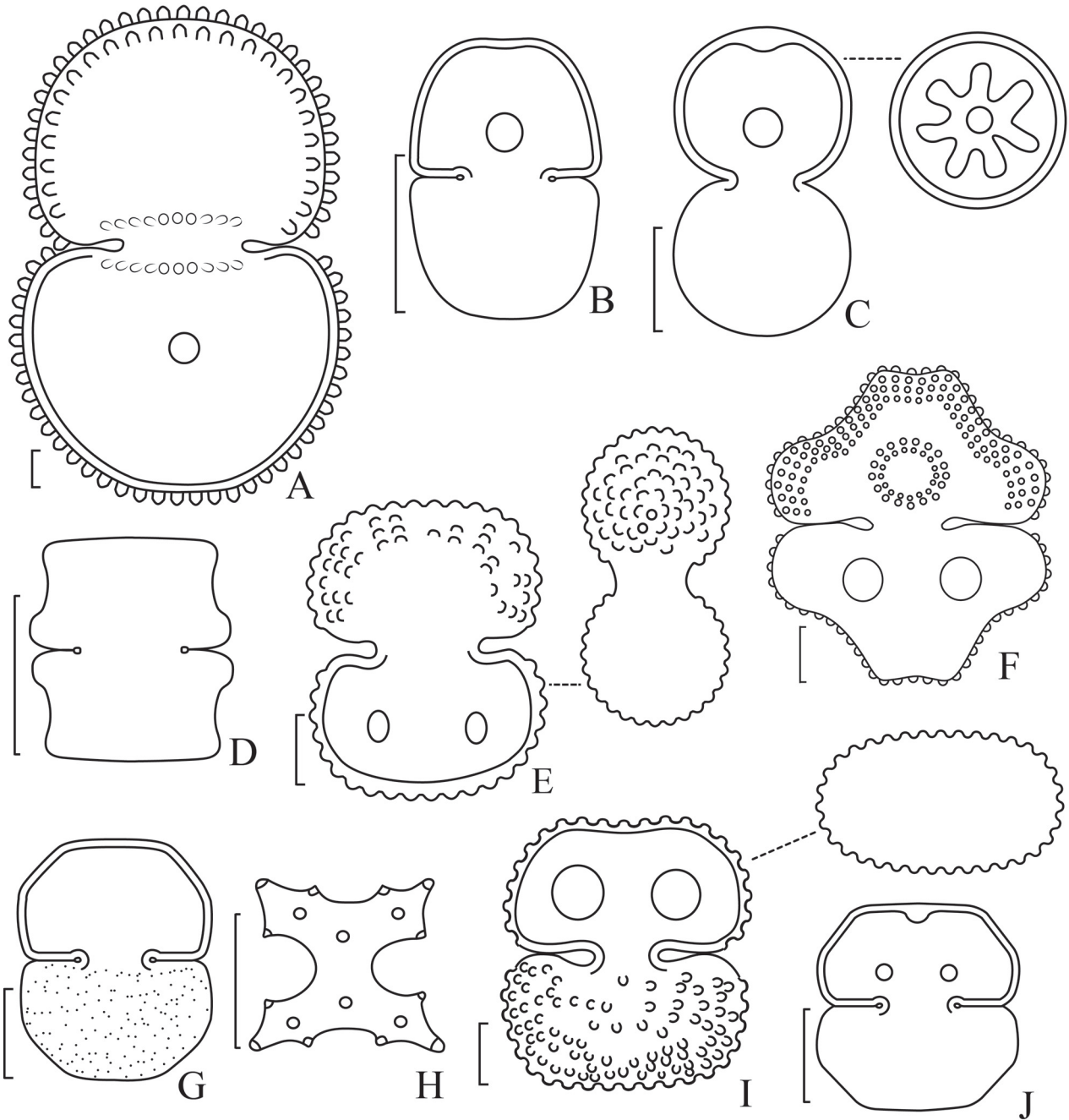


Figure 3. A. *Cosmarium ginzbergeri* Grönblad; B. *C. laeve* Rabenh. var. *laeve*; C. *C. moniliforme* (Turpin) Ralfs var. *moniliforme*; D. *C. norimbergense* Reinsch var. *norimbergense*; E. *C. portianum* Archer var. *portianum*; F. *C. protractum* (Nägeli) De Bary var. *protractum*; G. *C. rectangularare* var. *hexagonum* (Elfving) G.S. West & W. West; H. *C. regnesi* Reinsch var. *regnesi*; I. *C. reniforme* (Ralfs) Archer var. *reniforme*; J. *Cosmarium* sp. Scale bar = 10 µm.

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